SAND2016-3380R

1. Cover Page

Title: Nanoscale Electronics and Mechanics

Basic Energy Sciences: Scientific User Facilities Division, NSRC

Principal Investigator:
Brian Swartzentruber
Technical Staff Member
Sandia National Laboratories
Albuquerque, NM 87185
Phone: 505-844-6393
Email: bsswart@sandia.gov

Officials Signing for Laboratory:
Tanja Pietrass
Division Leader
Materials Physics and Applications Division
Los Alamos National Laboratory
Phone: 505-667-8475
Email: tanja@lanl.gov

Grant Heffelfinger
Director
Physical, Chemical and Nano Science Centers
Sandia National Laboratories
Phone: 505-845-7801
Email: gsheffe@sandia.gov

Funding Request (by year)

	FY16 ($K)	**FY17 ($K)**	**FY18 ($K)**	**Total ($K)**
Total	7,839	8,061	8,315	24,215

Human Subjects Use: No
Animal Subjects Use: No

Signatures:

Brian Swartzentruber, PI, SNL Date

Tanja Pietrass, Division Leader Date

Grant Heffelfinger, Director Date

2.0 Table of Contents

2.0 Table of Contents **2**

3.0 Tabular Budget and Staffing Summary **3**

4.0 Management Plan **4**
4.1 Overarching Center Goals 4
4.2 Overarching Thrust Goals 4
4.3 Staffing Resources 5
4.4 Resources and Connections across CINT 5
4.5 Laboratory Complementary Resources and In-reach 6
4.6 Distinguishing Characteristics of NEM Thrust 7

5.0 Abstract **8**

6.0 Narrative **9**
6.1 Background and Significance 9
6.2 Progress Report 9
6.3 Future Directions 17
6.4 Summary 24

7.0 Publications **25**
7.1 Literature Cited 25
7.2 Publications from Previous Support 29

8.0 Biographical Sketches **54**

9.0 Other Support of Investigators and Collaborators **72**

10.0 Budget and Budget Explanation **80**

11.0 Description of Facilities and Resources **89**

3.0 Budget and Budget Explanation

Total Budget and Level of Effort
Nanoscale Electronics and Mechanics Thrust

Total Operating Budget by Subtask

Requested Funding	FY16 ($K)	FY17 ($K)	FY18 ($K)	Total ($K)
Total	7,839	8,061	8,315	24,215

(Annual budgets cover loaded salaries, small purchases, postdoc salaries, and travel.)

Level of Effort

Key Personnel	FY13 (FTE)	FY14 (FTE)	FY15 (FTE)
Harris	0.5	0.5	0.5
Jungjohann	0.5	0.5	0.5
Lilly	0.5	0.5	0.5
Mara*	0.6	0.6	0.6
Nogan	1	1	1
Ohta	0.5	0.5	0.5
Reno	0.5	0.5	0.5
Swartzentruber*	0.75	0.75	0.75
Yoo	0.5	0.5	0.5
New Staff hires	1	1	1
Technicians	10	10	10
Postdocs	2	2	2

* Thrust Leader and Partner Science Leader for Nanoscale Electronics and Mechanics.

Materials and Supplies

Requested Funding	FY16 ($K)	FY17 ($K)	FY18 ($K)	Total ($K)
Total	1,547	1,595	1,646	4,788

4.0 Management Plan

4.1 Overarching Center Goals

The opportunities presented by nanomaterials are exciting and broad, with revolutionary implications spanning energy technologies, electronics, computing, sensing capabilities and biomedical diagnostics. Deriving the ultimate benefit from these materials will require the controlled assembly of diverse nanoscale materials across multiple length scales to design and achieve new properties and functionality, in other words, nanomaterials integration.

Integration has played a pivotal and revolutionary role in the development of nearly all science and technology. Perhaps the most familiar and dramatic illustration is the development of very large-scale integrated circuits where active and passive devices based on semiconductors, dielectrics, insulators, and metals are monolithically integrated on a single platform for specific applications. Even greater challenges exist as nanomaterials are integrated into new architectures to form functional systems. Interfaces and defects are formed whose structures and properties can dominate the chemical, mechanical, electronic and optical properties of the system. The effects of synthesis and fabrication processes on performance must be investigated and new directed- and self-assembly approaches developed for greater functional control. Combined bottom-up and top-down synthesis and assembly techniques must be optimized and/or invented to allow the intention design of hierarchical materials. Establishing the fundamental principles that underpin the integration of nanomaterials that display unique properties, such as quantum confinement, is of paramount importance to nanoscience and ultimately nanotechnology.

The goal of the Center for Integrated Nanotechnologies (CINT) is to plays a leadership role in integration of nanostructured materials to enable novel capabilities and applications through its function as a Department of Energy/Office of Science Nanoscale Science Research Center (NSRC) national user facility. By coupling open access to unique and world-class capabilities and scientific expertise to an active user community, CINT supports high-impact research that no other single institution could achieve – the whole of CINT including its user community is greater than the sum of its parts.

4.2 Overarching Thrust Goals

The NEM Thrust strives to i) lead in the cutting edge of science and technology of nanoscale electronics and mechanics via nanoscience and capability development, ii) attract high profile users from universities, national laboratories, and industrial sectors, and iii) contribute to the training of the future workforce in this field.

Reduced dimensions as well as much-enhanced surface areas in nanostructured materials can give rise to emergent functionalities not found in micro- and macro-scale systems. For electronic and mechanical systems, important integration issues involve energy transfer across nanoscale interfaces, the role of defects in nanostructured materials, and interactions between nanoscale building blocks in integrated structures. These scientific issues exist in both electrical and mechanical nanosystems as we bring nanostructures together to implement specific functions and combine different materials to modify electrical or mechanical behaviors, or texture materials at the nanoscale. Also, as user-inspired science is a significant part of the nanoscience integration issues being addressed in this thrust, the overall goals of NEM Thrust are to

- understand and control electrical and mechanical properties arising from confinement at the nanoscale and interactions within nanostructures;
- integrate heterogeneous nanostructures for higher levels of functionality;
- develop new capabilities for nanoscience such as discovery platforms, synthesis techniques, and probing methods; and
- engage our user community and CINT scientists to define and achieve our scientific objectives.

4.3 Staffing Resources

The NEM Thrust currently has nine scientific staff members with associated postdocs and technologists. Their expertise covers scientific and technological areas of nanoscale electronics and mechanics from wide angles.

Tom Harris has research interests in both measurement and modeling of carrier transport in low-dimensional structures such as inorganic nanowires, thin films, and carbon-based nanostructures, and the design, control, and fabrication of nanoscale electromechanical systems.

Quanxi Jia (CINT Director) has been involved in the research of epitaxial nanocomposite metal-oxide films with an emphasis on the synthesis and the study of structure-property relationships and multifunctional materials. His interests further include the development of novel techniques for the growth of electronic materials with controlled defect, interfaces, and functionalities.

Katherine Jungjohann has concentrated on developing in-situ scanning/transmission electron microscopy techniques with an emphasis on liquid-phase analysis of nanomaterials and bio-composites directed towards electrochemical cycling, growth, assembly, and corrosion.

Michael Lilly has research interests in the area of nanoelectronics. His most recent activity covers the study of the role of interactions in coupled nanoelectronic structures and coherent electronic effects in nanostructures. His interests also include 2D electron physics, the quantum Hall effects, transport in quantum wires, and quantum computing.

Nathan Mara (Partner Science Leader) has concentrated on nanomechanics with an emphasis on nanoindentation techniques for studying the mechanical behavior of nanomaterials, bulk synthesis of structural nanomaterials, and microstructural characterization of materials via electron microscopy.

Taisuke Ohta has research interests in the electronic structure of surfaces. His activities center on applications of the low energy and photoemission electron microscope (LEEM-PEEM) for problems in nanomaterials ranging from two-dimensional crystals to microelectronic device structures. Toward the goal of expanding the applicability of LEEM-PEEM to wider class of nanomaterials, he is also developing deep UV light sources to enhance the electron spectroscopy capabilities.

John Reno has research interests in the area of nanostructured electronic materials with an emphasis on the synthesis of high-purity, high-precision, and high-mobility AlGaAs-based heterostructures using molecular beam epitaxy for electronic and photonic studies. The use of arsenide materials containing indium is being investigated.

Brian Swartzentruber (Thrust Leader) has been developing novel implementations of scanning-probe-like instruments for direct and precise nanomanipulation for top-down construction of unique nanostructures and data acquisition and control systems for atomically-precise H-lithography via scanning tunneling microscopy. He has also been developing systems for thermoelectric characterization of nanowires and thin films.

Jinkyoung Yoo has worked in the area of growth and characterization of semiconductor heterostructured nanowires and thin films, fabrication of nanostructure-based electronic/photonic devices, and the development of growth techniques for doping and alloying nanomaterials.

4.4 Resources and Connections across CINT

Many research activities and user projects in the NEM Thrust rely on collaborations with other CINT scientists and resources at CINT. Within the Thrust, there are several research teams that work together.

Brian Swartzentruber, Jinkyoung Yoo, and Tom Harris are involved in the area of nanowires for new energy concepts. In the area of nanoscale electronics and mechanics, Nathan Mara and Quanxi Jia have worked closely to investigate the strain-induced structural and transport properties of nanostructured composites. Other CINT scientists in the Theory and Simulation of Nanoscale Phenomena (TSNP) (Normand Modine) and Nanophotonics and Optical Nanomaterials (NPON) (Jen Hollingsworth, Han Htoon, and Rohit Prasankumar) Thrusts are also participating in the nanowire area. In the area of low-dimensional nanoelectronics, Mike Lilly and John Reno work closely on supplying high-mobility 2D systems and fabricating nanoelectronics devices with users. In the area of mechanics of nanoscale materials, Nathan Mara, Katherine Jungjohann, and Bill Mook regularly collaborate to design and conduct in-situ TEM experiments on nanocomposites, nanowires, and other nanomaterials. Tom Harris and Katherine Jungjohann worked together to broaden the scope of the existing TEM discovery platform for energy storage systems. John Reno has several projects of growing optical devices for NPON user projects in collaboration with Igal Brener. In the area of nanostructured multifunctional materials, Quanxi Jia has worked very closely with Jianxin Zhu (TSNP), Stuart Trugman (TSNP), Rohit Prasankumar (NPON), and Hou-Tong Chen (NPON) to fundamentally understand the structure-property relationship of complex metal-oxides and to use these oxides for metamaterials. Jinkyoung Yoo collaborates with Jianxin Zhu (TSNP) to elucidate the electronic band structure of hybrid structures composed of Si(Ge) and 2D-materials (MoS_2, graphene, etc.). While this is not a complete list of connections between CINT scientists, it is meant to demonstrate the robust scientific environment at CINT and the highly collaborative nature of the CINT staff.

In addition to numerous active collaborations between CINT staff members, the NEM Thrust relies on a number of resources at CINT. The CINT Integration Lab, which falls under the NEM Thrust, is a critical resource for many of our projects, our users, and the other Thrusts. The Integration Lab has state-of-the-art fabrication facilities for top-down processing. One major advantage of this cleanroom is that our users, students, and postdocs can be trained on most of the equipment in the fabrication facility, and that a wide range of nanomaterials and platforms can be processed in the cleanroom without the restrictions found in many other cleanroom facilities. The Rigaku SmartLab X-ray diffraction (XRD) is also in the NEM Thrust but is used by a wide range of users across thrusts due to its flexible design. For example, it is used by NEM personnel for characterization of single crystal films and by SBCN for characterization of nanodot size and chemical phase. Activities in our Thrust also rely on the CINT in-house designed Liquid Cell Discovery Platform that is used for *in situ* electrochemical TEM experiments, and other rapid-prototype platforms used for electrical- and thermal-transport studies. While not a traditional scientific resource, interactions with our users are enhanced significantly by the extended operating hours of the CINT Core and Gateway facilities that allow visitors to access in the evenings and on weekends as well as during the normal business day.

4.5 Laboratory Complementary Resources and In-reach

The NEM Thrust benefits from complementary resources at Los Alamos National Laboratory and Sandia National Laboratories. Many of our research projects complement or benefit the labs such as nanowires for new energy concepts (photovoltaic and thermoelectric applications) and spin quantum computation. The Ion Beam Materials Laboratory at Los Alamos is an important tool for ion-matter interactions, and is important to our nanomechanics efforts. At Sandia, the Materials Development Laboratory (silicon fab) and the uFab (semiconductor processing facility) complement CINT's processing capabilities with access to fabrication expertise and specialized processing capabilities.

The core DOE BES projects involving CINT scientists provide complementary funding that supports the ongoing research at Sandia and at Los Alamos. Katherine Jungjohann is partially funded by the Joint Center for Energy Storage Research (JCESR), Nanostructures for Electrical Energy Storage: Energy Frontier Research Center (EFRC). Michael Lilly, Tom Harris, and John Reno are partially funded under the BES project *Quantum Electronic Phenomena and Structure* with a focus on the interplay between disorder and interactions in 2D systems and transport in one-dimensional quantum wires. Taisuke Ohta is partially supported by the SunShot BRIDGE Program. Nathan Mara is partially funded under the core program *Deformation Physics of Ultra-fine Scale Materials.*

LDRD projects involving NEM scientists further leverage the ongoing scientific activities. Nathan Mara, Quanxi Jia, Jinkyoung Yoo, Taisuke Ohta, Katherine Jungjohann, Tom Harris, and Brian Swartzentruber are partially supported by LDRD projects. In addition, Nathan Mara is partially funded through the LANL Institute for Materials Science, which is part of the LANL National Security Education Center, and serves as the face of LANL Materials Science to the outside community.

DARPA is funding work by John Reno on the use of quantum cascade lasers (QCL) to produce optical combs for spectroscopy. This project is leveraging existing expertise in the growth of THz QCLs and is funding increased capability in indium-based QCLs in the long wavelength infrared.

4.6 Distinguishing Characteristics of NEM Thrust

The NEM Thrust is focused on understanding and controlling electrical and mechanical properties of nanoscale materials. Our thrust has a strong presence in developing new capabilities and using top-down nanofabrication to integrate nanoscale building blocks into larger and more complicated structures. The NEM Thrust is strongly connected to CINT's Liquid Cell Discovery Platform that is used for *in situ* electrochemical TEM experiments. We are developing new capabilities for nanoscience such as the ability to manipulate nanoscale materials with scanning tunneling microscopy (STM) inspired probes in a scanning electron microscope (SEM), and *in situ* TEM and SEM imaging while measuring the electronic/ionic and/or mechanical properties of materials. The NEM Thrust is the home of several heavily subscribed user capabilities such as: the Integration Lab, transmission electron microscopy; molecular beam epitaxially grown GaAs heterostructures; pulsed laser deposition of nanocomposite multifunctional materials; ion beam facilities; and nanomanipulation. The NEM Thrust has strong interactions with our users and with the other thrusts at CINT, and we have cutting edge research on understanding integration science issues in electronic and mechanical nanoscale systems.

5.0 Abstract

The NEM Thrust includes nine scientific staff members with associated postdocs and technologists in the CINT Core Facility in Sandia and the CINT Gateway to Los Alamos Facility. Taking advantage of our expertise in nanoelectronics and nanomechanics, capabilities in controlled deposition and advanced characterization, and discovery platforms, the NEM Thrust works very closely with our user community to understand and control (1) the electronic and mechanical properties arising from confinement at the nanoscale, (2) interactions within nanostructures, and (3) the integration of heterogeneous nanostructures. The NEM Thrust addresses important integration issues for nanoscale electronic and mechanical systems, such as energy transfer across interfaces, the role of defects in nanostructured materials, and interactions between nanoscale building blocks in integrated structures. Research areas of the NEM Thrust cover advanced capabilities to study nanostructured materials and devices, single spin devices in semiconductors, nanoscale plasticity and fracture in structural materials, multifunctional nanocomposite metal-oxide films, and nanowires for new energy concepts. In order to achieve the scientific and technological goals of the NEM Thrust and our users, we have designed and built new tools for nanoscience that include platforms for transport and for electrochemical studies of a wide range of nanostructured materials, capabilities for nanomanipulation and in situ electrical and mechanical probing with simultaneous imaging with either transmission or scanning electron microscopy, and growth techniques to synthesize nanostructured materials with controlled electronic and structural properties.

6.0 Narrative

6.1 Background and Significance

Nanoscience integration extends from the synthesis and fabrication of individual nanoscale building blocks (which may, in turn, involve combining different materials into specific heterostructures) to the assembly of these building blocks and the generation of complex functional structures and systems. Such integration is key to exploiting nanomaterials in applications and scientific investigations that can ultimately impact national and international needs in areas such as energy, environment, and security. The NEM Thrust is focused on understanding and controlling electrical and mechanical properties of nanoscale materials. The science of the NEM Thrust also addresses issues related to nanoscience integration, such as the control of energy transfer across interfaces and over multiple length scales and the role of defects in affecting electronic and mechanical behavior in nanostructured materials.

The NEM Thrust strives to address scientific issues in both electrical and mechanical nanosystems by bringing nanostructures together to implement specific functions, combining different materials to modify electrical or mechanical behavior, or texturing materials at the nanoscale. In order to meet the needs of our user community and to accomplish our scientific goals, the NEM Thrust has developed unique capabilities, platforms, and tools to address scientific and technological issues never addressed before. The NEM Thrust houses molecular beam epitaxy (MBE) systems for high-quality GaAs heterostructured materials, an ion beam facility for ion implantation, analysis, and irradiation, a metal oxide molecular beam epitaxy system for synthesis of multi-functional materials, and a furnace-type solid-source CVD system for nanowire growth, among other state-of-the-art systems. Advanced capabilities enable the NEM Thrust to attract more users and to enhance the active collaborations between CINT scientists.

In this report, we highlight both internal CINT science projects and user projects, and we present our future plans for integration science in the NEM Thrust. While we have made many exceptional contributions to the field and demonstrated major advances on different fronts, the examples illustrated in this document cover only a limited selection of accomplishments. A more comprehensive collection of our achievements can be found in the publications over the last three years. Based on our expertise, capabilities, and interactions with users, this report will focus on the following key scientific areas where the NEM Thrust has made and will continue to make significant contributions to integration science issues: (1) advanced capabilities, (2) single spin devices, (3) nanoscale plasticity and fracture, (4) controlled functionalities in nanocomposite films, and (5) nanowires for new energy concepts.

6.2 Progress Report

This progress report highlights selected accomplishments of the NEM Thrust over the past three years. Many of these highlights are closely related to user projects. Many scientific discoveries rely on new capabilities, and Section 6.2.1 describes breakthroughs that have used our discovery platforms and advanced tools. Section 6.2.2 describes innovations in creating nanoelectronic devices, where our advanced MBE systems have been used to grow high-quality semiconductor materials. Section 6.2.3 showcases our ability to image localized plasticity events during small-scale mechanical testing in order to understand the scientific issues in mechanical nanosystems. Section 6.2.4 describes our major advances in the development of vertically-aligned nanocomposite films with improved functionalities, where both strain and interfaces play important roles in determining the functionalities. Section 6.2.5 illustrates our achievements in the area of nanowires for new energy concepts.

6.2.1 Advanced capabilities

(a) Electrochemical TEM Discovery Platform for in situ investigations

Using the Electrochemical Transmission Electron Microscopy (TEM) Discovery Platform, we successfully demonstrated our impact within the area of electrochemical research in nanomaterial growth and assembly and battery research. We are contributing to the community with both user access to this platform and advanced capabilities for enhanced environmental control within the liquid cell. In comparison to commercial electrochemical TEM cells, we provide the advantages of experimental customization of the electrode materials and layouts, evenly distributed thin liquid layers, 10 individually controlled electrodes for multiple experiments within the same environmental conditions, and low-current control for quantitative analysis of the electrochemical data and the structural and chemical information of nanoscale electrode areas.

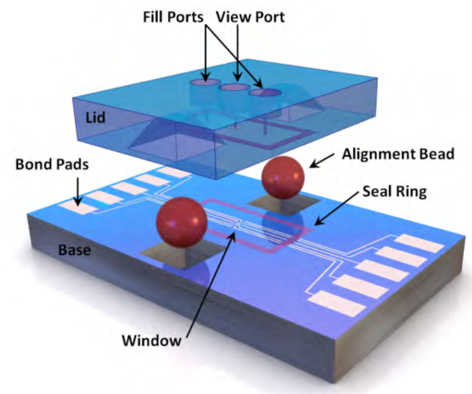

Fig. 1 Electrochemical TEM Discovery Platform.

The Electrochemical TEM Discovery Platform is microfabricated at the MESA facility at Sandia National Laboratories (SNL). The liquid cell (Figure 1) is composed of two independent chips where the lid and base parts are epoxied together to form a ~120-nm liquid gap between the independent windows. The lid part has two fill ports. The sample solution is introduced to the epoxy-sealed cell into one fill port, and capillary forces draw the solution to completely fill the window region in the cell. Once the cell is filled, the fill ports are sealed with a barrier layer and coated in epoxy.[1]

Our work over the past 3 years has optimized approaches for integrating nanomaterials onto the electrodes within the window region of the Electrochemical TEM Discovery Platform. Collaboration with our dual-nanomanipulator system within a scanning electron microscope (SEM) has enabled a pick-and-place technique for individual nanowires/nanofibers/nanoparticles, and integration with the focus ion beam (FIB) enables placement of sectioned nanoscale thick films. We make good electrical contact with these materials using localized metal contact deposition patterned with electron-beam lithography and FIB deposition of conductive carbon or platinum for air-sensitive materials.

A demonstration of the sensitivity and capability of the Electrochemical TEM Discovery Platform is shown in Figure 2. Lithium dendrite formation was investigated on <1 μm^2 Ti working electrodes within a commercially relevant Li-ion battery electrolyte (1 M $LiPF_6$ in EC/DMC).[2] This platform has allowed CINT researchers and users to investigate many electrochemical deposition, dissolution, intercalation, and assembly phenomena with quantitative control over the processes within the cell.

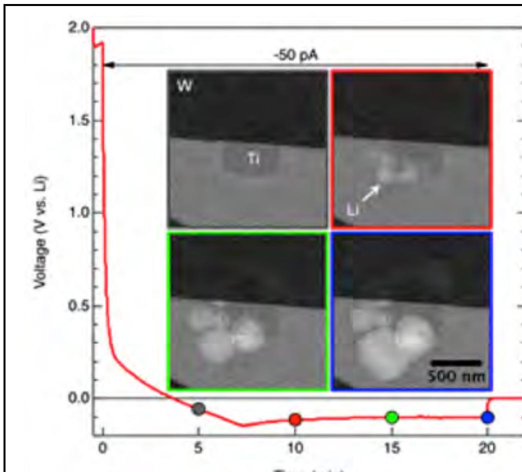

Fig. 2 Li deposition in situ. Quantitative electrochemical and TEM characterization

Using our previously-developed "open-cell" electrochemical cell within the TEM, our CINT user community has investigated anode cycling mechanisms for Li-ion and Na-ion batteries. We expect to continue our "open-cell" experiments for high-resolution imaging of structural changes and investigations on solid-state systems, as well as "closed-cell" experiments that mimic real working battery electrolyte and cell conditions.

Some research findings using the open cell are as follows:

i. We studied the degradation mechanisms of stress-induced buckling of an Sb thin film on the current collector during solid-state sodiation of a Na-ion anode. Interestingly we found that the buckling occurred within the Sb film, meaning the current collector-electrode interface was structurally more robust during the sodiation process than the anode material alone. This demonstrated a defining mechanism for capacity loss in these electrodes towards the development of high-performance Na-ion batteries.[3]

ii. We characterized the anisotropic strain experienced in carbon nanofiber anodes for solid state cycling of alkali-metal ion batteries (Na-ion and K-ion). Higher storage capacity of Na- or K-ions was observed for the disordered carbon structure as compared to the crystalline core. This high storage capacity caused longitudinal cracks along the interface, which was a primary source of mechanical degradation in these two-phase hollow anode structures.[4]

iii. We observed a size-dependent pulverization mechanism of Sn particles during Li cycling of anode materials. Aggregation and pulverization of nanoscale Sn particles was observed during lithiation, indicating a self-healing mechanism. Capacity loss occurred as a result of SEI formation around the small particles, which isolated the particles from further aggregation and prevented the self-healing mechanism.[5]

(b) Molecular beam epitaxy (MBE) of high-mobility III-V structures

Some research findings using the material grown in our MBE system are as follows:

i. New Compact Terahertz Laser Frequency Combs Using Terahertz Quantum Cascade Lasers[6]

Optical frequency combs are revolutionizing high-precision metrology and spectroscopy. At the heart of the newest frequency combs are terahertz quantum cascade lasers (QCLs), which are complex multilayer crystals grown by MBE. QCLs have both high power and broadband capabilities because they can be pulsed.

Researchers at MIT and CINT fabricated high performance QCLs and integrated them into a cavity to demonstrate new high-power, broadband frequency THz frequency combs. By applying dispersion compensation techniques from visible wavelengths to the THz QCL, an arbitrary gain medium can be made to produce passive combs to cover a frequency range of almost 500 GHz with more than 70 lines at 3.5 THz. This is nearly an order of magnitude improvement over the ten modes obtained by active mode-locking approaches. The comb's bandwidth covers 14% of its center frequency—the highest fractional bandwidth of integrated semiconductor frequency combs to date—suggesting that similar techniques can be used to improve Kerr-like combs at other wavelengths (including the mid-infrared). Shifted wave interference Fourier-transform (SWIFT) spectroscopy, a coherent detection scheme that can be used in combination with Fourier-transform spectroscopy to quantitatively measure the performance of such lasers and to measure the efficacy of comb formation, was demonstrated as well. By utilizing intracavity mixing, these lasers can compactly measure the frequency of single-mode lasers without the need for a high-speed terahertz detector or an external solid-state laser.

ii. Coupled Hole Quantum Dots in GaAs/AlGaAs[7]

One of the leading candidates for a solid-state quantum bit is the spin of a single electron confined in a semiconductor. The pioneering experiments that demonstrated coherent control of individual electron spins in quantum dots utilized high-mobility two-dimensional (2D) electron systems in GaAs/AlGaAs heterostructures. The major source of decoherence in such experiments is coupling between electron spins and nuclear spins in the host GaAs semiconductor. It is proposed that hole spins in GaAs are better suited for such experiments due to a lesser coupling between holes and nuclear spins. The stronger spin-orbit interaction for holes, as compared to electrons, may also provide a means for electrical spin manipulation.

We demonstrated a few-hole double quantum dot in an undoped (100) oriented GaAs/AlGaAs heterostructure (Figure 3). The device shows good charge stability and negligible hysteresis with respect to gate voltage. The interdot coupling can be tuned over a wide range, controlling the transition from a large single dot to two well-isolated quantum dots. Using charge sensing we show that the dot can be completely emptied of holes and operated in the few-hole regime. The device may provide a means for future experiments that focus on manipulation of single-hole spins in GaAs quantum dots.

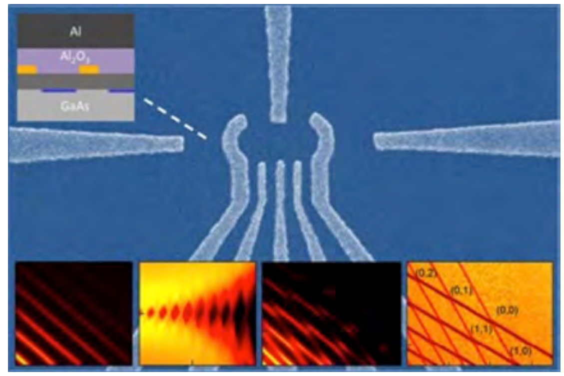

Fig. 3 SEM micrograph and a sketch of the cross-section of the device showing the metallic control gates (top). Charge conductance through the device operating as a large single dot (bottom, left). Demonstration of the device working as two separate dots and the control of the number of holes on each dot (bottom, right).

iii. Immunity to Heating in Nanodevices Under Strong Non-Equilibrium Conditions[8]

Electronic transport in a nanodevice can be made insensitive to local heating by – counterintuitively – driving the transport into strong non-equilibrium conditions. Our research suggests novel strategies to alleviate heating in nanoscale devices and may allow the realization of quantum devices in which the effects of decoherence (which disrupts device operation) are minimized.

Managing energy dissipation is critical to the scaling of current microelectronics and to the development of novel devices that use quantum coherence to achieve enhanced functionality. To this end, strategies are needed to tailor the electron–phonon interaction, which is the dominant mechanism for cooling non-equilibrium (“hot”) carriers. In experiments aimed at controlling the quantum state, the electron-phonon interaction causes decoherence that fundamentally disrupts device operation. We showed a contrasting behavior, however, in which strong electron–phonon scattering can be used to generate a robust mode for electrical conduction in GaAs quantum point contacts that are driven into extreme non-equilibrium by nanosecond voltage pulses. When the amplitude of these pulses is much larger than all other relevant energy scales, strong electron–phonon scattering induces an attraction between electrons in the quantum-point-contact channel that leads to the spontaneous formation of a narrow current filament and to a renormalization of the electronic states responsible for transport. The lowest of these electronic states coalesce to form a subband separated from all others by an energy gap larger than the source voltage. A suppression of heating-related signatures in the transient conductance, which becomes pinned near $2e^2/h$ (e, electron charge; h, Planck constant) for a broad range of source and gate voltages, is evidence for the renormalization of electronic states. This collective non-equilibrium mode is observed over a wide range of temperature (4.2–300 K) and may provide an effective means to manage electron–phonon scattering in nanoscale devices.

(c) LEEM/PEEM development

During FY13–FY15, we devoted major effort toward the development of a deep ultraviolet (DUV) light source for photoemission electron microscopy (PEEM) with tunable wavelength, which would enable us to access the band structure of many materials. Band alignment is an important parameter to evaluate electron transport at the interfaces between dissimilar materials, where offset electronic states are commonly found.

Our tunable DUV light source is based on a pressurized xenon lamp producing high-intensity white light in the ultraviolet and DUV spectral ranges. Tuning is accomplished by coupling a compact monochromator to the xenon lamp. Our light source is designed to spatially resolve and quantify the band alignment across lateral interfaces. To accomplish this, we developed two measurement modes based on the threshold photon energy for photoemission and the detection of the secondary-electron cut-off energy to determine the ionization energy and the work function, from which we extract the energy alignment of the valence bands and the surface potentials of the two dissimilar materials.

Two ongoing CINT user projects are validating the interpretation of the experimental data and the ability to extract surface work functions. These projects focus on the electronic properties and their inhomogeneity in atomically-thin transition metal dichalcogenides and polycrystalline photovoltaic materials.

6.2.2 Single spin devices

As electronic device sizes are reduced, quantum mechanics begins to dominate the electrical properties. Reducing the dimensionality from 3D to 2D to 1D also reduces the ability of electrons to avoid each other, and many-body electron interactions become important. Interactions give rise to new ground states such as the quantum Hall effects in 2D and Luttinger liquids in 1D. Further shrinking of dimensionality to 0D allows individual electrons to be isolated in quantum dots. Integration of multiple nanoelectronic devices enables measurement of single electron charge and spin on a very fast timescale and is the frontier for controlling quantum mechanics using quantum computing techniques. In the quantum transport group, we worked with users on single electron spin devices, novel fabrication techniques for low dimensional systems, and a top-down fabrication technique that uses scanning tunneling microscopy and can ultimately lead to sub-nanometer lithography.

In recent years, many techniques have been developed to fabricate devices that can be reduced to single electron, and techniques have been developed to read and control the spin of the electron. At CINT we have focused on integrating single electron transistors (SETs) with donors in silicon. Our goal is to create spin qubits. In semiconductors, the hyperfine interaction between the nuclear spins in the lattice and the electron spin can lead to a fluctuating magnetic field and spin decoherence. Silicon is an attractive material for single spin studies, since the primary isotope Si^{28} has a nuclear spin of 0 and the electron can have long spin lifetimes and coherence times.

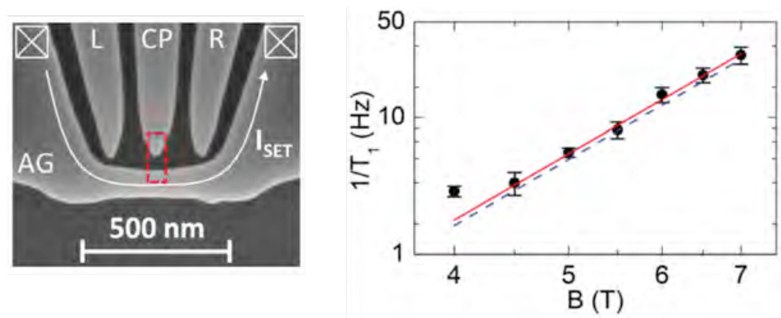

Fig. 4 SEM of the device region. A quantum dot is formed under the AG gate, and barriers between the dot and the source/drain are controlled with L and R. 120 keV Sb is implanted in the region of the red box. CP controls the donor occupation (left). Electron spin lifetime as a function of magnetic field. Solid red line is a fit to B>4 and the blue dashed line is the expected value from Wilson and Feher, Phys. Rev. 124, 1068 (1961) (right).

A typical donor-SET device is shown in Figure 4.[9] The image is a top view of a silicon wafer covered with 35 nm of silicon oxide, followed by 200 nm of conducting polysilicon. The polysilicon is etched to form gates (light regions). The AG gate is biased positively to form a skinny wire running from left to right, and the L and R gates are biased negatively to form a SET in the middle of the wire. A low density of Sb (4×10^{11}/cm^{-2}) is implanted at 120 keV between CP and AG. By tuning the gates and measuring Coulomb blockade through the SET, an individual donor can be identified.[10] In a magnetic field, the electron spin up and down is Zeeman split. Readout and initialization[11] are performed by pulsing the gates with the energy levels in the devices appropriately tuned so that a spin up—but not a spin down—can tunnel off the donor. We have demonstrated both average spin readout where many pulses are averaged to observe the signal, and in very sensitive devices we can measure the spin up or down of the electron in a single pulse sequence. We have used these techniques to initialize, readout, and manipulate single electrons in silicon devices.

In order for the electron spin to be useful, the lifetime of the excited spin up state must be long enough for spin operations and measurement to occur. To measure the spin lifetime, we prepare a spin up electron and wait; then we measure the spin using the pulsing technique described above. The spin decays exponentially, so we can extract the spin lifetime by varying the wait time. Electron spin lifetimes are shown in Figure 4 (right). The relaxation rate is proportional to B^5 and is consistent with spin relaxation due to g-factor anisotropy. For magnetic fields less than 5 T, the spin lifetime exceeds 100 msec. In subsequent measurements with similar devices, we demonstrated control of the electron spin (electron spin resonance) using microwave magnetic fields.

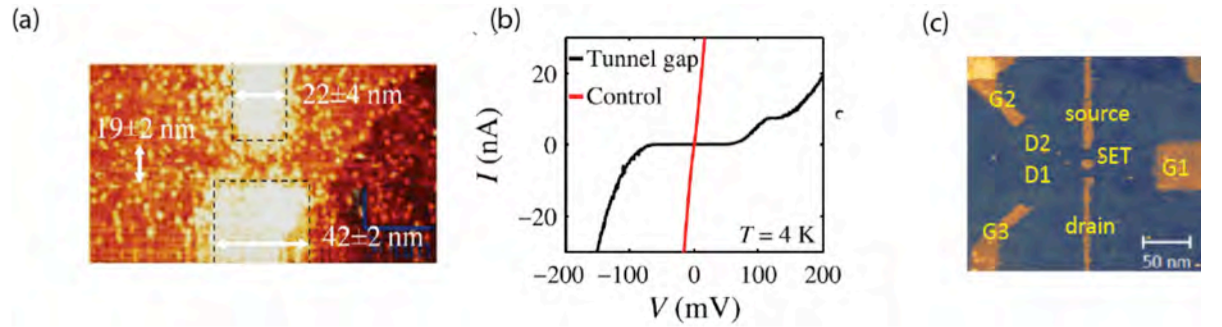

Fig. 5 Device with STM patterned tunnel junction (a). Non-linear transport (black) through the tunnel junction indicates a transport barrier, and linear transport (red) is through a control device with no barrier (b). STM patterning of a more complicated structure (c).

For single electron studies, the random location of the electron in the device described above can be used. For more complicated devices where two or more electrons need to be placed with precision, new nano-fabrication techniques are needed. Working with a CINT user (Bielejec), we have fabricated donor-SET devices surrounded by an integrated ion detector.[12] A special focused ion beam with a 25-nm spot size, beam alignment capability, and an E×B filter for multiple ion species is used to implant Sb with better than 25-nm alignment precision in our silicon device. The ion detector can detect single Sb implants, so more complicated donor-SET devices can be fabricated.

The ultimate precision in single donor placement in silicon devices can be achieved using a lithography technique (developed at CINT) that is based on scanning tunneling microscopy (STM).[13] A clean silicon surface is passivated with hydrogen in a UHV environment. A scanning tip is used to selectively remove the hydrogen at the atomic length scale, and subsequent dosing with phosphine allows individual P donors to be placed. Results from experiments with single tunnel junctions[14] are shown in Figure 5 (a) and (b). Here, a 19-nm gap is formed between a conducting source and drain, and a gap is observed in the *I-V* plot. More complicated devices with gates, SETs, and individually placed donors are being fabricated. STM patterning of one such structure is shown in Figure 5(c).

6.2.3 Nanoscale plasticity and fracture

As microstructural length scales become <10 nm, the volume fraction of material located at biphase interfaces or free surfaces increases substantially. In materials such as nanofoams, nanolayered composites, or composites containing amorphous phases, local atomic structure plays an increasingly important role in determining the behavior and stability of material under extreme environments (stress, temperature, strains, strain rates, radiation).[15] The properties of the material are no longer dependent upon the constituent materials so much as the character of the interface between them. This work is facilitated by the unique combination found at CINT in both synthesis (magnetron sputtering) and mechanics characterization inside of SEM and TEM.

Research highlights of our nanoscale plasticity and fracture work are as follows:

i. We performed fabrication and nanomechanical tension experiments on as-fabricated and helium-implanted ~130-nm diameter $Ni_{0.73}P_{0.27}$ metallic glass nanocylinders. The nanocylinders were fabricated by a templated electroplating process and implanted with He+ at energies of 50, 100, 150, and 200 keV in order to create a uniform helium concentration of ~3 atom % throughout the nanocylinders. TEM imaging and through-focus analysis revealed that the specimens contained ~2-nm helium bubbles distributed uniformly throughout the nanocylinder volume. In situ tensile experiments indicate that helium-implanted specimens exhibit enhanced ductility as evidenced by a 2-fold increase in plastic strain over as-fabricated specimens with no sacrifice in yield and ultimate tensile strengths. This improvement in mechanical properties suggests that metallic glasses may exhibit a favorable response to high levels of helium implantation.[16]

ii. We synthesized nanoporous copper (NP Cu) by electrochemical dealloying of amorphous $Cu_{0.41}Si_{0.59}$ under compressive residual stress. TEM revealed the struts are nanocrystalline with a grain size equal to the strut thickness. Moreover, a significant population of twins with spacing of ~7 nm was present within each imaged grain. The hardness of this nanocrystalline, nanotwinned NP Cu is approximately one order of magnitude greater than reports on NP Cu in the literature. The yield strength of individual struts inferred through dimensional analysis is approximately an order of magnitude greater than bulk copper and compares well with other nanostructured copper systems.[17]

iii. Experimental quantification of the critical resolved shear stress (CRSS) at the level of unit dislocation glide is still a challenge. By using in situ nanoindentation in a high-resolution transmission electron microscope and strain analysis of the acquired structural images, we measured the CRSS for the motion of individual dislocations on $\{110\}\langle 011\rangle$ slip system and glide dislocation re-emission from a tilt grain boundary in TiN. This work offers an approach to measure the local stresses associated with dislocation motion in high-strength materials.[18]

iv. Bulk nanostructured metals can attribute both exceptional strength and poor thermal stability to high interfacial content, making it a challenge to utilize them in high-temperature environments. We reported that a bulk two-phase bimetal nanocomposite synthesized via severe plastic deformation uniquely possesses simultaneous high-strength and high thermal stability. For a bimetal spacing of 10 nm, this composite achieves an order of magnitude increase in hardness of 4.13 GPa over its constituents and maintains it at 4.07 GPa, even after annealing at 500 °C for 1 h. This extraordinary property is due to an atomically well-ordered bimaterial interface that results from twin-induced crystal reorientation, persists after extreme strains, and prevails over the entire bulk. This discovery proves that interfaces can be designed within bulk nanostructured composites to radically outperform previously-prepared bulk nanocrystalline materials with respect to both mechanical and thermal stability.[19]

6.2.4 Controlled functionalities of nanocomposite films

Tuning the concentration of defects in metal oxides provides a novel approach to controlling new functionalities of nanocomposite films. Through a joint effort with CINT users (both Prof. MacManus-Driscoll from Univ. of Cambridge and Prof. Wang from Texas A&M), we demonstrated electroforming-free reversible electroresistance in nanocomposite films at room temperature.[20] We grew nanoscaffold films of $SrTiO_3$:Sm_2O_3 nanocomposite films on conductive Nb-doped $SrTiO_3$ substrates using pulsed laser deposition. Using conductive atomic force microscopy (c-AFM), we found that high conductivity (or resistive switching behavior) is confined at vertical interfaces (Figure 6). The resistance variations exceeded two orders of magnitude with very high uniformity and tunability. Using

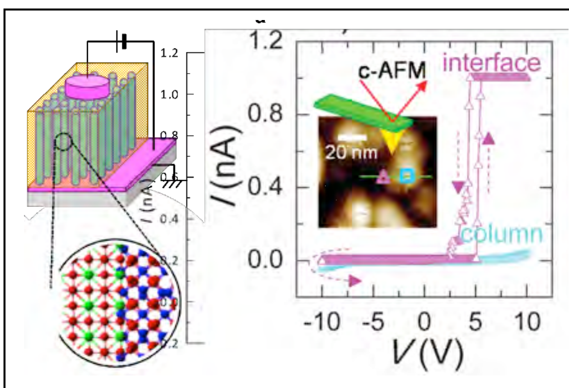

Fig. 6 Schematic diagram of the device structure based on nanoscaffold nanocomposite structure (left panel). Current vs voltage curves at interface and inside nanocolumn using conductive AFM. The inset shows the surface topography of the nanoscaffold film (right panel).

nanscaffold nanocomposite films for memristors could potentially lead to terabit memory density (~ 40 Tb/in^2). Using electron energy loss spectroscopy, we found oxygen deficiency at the vertical interfaces of nanocolumns and the matrix. A large concentration of oxygen deficiency across the vertical interface is attributed to the resistive switching across the interface between $SrTiO_3$ and Sm_2O_3. By using nanoscaffold structures to engineer oxygen vacancies, the conduction channels are spatially confined at vertical interfaces and device performance is better controlled with high uniformity and reproducibility. Our experimental results provide the fundamental basis to develop ionotronic technologies which may find wide applications in clean energy.

Oxygen vacancies in transition metal oxides have attracted renewed attention as functional ionic defects for the application of ionotronics and energy materials. We designed layered and vertically aligned yttria-stabilized ZrO_2 nanocomposite films. The ionic conductivity of these films is enhanced by more than two orders of magnitude when compared with conventional architectures.[21] Compared to earlier work where high ionic conductivity was accomplished only in ultrathin films, these new nanocomposite thick films show high ionic conductivity at 360 °C and may have applications in low-temperature solid-oxide fuel cells and ionotronics.

6.2.5 Nanowires for new energy concepts

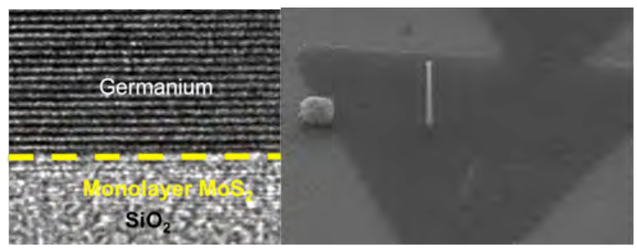

Fig. 7 Single crystalline Ge thin film grown on monolayer MoS_2 (left). A Si nanowire selectively grown on monolayer MoS_2 (right).

The novel properties of nanowires offer tremendous opportunities for transformative energy applications. Nanowires are multi-purpose materials that combine nanoscale and quantum-confinement effects that enhance transport properties. A focus of CINT scientists and our user community is to understand and control the functionality and integration of heterogeneous semiconducting nanowires for new energy harvesting and storage concepts. We emphasize heterogeneous nanowires in order to realize an unprecedented level of control over material performance by tuning interface, strain, and materials-mixing effects. We combine new synthesis strategies with structural, electrical, optical, and thermal characterization. Initially, our focus is at the single-nanowire level to address critical science questions underlying new nanowire materials concepts for photovoltaics, thermoelectrics, and energy storage. We also drive toward functional integration of nanowires into 2D and 3D architectures.

We have successfully grown single-crystalline Ge thin films and nanowires on monolayer MoS_2 and graphene via chemical vapor deposition (Figure 7). Since monolayer MoS_2 and graphene do not have dangling bonds on the surfaces, the Ge growth was explained by van der Waals epitaxy, which has not been thoroughly studied in the 150-year history of epitaxy research. The heterostructures formed atomically-thin n-type MoS_2 and single-crystalline p-type Ge, exhibiting rectifying behavior similar to that of p-n junctions.

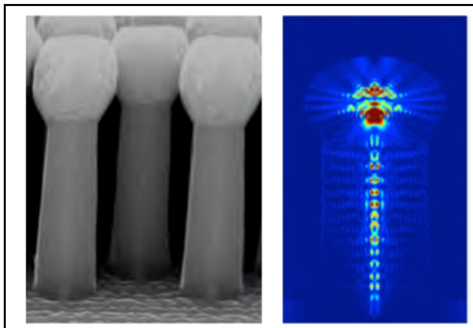

Fig. 8 Scanning electron microscopy image of Si radial p-i-n junction wire arrays with match heads (left). Optical absorption profile in single Si match head wire at 587 nm wavelength (right).

We discovered a method to achieve enhanced light absorption and photovoltaic efficiency with crystal growth.[22] Crystal growth on the tops of nano/microwires forms three-dimensional structures that look like "match heads" to lower the total energy of the material by surface minimization (Figure 8). These natural match heads can be formed with various materials. The match heads can focus incident light for greater overall efficiency in radial p-n junction nano/microwires. According to the CINT research, for Si radial p-i-n junction wire arrays, light absorptance and photovoltaic efficiency were increased by 36 and 20%, respectively, compared to arrays without match heads.

Si nanowires are considered promising building blocks for anodes of lithium ion batteries due to their large gravimetric capacity and high resistance to mechanical fracture. However, direct preparation of Si nanowires on metal current collectors induces an unintentional formation of Si clumps that can be easily fractured during charging-discharging cycles. Eventually, these Si clumps limit the overall electrochemical performance of Si-based Li ion battery anodes. We demonstrated that anodized-aluminum-oxide-assisted Si nanowire growth can eliminate Si clump formation. Furthermore, electrochemical performance tests show that Si nanowires without Si clumps have significantly enhanced cyclability compared to Si nanowires with Si clumps.[23]

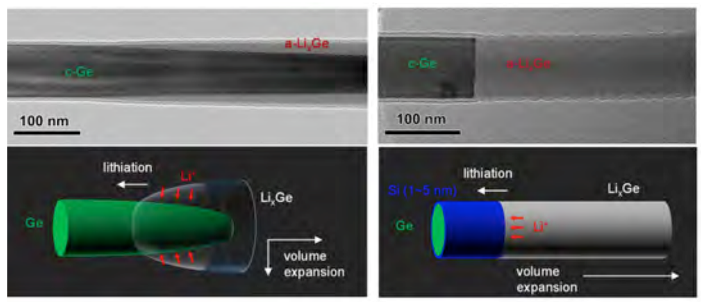

Fig. 9 In situ TEM lithiation results of homogeneous Ge NW (left) and Ge/Si core/shell NW heterostructure (right).

Control of lithiation behavior in nanomaterials has been intensively studied to understand Li ion transport and to enhance Li ion battery performance. The most common method to control lithiation behavior is external mechanical confinement, which employs an outer shell to mechanically hold the structure of nanomaterials. However, the mechanical confinement is very sensitive to defects. Interfacial control of Li ion transport is another way of controlling Li ion transport. As shown in Figure 9, our research revealed that radial heterojunctions in Ge/Si core/shell nanowires change the Li ion insertion route dramatically. By deposition of thin (3-nm thick) Si shells on Ge nanowires, the Li ion insertion route is limited along the axial direction of the nanowires. This is the first direct observation of such an interfacial effect on ionic transport at the nanoscale.[24]

6.3 Future Directions

Based on our expertise, capabilities, and interests of the user community, we highlight the future scientific and technological areas of NEM Thrust that will have great impact on nanoscale science and technology.

6.3.1 Advanced capabilities

(a) Liquid-Mechanical Discovery Platform and TEM

To advance our liquid-cell TEM capabilities, we are integrating mechanical control over a nanoscale wire/thin-film specimen into our Electrochemical TEM Discovery Platform. This is a first-of-its-kind platform for quantitative mechanical loading within a hermetically sealed liquid environment for high-resolution TEM analysis; the platform provides enhanced environmental control over a specimen, including quantitative stress control and electrochemical and elevated temperature control. The platform will be used to study the nanoscale mechanisms of stress-induced failure of electrodes in battery materials, stress-corrosion-cracking, and the mechanical characterization of nanoscale bio-composites.

The base platform design is being reconfigured from the existing state-of-the-art Electrochemical TEM Discovery Platform with the integration of a TEM compatible uniaxial tensile device[25] that is currently being assimilated for use at CINT. This load-controlled tensile testing unit will operate un-obstructed within the imaging gap of ~500 nm for optimal imaging through the liquid enclosure. Two design and fabrication sequences will be performed, the first sequence will focus on various microelectromechanical systems actuators (thermal, electrostatic, and piezoelectric) on the base chip and the second sequence will focus on optimization.

We are also developing enhanced stage control to manipulate samples within the TEM discovery platforms. Holder designs will be produced in order to lend the stages and platforms out to users for experimental research conducted with these unique CINT capabilities at their home institutions. Dissemination of our resources will broaden the impact of CINT's TEM discovery platforms for use anywhere in the world on compatible JEOL and FEI TEMs.

In the development of our "Lab-in-a-Gap" TEM characterization and analysis capabilities, we are pursuing opportunities to bring in advanced high-speed cameras to enable the acquisition of data at the rate that changes are occurring in dynamic experiments. Currently, we are limited to frame rates of 33 frames per second in TEM mode and about 1 frame per second in STEM mode, though high frame rates usually scale with increased beam dose to the specimen. For analysis of mechanical properties, transport properties, electrochemical deposition/dissolution, nanoscale growth, phase-changes, and assembly of materials in the TEM, we need to increase our acquisition frame rate while retaining or reducing the detrimental effects of the electron beam. Therefore, we are interested in using direct-electron detection to accomplish improved data acquisition while limiting electron beam degradation of samples, enabling us to acquire clear evidence of the nanoscale mechanisms that control the physical properties of nanoscale materials.

Through a new CINT-LANL partnership, we have the opportunity to expand our electron microscopy (EM) capability to include two 5-year-old instruments housed in LANL's Electron Microscopy Laboratory (EML). This opportunity will allow users to conduct in situ TEM experiments at an atomic resolution not previously accessible through the existing user program. CINT currently houses one of the most comprehensively equipped nanomechanics laboratories worldwide (including in situ TEM straining capability) and leads the world in operando electrochemical behavior studies using TEM. We propose to forge new inroads in "Lab-in-a-Gap" experimental capability by expanding user access to aberration-corrected TEM. Access to the LANL FIB expands current CINT FIB capacity and capabilities to EM sample fabrication and in situ testing previously off-limits to CINT users, particularly for mildly radioactive samples. Through a partnership with LANL's EML, CINT staff will have preferred access to the instruments to work with and train users. Critical to this approach, LANL institutional support for the facility has been secured in the form of funds to support these two instruments as well as other instruments in the facility, such as a Tecnai TEM, two other SEMs, and laboratory space and equipment that may be leveraged for sample preparation. CINT users will gain accessibility to the following instruments under this model:

- *FEI Titan aberration-corrected TEM*
- *FEI Helios Dual-Beam FIB*

CINT is a worldwide nanoscience resource and leader in determining structure-property relationships in functional (electrical, photonic, magnetic) and structural nanomaterials. The recent success of CINT's Electrochemical TEM Discovery Platform, coupled with the broadest nanomechanics capability in the Nanoscale Science Research Center (NSRC) system, provides the necessary scientific leadership and user base to define the next generation of tools and approaches for in situ and operando studies. We intend to expand our "Lab-in-a Gap" capabilities through access to these new instruments. CINT already has over a dozen in situ TEM holders that are compatible with both the Tecnai TEM at the CINT Core Facility and the Titan aberration-corrected microscope. Users that currently conduct in situ heating and straining experiments at the Core Facility will gain access to stable atomic resolution imaging not previously accessible through the existing user program. We will optimize usage at the two sites by sharing holders between locations to develop a nanomechanics and high-temperature focus at the Gateway to Los Alamos Facility and a liquid, electrochemical, and cryogenic focus at the Core Facility. CINT's current efforts to develop a novel Liquid-Mechanical Discovery Platform will benefit and, coupled with aberration-correction, will attract an entirely new field of users. Moreover, through a recently established leveraged partnership with SNL's Ion Beam Laboratory, CINT expanded its microscopy capabilities to include the unique in situ TEM to simultaneously impose heating and mechanical straining during ion irradiation.

Further expansion to include user access to aberration-corrected TEM with an emphasis on in situ experimentation is the logical next step in executing our vision for CINT to emerge as a worldwide home for “Lab-in-a-Gap” nanoscale discoveries.

(b) Molecular beam epitaxy of high-mobility III-V structures

The future holds a new capability for the MBE system. Due to requests from users, we will develop the growth of indium-bearing (In-bearing) alloys (InGaAs and InAlAs) on both GaAs and InP substrates. In-bearing materials are strained on GaAs, and the bandgap for InGaAs is lower than GaAs. This allows for nanophotonic work in new wavelength ranges. Growth of In-bearing compounds on InP or GaAs opens the possibility of low-dimensional work in the mid- to long-wavelength infrared.

(c) LEEM/PEEM development

Extending our development of tunable DUV light sources, we will expand our PEEM capability to use an ultrafast DUV laser as a new light source. Ultrafast lasers have been used in PEEM studies of plasmon polaritons on noble metal surfaces using infrared and visible light.[26] A drawback in using infrared and visible light is its insufficient energy to stimulate the photoemission process for most materials, where the work function is larger than the photon energy. Such measurements rely on a two-photon (or higher order) photoemission process or on the chemical modification of material surfaces to reduce their work function, thus modifying the intrinsic properties of the samples. To overcome this limitation, we will develop a PEEM coupled to a DUV ultrafast laser with higher energy than the work function of most semiconductor and metallic materials. Both the steady increase in commercially available laser power and the rapid development of non-linear optics have increased the availability of relatively high power DUV ultrafast lasers.

By coupling a DUV laser to PEEM, we will develop two major measurement schemes: polarization control of light to interrogate orbital symmetry and magnetism and a pump-probe beam line to study ultrafast electron dynamics. In many nanoscale materials, inversion symmetry is lifted at the surface, altering the symmetry of the atomic arrangement or lifting the spin degeneracy. In addition, the electron dynamics are often significantly different from those of ordinary bulk materials due to the unique dielectric environment in nanomaterials. We will use linear and circular dichroic imaging to study orbital symmetry and magnetism in two-dimensional crystals in which inversion symmetry is generally broken. We will apply pump-probe studies to spatially-inhomogeneous polycrystalline materials to investigate charge carrier lifetimes within crystalline grains and at grain boundaries dictating the carrier transport.

Worldwide, PEEM instruments coupled to ultrafast DUV lasers are only in the development stage; there are no DUV-laser PEEM in any NSRC user facility. Once developed, DUV-laser PEEM will be a differentiating capability of CINT and will complement other optical and microscopy capabilities at CINT.

(d) New Capabilities for Understanding Electron and Phonon Carrier Transport

Possessing a fundamental understanding of energy carrier transport in nanostructured materials is vital for developing next-generation solid-state electronics, energy conversion capabilities, and energy storage devices. With keen knowledge of electron and phonon transport in low-dimensional systems, materials can be tailored and engineered to perform effectively. Nanoscale materials, because of their relatively small size, exhibit transport behavior that deviates from transport in bulk materials as a result of classical (boundary) and quantum (wave) size effects. The wave nature of carriers is always present. Boundary scattering dominates when the characteristic size L_c of an object is much larger than the carrier’s average wavelength (but comparable to the carrier’s mean free path), and in this case the model of energy carriers as particles is appropriate. However, when L_c is much smaller than the average carrier wavelength λ, the wave nature of the carrier is expressed, and transport occurs in the quantum-limited regime. Figure 10 shows λ for both electrons and phonons as a function of temperature. At room temperature, λ is on the order of 1 nm, and nanoscale materials with L_c in the range of 10–100 nm are dominated by classical size effects (e.g., boundary scattering). At significant cryogenic temperatures (~10mK), λ can be substantially larger than L_c, allowing one to exploit the quantum mechanical nature of the material system. Schwab[27] demonstrated that nanoscale beams with L_c of ~100nm exhibit purely coherent (wave) phonon transport at temperatures below 600mK. In superlattice films with L_c of ~10nm, Chen[28] showed that partially coherent phonon transport could be observed at a temperature of 30K and, furthermore, that the wave nature of phonons persisted at temperatures as high as 150K. This persisting coherent phonon behavior is due to the broad range of wavelengths that exist in the material system and the distribution of energies associated with these wavelengths. For nanoscale materials with L_c of ~10–100nm, Figure 10 illustrates an approximate mixed regime where neither boundary nor wave effects dominate. This crossover regime—along with the contributions of particle and wave effects—remains an unexplored area in carrier dynamics for both electrons and phonons because of current technological limitations that allow for the acquisition of the full range of transport data. To address this issue we propose developing a wide-temperature range (10mK–330K) dilution refrigerator. Typical cryogenic systems only permit a narrow range of operation, for example 10mK-1K or 1K-300K. This wide-range instrument fills a technical void and would allow one to acquire transport data from a purely classical regime to a purely quantum-limited regime, providing an incredibly thorough and fundamental understanding of electron and phonon transport. This instrument would be the first-ever in its design and exist only at CINT. To benefit users, this tool would be equipped with a magnet to enable magneto transport studies and optical access, which is a feature rarely found in dilution refrigerators. In contrast to conventional electrical transport measurements that probe ground- and low-energy states, optical probes allow the direct study of high-energy excited states. Optical access in such an instrument would attract users interested in high-energy excitations of composite fermions, spin texture of quantum Hall states, dispersion of magneto-plasmons, and excitations of Wigner crystals.

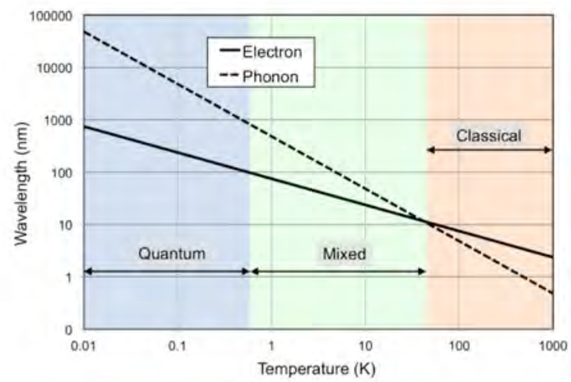

Fig. 10 The average wavelength of electrons and phonons as a function of temperature. Approximate transport regimes are highlighted for materials with critical dimensions in the range of 10–100nm.

At CINT, we developed several novel techniques for performing high-frequency (microwave) electrical measurements. This expertise, combined with a dilution refrigerator, would further extend our user base to those interested in spin qubit research for quantum computing applications. Most spin qubit research to date has focused on manipulating single-electron spins in quantum dots. However, hole spins are predicted to have some advantages over electron spins, such as reduced coupling to host semiconductor nuclear spins and the ability to electrically control hole spins using the large spin-orbit interaction. The energy scales involved with confining and manipulating single hole spins are small enough to require dilution refrigerator temperatures (< 100 mK). However, because of the expectation of longer spin coherence times for 2D holes than for electrons in GaAs, this work could eventually provide new capabilities in the area of solid-state quantum information processing.

6.3.2 Single spin devices

(a) Nanoelectronics for quantum information

Silicon is a promising material to study single spin devices due to the long electron spin lifetimes and coherence time.[29] Single electron devices can reveal interesting interaction physics, are important for semiconductor quantum computing, and have a variety of interesting quantum effects. We developed techniques to isolate, measure, and control single electron spins in silicon devices. In the next three years, we plan to move from single spin devices to building more complicated devices where interactions between single electrons are controlled and transport of coherent spins are studied. In our donor-dot structures, the donors (P, Sb) provide a well-known potential well for holding a single electron and allow coupling to the nuclear spin degree of freedom. Electron spins have lifetimes that exceed seconds, and nuclear spins can have lifetimes longer than 10 minutes. The quantum dots, on the other hand, allow very refined gate control of the electron number and control over the interaction between adjacent surface quantum dots. Quantum dots can also be used to move electrons laterally on the surface for studying transport of coherent spin states. We will use this rich system to demonstrate multiple qubits in silicon metal oxide semiconductor, GaAs, SiGe, and STM atomic-scale lithography nanostructures.

The study of single-electron devices relies on starting with high purity, low disorder materials. Part of our effort on single-electron nanostructures will focus on improving material characterization, growth and fabrication. At low temperature and energy, all low energy states such as valley states in silicon, valley-orbit coupling, and disorder near the quantum dot can affect single spin behavior. Making integrated nanoelectronics requires significant processing of materials. This processing can result in additional fixed charges near the sensitive single electron regions, e.g., as a result of bombarding the device with charged ions during a dry etch or using atomic layer deposition to make an oxide with a small number of unsatisfied bonds. We will develop characterization methods to identify the largest issues and improve fabrication techniques and material quality to minimize the impact of disorder and low energy states. This will be important for our devices and our users in the quantum computing community.

(b) Limits of fabrication

High-resolution fabrication techniques provide tools that allow us to build more complex, integrated nanoelectronics structures. Many interesting devices can be made with electron beam lithography techniques at a resolution of 10 nm and larger. We are working with users to develop new techniques in deterministic donor implantation and atomic scale lithography to extend our resolution to even smaller length scales. We will use deterministic donor implantation techniques to make donor-dot devices for electrical transport and work with scientists and users in the Nanophotonics Thrust to use similar techniques for making single-ion implant optical devices. In top-down lithography, the ultimate limit of lithography is patterning at the atomic scale. Using hydrogen resist on a clean silicon surface and STM techniques, we have shown the ability to control the surface at near atomic resolution. The next phase of this work is to make reliable devices with nm-scale quantum wires, quantum dots, and single donor components.

(c) Integrated cryo-devices for measurements

The strength of integrating multiple nanoelectronic structures together is that the properties of one device can be used to sense the quantum state of another. A good example of this was discussed in Section 6.2.2 where we used electrical transport through a quantum dot to measure the spin of an electron on a nearby donor. In many cases, however, the signals are extremely small. We can take advantage of the low temperature environment where our devices are measured, and integrate the first level of amplification stage in the cryostat. This has the dual benefit of increasing the measurement bandwidth and decreasing the noise. We will explore both low-power transistor amplifiers (some custom designed with high mobility GaAs MBE) and other devices such as superconducting circuits to push our measurement capability toward the quantum limit. Such techniques will be of general interest to any CINT user working on transport at low temperatures.

6.3.3 In situ mechanical characterization of nanostructured materials

We are expanding our efforts in high-temperature nanoindentation with a new Hysitron Triboindenter 950 installed at the Gateway to Los Alamos Facility in January 2015. This state-of-the-art nanoindenter is a replacement and upgrade for the antiquated Agilent/Keysight nanoXP, which served a large user base (~15 users annually) but was no longer supported by the manufacturer. New capabilities include small scale mechanical testing under an inert gas environment at temperatures up to 800°C and dynamic mechanical measurements, such as continuous stiffness at elevated and ambient temperatures at loads ranging from nanoNewtons up to ~5 Newtons. CINT was the first site in the world to have this unique combination of capabilities. In addition to the previous user base of the nanoXP, two new users (one SNL staff member working on fundamental response of Ni and one LANL postdoc working on nanomechanical response of nuclear fuel materials) use the high temperature capability..

We have been collaborating with nanomechanical equipment vendors to further develop small-scale test techniques to probe materials under extreme environments. For such technique development endeavors, CINT is an ideal collaborator because of its access to a library of materials for service in extreme environments. Further, under the encouragement of DOE-BES program management, collaborations in nanomechanics between both CINT sites (scientists Jungjohann, Hattar, Li, Mara, Mook) and Core BES programs (SNL PI: Boyce, LANL PI: Mara) have been formalized. Over the next three years, through letters of support for BES Core program proposals, the investigators have committed to ongoing collaborations in both nanomechanical behaviors of materials and new technique development.

6.3.4 Controlled functionalities in nanocomposite films

Lattice-strained epitaxial nanoscaffolding films (epi-NSFs) occur when a parallel array of nanoscaled material *A* interfaces with another material *B* and forms a regular lateral arrangement of *A:B* on a substrate. Epi-NSFs provide a new design paradigm to tune or manipulate functionalities that cannot be obtained in individual constituents (*A* or *B*). The most important features of epi-NSFs include (1) emergent phenomena and improved functionalities can be induced through vertically interfacing appropriate materials, (2) the thickness limitation for a full strain relaxation—typically occurring by around 100 nm in a usual single layer or superlattice film—can be circumvented (e.g., strained films with a thickness of an order of magnitude larger than a single layer film can be maintained in the epi-NSFs), and (3) functionalities of an active phase in the epi-NSFs can be tuned by a second phase or a passive phase.

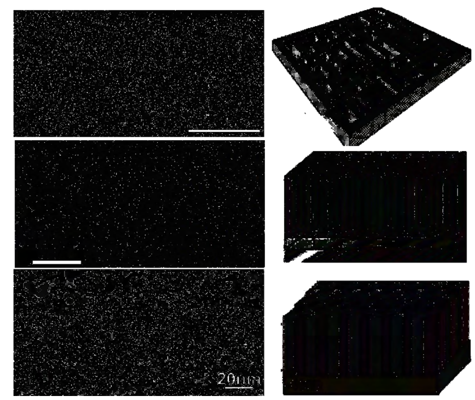

Fig. 11 TEM plan-view images (left column) and schematic illustrations (right column) of different surface morphologies of epi-NSFs. Possible surface morphology includes nanomaze (top panel), nanopillar (middle panel), and nanocheckerboard (bottom panel).

While the demonstrations of desired and new functionalities in epi-NSFs are technologically exciting, the tuning and controlling of functionalities in epi-NSFs are still in the very early stage. Furthermore, various research groups have reported totally different surface morphologies of epi-NSFs, as shown in Figure 11. Depending on the combination of materials (both the film and the substrate), the surface of epi-NSFs can appear as nanomaze[30], nanopillar[31,32], and/or nanocheckerboard.[33] As a result, it is difficult to determine the critical factors (such as surface morphology, vertical interface strain, and interface chemistry) that can lead to the emergent behavior and improved functionality. A fundamental understanding of the relationship between the functionality and these factors is needed. Taking advantage of our advanced synthesis and unique characterization capabilities and well-established modeling tools in CINT, we propose to address these challenging issues. Specifically, we will use CINT's well controlled laser-MBE to grow LSMO:ZnO (here ZnO is the active phase but the passive phase for LSMO) epi-NSFs. As discussed above, epi-SNFs allow us to grow strained films with less thickness restriction. The ability to control strain in much thicker films can be significant for LSMO:ZnO since a much thicker film is needed to use the magnetostrictive effect of LSMO to tune the optical properties of ZnO. Given our expertise, capabilities, and preliminary experimental results, we believe that we are positioned to achieve the scientific and technological milestones and to accomplish our objectives. The proposed work has also great technological impact on areas of functional materials for application in photonic devices and sensing components.

6.3.5 Nanowires for new energy concepts

The topological aspect of the properties of semiconductors is an area that has not been intensely studied in nanoscience. Ring-shaped nanowires and thin films have essentially the same (planar) topology. Ring topology has been studied in topological insulators, but exciting phenomena (e.g., snaking states under magnetic field) in conventional semiconductors, which have been theoretically predicted,[34] haven't been observed yet. Core/multi-shell nanowire heterostructures in which charge carriers are confined in sandwiched shells are a suitable platform to make tubular conduction channels. In preliminary work, we achieved tubular conduction channels in n-type SiGe/p-type Si/n-type SiGe core/multi-shell nanowire heterostructures (Figure 12). Control of the nanowire diameter and the electronic band profile in single nanowire heterostructures provides us with a material platform to study the size-dependent ring topological aspects from nano to microscale. To study the theoretically predicted phenomena in ring topology, enhancement of carrier mobility in core/multi-shell nanowire heterostructures is necessary. Achieving carrier mobility of ≥1000 cm^2/Vs will have a huge impact on electronic applications of semiconductor nanomaterials. The advanced nanofabrication suite at CINT will be employed to prepare sophisticated devices (e.g., Hall bars on single nanowire heterostructures).

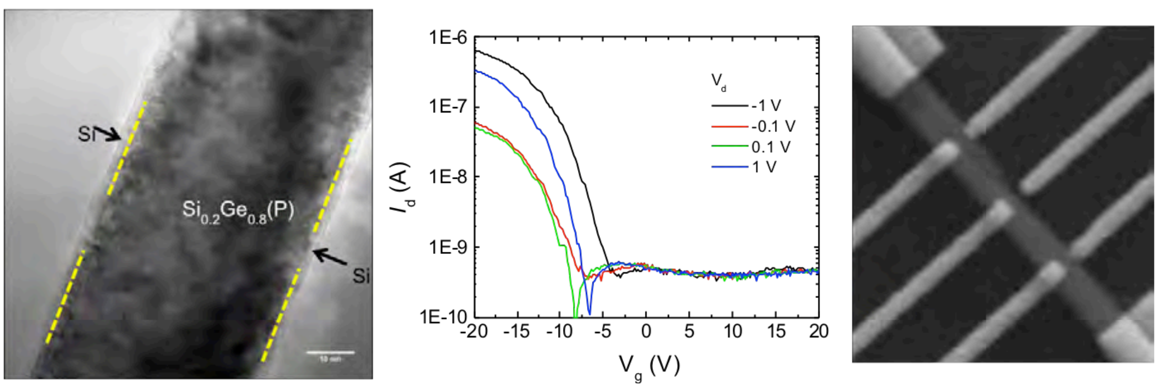

Fig. 12 Transmission electron microscopy image (left) and field-effect transistor characteristic curve (middle) of n-type SiGe/p-type Si core/shell NW heterostructure. Hall bar fabrication on a single SiGe/Si/SiGe core/multi-shell NW heterostructure for magnetotransport measurement (right).

We will pursue innovative hybrid structures through the growth of conventional semiconductor nanowires on emerging 2D materials. CINT's demonstration of the growth of single crystalline Ge nanowires on monolayer MoS_2 implies that novel heterostructures, not limited by lattice match, are on the horizon. We have begun an in-depth and integrative study of semiconductor on emerging 2D materials such as graphene, hexagonal boron nitride (h-BN), and transition metal dichalcogenides (TMDCs), and we find that heterostructuring changes the physical properties of both the semiconductor and the 2D material. For instance, the Ge/MoS_2 heterostructure is metallic even though both components are semiconducting. Studies of conventional semiconductor on emerging 2D material heterostructures have focused on the heterostructure preparation itself.[35] We will focus on understanding and using the novel functionality of semiconductors on 2D material heterostructures in integrated devices. Since there are an enormous number of combinations of semiconductors (Si, Ge, III-V, II-VI) and 2D materials (graphene, h-BN, TMDCs), there is a lot of phase space to explore. These heterostructures are also suitable building blocks for flexible devices because they are prepared on atomically-thin 2D materials. We plan to develop schemes for integrating these nanomaterial heterostructures into flexible circuits.

High spatial resolution mapping of carrier transport in single nanomaterials is a powerful method to measure the transport properties at nanoscale interfaces. CINT is building an electron beam induced current measurement (EBIC) system to study carrier transport behavior in single nanostructures. In combination with a temperature-controlled probe station, EBIC will reveal detailed carrier transport characteristics at the nanoscale. We will use the advanced suite of nanofabrication tools at CINT to prepare devices for these EBIC studies.

6.4 Summary

The future research efforts of the NEM Thrust strive to (1) understand and control electrical and mechanical properties arising from confinement at the nanoscale and interactions within nanostructures and (2) integrate heterogeneous nanostructures for higher levels of functionality. Specifically, we address key science issues in research areas that include spins in semiconductors, the integration of quantum dots and single donors in Si systems, surface and interface phenomena during small-scale mechanical deformation in nanostructured materials, the interplay between the defect landscape and functionality in nanocomposite metal-oxide films, and semiconductor nanowires for new energy concepts. We further develop new capabilities such as discovery platforms, synthesis techniques, and characterization methods, and we engage our user community and CINT scientists to define and achieve our collective scientific objectives. Both internal CINT science activities and user-driven activities are included in our future plans, with a significant interplay between the two activities. We envision that the combination of successful internal science activities and the development of new capabilities will lead to new opportunities for our user community. Equally important, our interactions with users help us to shape the future scientific directions and opportunities that the NEM Thrust can explore.

7.0 Publications

7.1 Literature Cited

[1] Leenheer, A.J., Sullivan, J.P., Shaw, M., Harris, C.T. (2015) "A sealed liquid cell for in-situ

[2] Leenheer, A.J., Jungjohann, K.L., Zavadil, K.R., Sullivan, J.P., Harris, C.T. (2015) "Lithium electrodeposition dynamics in aprotic electrolyte observed in situ via transmission electron microscopy" ACS Nano: 9, 4

[3] Li, Z., Tan, X., Kalisvaart, P., Janish, M.T., Mook, W.M., Jungjohann, K.L., Carter, C.B., Mitlin, D. (2015) "Coupling in-situ TEM and ex-situ analysis to understand heterogeneous sodiation of antimony" Nano Letters: 15, 10 U2013B0051

[4] Liu, Y., Fan, F., Wang, J., Liu, Y., Chen, H., Jungjohann, K.L., Xu, Y., Zhu, T., Wang, C. (2014) "In situ TEM study of electrochemical sodiation and potassiation of carbon nanofibers" Nano Letters: 14, 3445-3452

[5] Wang, J., Fan, F., Liu, Y., Jungjohann, K.L., Lee, S.W., Mao, S.X., Liu, X., Zhu, T. (2014) "Structural evolution and pulverization of tin nanoparticles during lithiation-delithiation cycling" Journal of Electrochemical Society: 161, 11 U2012B0018

[6] Burghoff, D., Kao, T.Y., Han, N.R., Chan, C.W.I., Cai, X.W., Yang, Y., Hayton, D.J., Gao, J.R., Reno, J.L., Hu, Q. (2014) "Terahertz laser frequency combs" Nature Photonics: 8, 6 C2013A0020

[7] Tracy, L.A., Hargett, T.W., Reno, J.L. (2014) "Few-hole double quantum dot in an undoped GaAs/AlGaAs heterostructure" Applied Physics Letters: 104, 123101 U2011A1019

[8] Lee, J., et al. (2014) "Formation of a protected sub-band for conduction in quantum point contacts under extreme biasing" Nature Nanotechnology: 9, 101
Cahay, M. (2014) "Immune to local heating" Nature Nanotechnology: 9, 97

[9] Tracy, L.A., Lu, T.M., Bishop, N.C., Ten Eyck, G.A., Pluym, T., Wendt, J.R., Lilly, M.P., Carroll, M.S. (2013) "Electron spin lifetime of a single antimony donor in silicon" Applied Physics Letters: 103, 143115 U2011A1019

[10] Morello, A., Pla, J.J., Zwanenburg, F.A., Chan, K.W., Tan, K.Y., Huebl, H., Mottonen, M., Nugroho, C.D., Yang, C., van Donkelaar, J.A., Alves, A.D.C., Jamieson, D.N., Escott, C.C., Hollenberg, L.C.L., Clark, R.G., Dzurak, A.S. (2010) "Single-shot readout of an electron spin in silicon" Nature: 467, 687-691

[11] Elzerman, J.M., Hanson, R., Willems van Beveren, L.H., Witkamp, B., Vandersypen, L.M.K., Kouwenhoven, L.P. (2004) "Single-shot read-out of an individual electron spin in a quantum dot" Nature: 430, 431-435

[12] Singh, M., Pacheco, J.L., Perry, D., Garratt, E., Ten Eyck, G., Bishop, N.C., Wendt, J.R., Manginell, R.P., Dominguez, J., Pluym, T., Luhman, D.R., Bielejec, E., Lilly, M.P., Carroll, M.S. (2016) "Electrostatically defined silicon quantum dots with counted antimony donor implants" Applied Physics Letters: 108, 062101

[13] Fuechsle, M., Miwa, J.A., Mahapatra, S., Ryu, H., Lee, S., Warschkow, O., Hollenberg, L.C.L.,

Klimeck, G., Simmons, M.Y. (2012) “A single-atom transistor” Nature Nanotechnology: 7, 242-246

[14] Rudolph, M., Carr, S.M., Subramania, G., Ten Eyck, G., Dominguez, J., Pluym, T., Lilly, M.P., Carroll, M.S., Bussmann, E. (2014) “Probing limits of STM field emission patterned Si:P-doped devices” Applied Physics Letters: 105, 163110 C2013B0052

[15] Han, W., Demkowicz, M.J., Mara, N.A., Fu, E., Sinha, S., Rollett, A.D., Wang, Y., Carpenter, J.S., Beyerlein, I.J., Misra, A. (2013) “Design of radiation tolerant materials via interface engineering” Advanced Materials: 25, 48

Mara, N.A., Beyerlein, I.J. (2014) “Review: Effect of bimetal interface structure on the mechanical behavior of Cu/Nb nanolayered composites” Journal of Materials Science: 49, 6497 U2008B092

Beyerlein, I.J., Caro, J.A., Demkowicz, M.J., Mara, N.A., Misra, A., Uberuaga, B.P. (2013) “Radiation-damage-tolerant Nanomaterials” Materials Today: 16, 443-449. U2011A1071

Demkowicz, M.J., Hoagland, R.G., Hirth, J.P. (2008) “Interface structure and radiation damage resistance in Cu-Nb multilayer nanocomposites” Physical Review Letters: 100, 136102

Mara, N.A., Bhattacharyya, D., Dickerson, P., Hoagland, R.G., Misra, A. (2008) “Deformability of ultrahigh strength nanolayered composites” Applied Physics Letters: 92, 231901

Mara, N.A., Bhattacharyya, D., Hirth, J.P., Dickerson, P., Misra, A. (2010) “Mechanism for shear banding in nanolayered composites” Applied Physics Letters: 97, 021909

Antoniou, A., Bhattacharyya, D., Baldwin, J.K., Goodwin, P., Nastasi, M., Picraux, S.T., Misra, A. (2009) “Controlled nanoporous Pt morphologies by varying deposition parameters” Applied Physics Letters: 95, 073116

Liu, R., Antoniou, A. (2013) “A relationship between the geometrical structure of a nanoporous metal foam and its modulus” Acta Materialia: 61, 7

Liu, R., Zheng, S., Baldwin, K.J., Kuthuru, M., Mara, N., Antoniou, A. (2013) “Synthesis and mechanical behavior of nanoporous nanotwinned copper” Applied Physics Letters: 103(24). U2012A0107

[16] Liontas, R., Gu, X.W., Fu, E., Wang, Y., Li, N., Mara, N.A., Greer, J.R. (2014) “Effects of Helium Implantation on the tensile properties and microstructure of Ni73P27 Metallic glass nanostructures” Nano Letters: 14, 5176

[17] Liu, R., Zheng, S., Baldwin, K.J., Kuthuru, M., Mara, N., Antoniou, A. (2013) “Synthesis and mechanical behavior of nanoporous nanotwinned copper” Applied Physics Letters: 103(24). U2012A0107

[18] Li, N., Misra, A., Shao, S., Wang, J. (2015) “Experimental quantification of resolved shear stresses for dislocation motion in TiN” Nano Letters: 15, 7

[19] Zheng, S., Beyerlein, I.J., Carpenter, J.S., Kang, K., Wang, J., Han, W.Z., Mara, N.A. (2013) “High strength and thermally stable bulk nanolayered composites due to twin-induced interfaces” Nature Communications: 4, 1696 U2011B27

[20] Lee, S., Sangle, A., Lu, P., Chen, A., Zhang, W., Lee, J.S., Jia, Q.X., MacManus-Driscoll, J.L. (2014) “Novel electroforming-free nanoscaffold memristor with very high uniformity, tenability and density” Advanced Materials: 26, 6284

[21] Lee, S., Zhang, W., Khatkhatay, F., Wang, H., Jia, Q.X., MacManus-Driscoll, J.L. (2015) “Ionic

conductivity increased by two orders of magnitude in micrometer-thick vertical yttria-stabilized ZrO2 nanocomposite films” Nano Letters: 15, 7362 C2013A0005

[22] Yoo, J., Nguyen, B.M., Campbell, I.H., Dayeh, S.A., Schuele, P., Evans, D., Picraux, S.T. (2015) “Si radial p-i-n junction photovoltaic arrays with built-in light concentrators” ACS Nano: 9, 5

[23] Cho, J.H., Picraux, S.T. (2013) “Enhanced lithium ion battery cycling of silicon nanowire anodes by template growth to eliminate silicon underlayer islands” Nano Letters: 13, 11

[24] Liu, Y., Liu, X.H., Nguyen, B.M., Yoo, J., Sullivan, J.P., Picraux, S.T., Huang, J.Y., Dayeh, S.A. (2013) “Tailoring lithiation behavior by interface and bandgap engineering at the nanoscale” Nano Letters: 13, 4876

[25] Hosseinian, E., Pierron, O.N. (2013) “Quantitative in situ TEM tensile fatigue testing on nanocrystalline metallic ultrathin films” Nanoscale: 5, 12532-12541

[26] Kubo, A., Onda, K., Petek, H., Sun, Z., Jung, Y.S., Kim, H.K. (2005) “Femtosecond imaging of surface plasmon dynamics in a nanostructured silver film” Nano Letters: 5, 1123

Kahl, P., Wall, S., Witt, C., Schneider, C., Bayer, D., Fischer, A., Melchior, P., Horn-von Hoegen, M., Aeschlimann, M., Meyer zu Heringdorf, F.J. (2014) “Normal-incidence photoemission electron micrsocopy (Ni-PEEM) for imaging surface plasmon polaritons” Plasmonics: 9

[27] Schwab, K., Henriksen, E.A., Worlock, J.M., Roukes, M.L. (2000) “Measurement of the quantum of thermal conductance” Nature: 404, 974-977

[28] Luckyanova, M.N., Garg, J., Esfarjani, K., Jandl., A., Bulsara, M.T., Schmidt, A.J., Minnich, A.J., Dresselhaus, M.S., Fitzgerald, E.A., Chen, G. (2012) “Coherent phonon heat conduction in superlattices” Science: 338, 936-939

[29] Saeedi, K., Simmons, S., Salvail, J.Z., Dluhy, P., Riemann, H., Abrosimov, N.V., Becker, P., Pohl, H.J., Morton, J.J.L., Thewalt, M.L.W. (2013) “Room-temperature quantum bit storage exceeding 39 minutes using ionized donors in silicon-28” Science: 342, 6160

[30] Chen, A., Zhang, W., Khatkatay, F., Su, Q., Tsai, C.F., Chen, L., Jia, Q.X., MacManus-Driscoll, Wang, H. (2013) “Magnetotransport properties of quasi-one-dimensionally channeled vertically aligned heteroepitaxial nanomazes” Applied Physics Letters: 102, 093114 U2011B3

[31] Zheng, H., Wang, J., Lofland, S.E., Ma, Z., Mohaddes-Ardabili, L., Zhao, T., Salamanca-Riba, L., Shinde, S.R., Ogale, S.B., Bai, F., Viehland, D., Jia, Y., Schlom, D.G., Wuttig, M., Roytburd, A., Ramesh, R. (2004) “Multiferroic BaTiO3-CoFe2O4 nanostructures” Science: 303, 661

[32] Harrington, S.A., Zhai, J., Denev, S., Gopalan, V., Wang, H., Bi, Z., Redfern, S.A.T., Baek, S.H., Bark, C.W., Eom, C.B., Jia, Q.X., Vickers, M.E., MacManus-Driscoll, J.L. (2011) “Thick lead-free ferroelectric films with high Curie temperatures through nanocomposite-induced strain” Nature Nanotechnology: 6, 491

[33] MacManus-Driscoll, J.L., Zerrer, P., Wang, H., Yang, H., Yoon, J., Foltyn, S.R., Blamire, M.G., Jia, Q.X. (2008) “Strain control and spontaneous phase ordering in vertical nanocomposite heteroepitaxial thin films” Nature Materials: 7, 314

[34] Muller, J.E. (1992) "Effect of a nonuniform magnetic field on a two-dimensional electron gas in the ballistic regime" Physical Review Letters: 68, 385

Rosdahl, T.O., Manolescu, A., Gudmundsson, V. (2015) "Signature of snaking states in the conductance of core-shell nanowires" Nano Letters: 15, 1

[35] Chung, K., Lee, C.H., Yi, G.C. (2010) "Transferable GaN layers grown on ZnO-coated graphene layers for optoelectronic devices" Science: 330, 6004

Hong, Y.J., Fukui, T. (2011) "Controlled van der Waals heteroepitaxy of InAs nanowires on carbon honeycomb lattices" ACS Nano: 5, 9

Utama, M.I.B., Zhang, Q., Zhang, J., Yuan, Y., Belarre, F.J., Arbiol, J., Xiong, Q. (2013) "Recent developments and future directions in the growth of nanostructures by van der Waals epitaxy" Nanoscale: 5, 3570-3588

Kim, J., Bayram, C., Park, H., Cheng, C.W., Dimitrakopoulos, C., Ott, J.A., Reuter, K.B., Bedell, S.W., Sadana, D.K. (2014) "Principle of direct van der Waals epitaxy of single-crystalline films on epitaxial graphene" Nature Communications: 5, 4836

7.2 Publications from Previous support

	NEM Publication Count			
NSRC High Impact Journals	**2013**	**2014**	**2015**	**Total**
ACS Nano	3	0	2	**5**
Advanced Functional Materials	0	2	3	**5**
Advanced Materials	2	1	0	**3**
Angewandte Chemie International Edition	0	1	0	**1**
Applied Physics Letters	19	13	9	**41**
Chemistry of Materials	3	0	0	**3**
Journal of the American Chemical Society	0	1	1	**2**
Nano Letters	9	6	7	**22**
Nanoscale	0	0	3	**3**
Nature	0	0	0	**0**
Nature Chemistry	0	0	0	**0**
Nature Communications	3	4	4	**11**
Nature Materials	0	0	1	**1**
Nature Nanotechnology	1	1	1	**3**
Nature Photonics	0	1	0	**1**
Nature Physics	0	0	0	**0**
Physical Review Letters	0	2	0	**2**
Proceedings of the National Academy of Sciences USA	0	1	0	**1**
Science	0	1	0	**1**
Small	1	0	1	**2**
TOTAL:	41	34	32	**107**

NEM Publication totals:

2013 Publication total: 107
CINT science: 15
CINT user science (internal): 24
CINT user science (external):68

2014 Publication total: 115
CINT science: 12
CINT user science (internal): 33
CINT user science (external): 70

2015 Publication total: 98
CINT science: 4
CINT user science (internal): 22
CINT user science (external): 72

Note: CINT Scientist authors are indicated in red; CINT User authors are indicated in green (external) and orange (internal).

Citations for 2013 (107) total

CINT Science (15)

Brady, N.K., Perkins Jr., B.G., Hwang, H.Y., Brandt, N.C., Torchinsky, D., Singh, R., Yan, L., Trugman, D., Trugman, S.A., Jia, Q.X., Taylor, A.J., Nelson, K.A., Chen, H.T. (2013) "Nonlinear high-temperature superconducting terahertz metamaterials," New Journal of Physics: 15, 105016

Caviezel, A., Staub, U., Johnson, S.L., Mariager, S.O., Mohr-Vorobeva, E., Ingold, G., Milne, C.J., Garanourakis, M., Scagnoli, V., Huang, S.W., Jia, Q.X., Cheong, S.W., Beaud, P. (2013) "Femtosecond dynamics of the structural transition in mixed valence manganites" Physical Review B: 86, 174105

Chen, D., Zhang, M., Liu, S., Wang, Y.Q., Nastasi, M., Wang, X., Di, Z.F. (2013) "Sharp crack formation in low fluence hydrogen implanted Si0.75Ge0.25/B doped Si0.70Ge0.30/Si heterostructure" Applied Physics Letters: 103, 142102

Guo, Q., Landau, P., Hosemann, P., Wang, Y.Q., Greer, J.R. (2013) "Helium implantation effects on the compressive response of Cu nano-pillars" Small: 9, 691-696

Grady, N.K., Perkins Jr., B.G., Hwang, H.Y., Brandt, H.Y., Torchinsky, D., Singh, R., Yan, L., Trugman, D., Trugman, S.A., Jia, Q.X., Taylor, A.J., Nelson, K.A., Chen, H.T. (2013) "Nonlinear high temperature superconducting terahertz metamaterials" New Journal of Physics: 15, 105016 C2011B23

Jilek, R.E., Bauer, E., Burrell, A.K., McCleskey, T.M., Jia, Q.X., Scott, B.L., Beaux, B.F., Duakiewicz, T., Joyce, J.J., Rector, K.D., Xiong, J., Gofryk, K., Ronning, F., Martin, R.L. (2013) "Preparation of epitaxial uranium dicarbide thin films by polymer-assisted deposition," Chemical Materials: 25, 4373-4377

Kashinath, A., Wang, P., Majewski, J., Baldwin, J. K., Wang, Y. Q., et al. (2013) "Detection of helium bubble formation at fcc-bcc interfaces using neutron reflectometry" Journal of Applied Physics: 114, 4

Lu, P., Xiong, J., Van Benthem, M., Jia, Q.X. (2013) "Atomic-scale chemical quantification of oxide interfaces using energy dispersive x-ray spectroscopy" Applied Physics Letters: 102, 173111

McCleskey, T.M., Bauer, E., Jia, Q.X., Burrell, A.K., Scott, B.L., Conradson, S.D., Mueller, A., Roy, L., Wen, X.D., Scuseria, G.E., Martin, R.L. (2013) "Optical band gap of NpO_2 and PuO_2 from optical absorbance of epitaxial films," Journal of Applied Physics: 13, 013515

Ren, F., Zhou, X.D., Liu, Y.C., Wang, Y.Q., Cai, G.X., Xiao, X.H., Dai, Z.G., Li, W.Q., Yan, S.J., Wu, W., Zhang, C., Ni, H.W., Jiang, C.Z. (2013) "Fabrication and properties of TiO2 nanofilms on different substrates by a novel and universal method of Ti-ion implantation and subsequent annealing" Nanotechnology: 24, 255603

Seo, M.A., Yoo, J., Dayeh, S.A., Picraux, S.T., Taylor, A.J., Prasankumar, R.P. (2013) "Mapping carrier diffusion in single silicon core-shell nanowires with ultrafast optical microscopy," Ultrafast Dynamics in Molecules, Nanostructures, and Interfaces, G. G. Gurzadyan, G. Lanzani, C. Soci, T. C. Sum eds, World Scientific: p. 128

Sheu, Y.M., Trugman, S.A., Yan, L., Chuu, C.P., Bi, Z., Jia, Q.X., Taylor, A.J., Prasankumar, R.P. (2013) "Photoinduced stabilization and enhancement of the ferroelectric polarization in $Ba_{0.1}Sr_{0.9}TiO_3/La_{0.7}Ca(Sr)_{0.3}MnO_3$ thin film heterostructures," Physical Review B: 88, 020101

Sheu, Y.M., Trugman, S.A., Park, Y.S., Lee, S., Yi, H.Y., Cheong, S.W., Jia, Q.X., Taylor, A.J., Prasankumar, R.P. (2013) "Ultrafast carrier dynamics and radiative recombination in multiferroic BiFeO3 single crystals and films" 18th International Conference on Ultrafast Phenomena, M. Chergui, A. J. Taylor eds., Oxford University Press: p. 03018

Sheu, Y.M., Trugman, S.A., Park, Y.S., Lee, S., Yi, H.Y., Cheong, S.W., Jia, Q.X., Taylor, A.J., Prasankumar, R.P. (2013) "Ultrafast carrier dynamics and radiative recombination in multiferroic BiFeO3 single crystals and films" European Physical Journal: 41, 03018

Zhuo, M.J., Uberuaga, B.P., Yan, L., Fu, E.G., Dickerson, R.M., Wang, Y.Q., Misra, A., Nastasi, M., Jia, Q.X. (2013) "Radiation damage at the coherent anatase TiO2/SrTiO3 interface under Ne ion irradiation" Journal of Nuclear Material: 429, 177

CINT User Science - Internal (24)

Anderoglu, O., Zhou, M.J., Zhang, J., Wang, Y.Q., Maloy, S., Baldwin, J.K., Misra, A. (2013) "He+ ion irradiation response of Fe-TiI2 multilayers" Journal of Nuclear Materials: 435, 96. C2011B83

Beyerlein, I.J., Caro, J.A., Demkowicz, M.J., Mara, N.A., Misra, A., Uberuaga, B.P. (2013) "Radiation-damage-tolerant Nanomaterials" Materials Today: 16, 443-449. U2011A1071

Beyerlein, I.J., Wang, J., Kang, K., Zheng, S.J., Mara, N.A. (2013) "Twinnability of bimetal interfaces in nanostructured composites" Materials Research Letters: 1, 89-95 U2012B0018

Bi, Z., Uberuaga, B.P., Fu, E.G., Wang, Y.Q., Li, N., Wang, H.Y., Misra, A., Jia, Q.X. (2013) Radiation damage in heteroepitaxial $BaTiO_3/SrTiO_3$ thin films under Ne ion irradiation," Journal of Applied Physics: 113, 023513

Bronkhorst, C.A., Mayeur, J.R., Beyerlein, I.J., Mourad, H.M., Hansen, B.L., Mara, N.A., Carpenter, J.S., McCabe, R.J., Sintay, S.D. (2013) "Meso-scale modeling the orientation and interface stability of Cu/Nb-Layered Composites by Rolling" Journal of Materials: 65, 431 U2011B27

Carpenter, J.S., McCabe, R.J., Beyerlein, I.J.,Wynn, T.A., Mara, N.A. (2013) "A wedge-mounting technique for nanoscale electron backscatter diffraction" Journal of Applied Physics: 113, 9 RA2012B0013

Carpenter, J.S., Zheng, S.J., Zhang, R.F., Vogel, S.C., Beyerlein, I.J., Mara, N.A (2013) "Thermal stability of Cu-Nb nanlamellar composites fabricated via accumulative roll bonding" Philos. Magazine: 93, 718 U2011B27

Cheaito, R., Duda, J.C., Beechem, T.E., Piekos, E.S., Ihlefeld, J. F., et al. (2013) "The effect of ballistic electron transport on copper-niobium thermal interface conductance" ASME 2013 Heat Transfer Summer Conf. Collocated with the ASME 2013 7th Int. Conf. on Energy Sustainability and the ASME 2013 11th Int. Conf. on Fuel Cell Science, Engineering and Technology 1,V001T03A009

Dayal, P., Bhattacharyya, D., Mook, W.M., Fu, E.G., Wang, Y.Q., Carr, D.G., Anderoglu, O., Mara, N.A., Misra, A., Harrison, R.P., Edwards, L. (2013) "Effect of double ion implantation and irradiation by Ar and He ions on nano-indentation hardness of metallic alloys" Journal of Nuclear Materials: 438, 108-115 C2011A1105

Han, W.Z., Fu, E.G., Demkowicz, M.J., Wang, Y.Q., Misra, A. (2013) "Irradiation damage of single crystal, coarse-grained and nano-grained copper under helium bombardment at 450C" Journal of Material Resources: 28, 2763-2770 U2008A119

Hansen, B.L., Carpenter, J.S., Sintay, S.D., Bronkhorst, C.A., McCabe, R.J., Mayeur, J.R., Mourad, H.M., Beyerlein, I.J., Mara, N.A., Chen, S.R., Gray III, G.T. (2013) "Modeling the texture evolution of Cu/Nb layered composites during rolling" International Journal of Plasticity: 89, 71-84 U2011B27

Liu, Y.H., Xiong, J., Haraldsen, J.T., Yan, L., Balatsky, A.V., Jia, Q.X., Taylor, A.J., Yarotski, D. (2013) "Tuning the electronic properties of ultrathin $La_{0.7}Sr_{0.3}MnO_3$ films by interfacing with superconducting $EuBa_2Cu_3O_{7-d}$," Physical Review B: 87, 165140

Magedov, I.V., Frolova, L.V., Ovezmyradov, M., Bethke, D., Shaner, E.A., Kalugin, N.G. (2013) "Benzyne-functionalized graphene and graphite characterized by raman spectroscopy and energy dispersive X-ray analysis" Carbon: 54, 192-200 C2011B47

Martinez, J.A., Cho, J.H., Liu, X., Luk, T.S., Huang, J., Picraux, S.T., Sullivan, J.P., Swartzentruber, B.S. (2013) "Contribution of radial dopant concentration to the thermoelectric properties of core-shell nanowires" Applied Physics Letters: 102, 103101

Nguyen, K.T., Lilly, M.P., Nielsen, E., Bishop, N.C., Rahman, R., Young, R., Wendt, J., Dominguez, J., Pluym, T., Stevens, J., Lu, T.M., Muller, R., Carroll, M.S. (2013) "Charge sensed Pauli blockade in metal-oxide-semiconductor lateral double quantum dot" Nano Letters: 13, 5785 U2011A1066
Ribaudo, T., Peters, D.W., Ellis, A.R., Davids, P.S., Shaner, E.A. (2013) "Highly directional thermal emission from two-dimensional silicon structures" Optics Express: Vol. 21, Issue 6, pp. 6837-6844 C2010A972

Seo, M.A., Boubanga-Tombet, S., Yoo, J., Ku, Z., Gin, A.V., Picraux, S.T., Brueck, S.R.G., Taylor, A.J., Prasankumar, R.P. (2013) "Utrafast optical wide field microscopy" Optics Express: 21, 7, 8763 C2010A1011

Singh, R., Chowdhury, D.R., Xiong, J., Yang, H., Azad, A.K., Taylor, A.J., Jia, Q.X., Chen, H.T. (2013) "Influence of film thickness in THz active metamaterial devices: A comparison between superconductor and metal split-ring resonators" Applied Physics Letters: 103, 061117

Tracy, L.A., Lu, T.M., Bishop, N.C., Ten Eyck, G.A., Pluym, T., Wendt, J.R., Lilly, M.P., Carroll, M.S. (2013) "Electron spin lifetime of a single antimony donor in silicon" Applied Physics Letters: 103, 143115 U2011A1019
Wynn, T., Bhattacharyya, D., Hammon, D., Misra, A., Mara, N. (2013) "Large strain deformation of bimodal layer thickness Cu/Nb Nanolamellar Composites" Materials Science and Engineering: 564, 213-218 C2011A1105

Zhang, S.X., Li, Y., Dayeh, S.A., Crooker, S.A., Smith, D.L., Picraux, S.T. (2013) "Electrical spin injection and detection in silicon nanowires through oxide tunneling barriers" Nano Letters: 13 U2011A1004

Zheng, S., Beyerlein, I.J., Carpenter, J.S., Kang, K., Wang, J., Han, W.Z., Mara, N.A. (2013) "High strength and thermally stable bulk nanolayered composites due to twin-induced interfaces" Nature Communications: 4, 1696 U2011B27

Zhuo, M.J., Yan, L., Fu, E.G., Wang, Y.Q., Misra, A., Nastasi, M., Uberuaga, B.P., Jia, Q.X. (2013) "Phase transformations and defect clusters in single crystal $SrTiO_3$ irradiated at different temperatures," Journal of Nuclear Material: 442, 143-147

Zhuo, M.J., Uberuaga, B.P., Yan, L., Fu, E.G., Dickerson, R.M., Wang, Y.Q., Misra, A., Nastasi, M., Jia, Q.X. (2013) "Radiation damage at the coherent anatase TiO2/SrTiO3 interface under Ne ion irradiation" Journal of Nuclear Material: 429, 177

<u>*CINT User Science - External (68)*</u>

Beyerlein, I.J., Mara, N.A., Carpenter, J.S., Nizolek, T.R., Kang, K., Zheng, S., Wang, J., Pollock T.M. (2013) "Interface-driven microstructure development and ultra high strength of bulk nanostructured Cu-Nb multilayers fabricated by sever plastic deformation" Journal of Materials Research: 1-14 U2011B27

Bi, Z., Uberuaga, B.P., Vernon, L.J., Fu, E., Wang, Y., Li, N., Wang, H., Misra, A., Jia, Q.X. (2013) "Radiation Damage in Heteroepitaxial BaTiO3 Thin Films on SrTiO3 under Ne Ion Irradiation", Journal of Applied Physics: 113, 023513 C2013A0036.

Brons, J.G., Padilla II, H.A., Thompson, G.B., Boyce, B.L. (2013) "Cryogenic indentation-induced grain growth in nanotwinned copper" Scripta Materialia: 68 C2010A911

Bufford, D., Bi, Z., Jia, Q.X., Wang, H., Zhang, X. (2013) "Nanotwins and stacking faults in high-strength epitaxial Ag/Al multilayer films" Applied Physics Letters: 101, 223112 C2012A0017

Bufford, D., Bi, Z., Jia, Q.X., Wang, H., Zhang, X. (2013) "Nanotwins and stacking faults in high-strength epitaxial Ag/Al multilayer films" Applied Physics Letters: 101, 223112 C2012A0017

Chan, C.W.I., Hu, Q., et al. (2013) "Tall-barrier terahertz quantum cascade lasers" Applied Physics Letters: 103, 15 C2010B1033

Chen, A., Bi, Z., Jia, Q.X., MacManus-Driscoll, J.L., Wang, H. (2013) "Strain-induced ferromagnetism and magnetoresistance in epitaxial thin films of $LaCoO_3$ prepared by polymer assisted deposition," Chemistry of Materials: 25, 55-58 U2011B3

Chen, A., Zhou, H., Bi, Z., Zhu, Y., Luo, Z., Bayraktaroglu, A., Phillips, J., Choi, E.M., McManus-Drisoll, J.L., Pennycook, S.J., Narayan, J., Jia, Q.X., Zhang, X., Wang, H. (2013) "A new class of room-temperature multiferroic thin films with bismuth-based supercell structure" Advanced Materials: 10, 201203051 U2011B3

Chen, A., Zhang, W., Jian, J., Wang, H., Tsai, C.F., Su, Q., Jia, Q.X., MacManus-Driscoll, J.L. (2013) "Role of boundaries on low-field magnetotransport properties of $La_{0.7}Sr_{0.3}MnO_3$-based nanocomposite thin films," Journal of Material Resources: 28, 1707-1714 U2011B3

Chen, A., Zhang, W., Khatkatay, F., Su, Q., Tsai, C.F., Chen, L., Jia, Q.X., MacManus-Driscoll, Wang, H. (2013) "Magnetotransport properties of quasi-one-dimensionally channeled vertically aligned heteroepitaxial nanomazes" Applied Physics Letters: 102, 093114 U2011B3

Chan, C.W.I, Hu, Q., Reno, J.L. (2013) "Tall-Barrier Terahertz Quantum Cascade Lasers," Applied Physics Letters: 103, 151117 C2010B1033

Cui, M., Hovenier, J.N., Ren, Y., Vercruyssen, N., Gao, J.R., Kao, T.Y., Hu, Q., Reno, J.L. (2013) "Beam and phase distributions of a terahertz quantum cascade wire laser" Applied Physics Letters: 102, 111113

Demming, A., Tonouchi, M., et al. (2013) "Terahertz nanotechnology" Nanotechnology: 24, 21

Field III, R.L., Jin, Y., Dannecker, T., Jock, R.M., Goldman, R.S., Cheng, H., Kurdak, C., Wang, Y. (2013) "Influence of N incorporation on persistent photoconductivity in GaAsN alloys" Physical Review B: 8, 87 C2010B1038

Fu, E.G., Wang, H., Carter, J., Shao, L., Wang, Y.Q., Zhang, X. (2013) "Fluence –dependent radiation damage in helium (He) ion-irradiated Cu/V multilayers" Philosophical Magazine: 93, 883-898 C2012A0017

Gamaski, A.D., Perea, D.E., Yoo, J., Li, N., Olszta, M.J., Colby, R., Screiber, D.K., Ducati, C., Picraux, S.T., Hofmann, S. (2013) "Catalyst composition and impurity-dependent kinetics of nanowire heteroepitaxy" ACS Nano: 7, 7689-7697 C2011A1005

Gan, Z., Perea, D.E., Yoo, J., Picraux, S.T., Smith, D.J., McCartney, M.R. (2013) "Mapping electrostatic profiles across axial p-n junctions in Si nanowires using off-axis electron holography" Applied Physics Letters: 103, 153108 C2011A1005

Gram, M.D., Carpenter, J.S., Payzant, E.A., Misra, A., Anderson, P.M. (2013) "Forward and reverse plastic flow in nanoscale layers: results from heated diffraction studies" Material Resources Letters: C2010B1062

Gregorczyk, K.E., Liu, Y., Sullivan, J.P., Rubloff, G.W. (2013) "In situ transmission electron microscopy study of electrochemical lithiation and delithiation cycling of the conversion anode RuO2" ACS Nano: 7, 6354 U2011A1061

Haberkorn, N., Zhang, Y.Y., Kim, J., McCleskey, T.M., Burrell, A.K., DePaula, R.F., Tajima, T., Jia, Q.X., Civale, L. (2013) "Upper critical magnetic field and vortex-free state in very thin epitaxial d-MoN films grown by polymer-assisted deposition," Superconductor Science and Technology: 26, 105023 C2011B101

Harriman, T.A., Bi, Z., Jia, Q.X., Lucca, D.A. (2013) "Frequency shifts of E_2^{High} Raman mode due to residual stress in epitaxial ZnO thin films," Applied Physics Letters: 103, 121904 U2013A0076

Hayton, D.J., Khudchencko, A., Pavelyev, D.G., Hovenier, J.N., Baryshev, A., Gao, J.R., Kao, T.Y., Hu, Q., Reno, J.L., Vaks, V. (2013) "Phase locking of a 3.4 THz third-order distributed feedback quantum cascade laser using a room-temperature superlattice harmonic mixer" Applied Physics Letters: 103, 051115 C2010B1033

Huang, J.Y., Lo, Y.C., Jun, J.N., Kushima, A., Qian, X., Zhong, L., Mao, S.X., Li, J. (2013) "Nanowire liquid pumps" Nature Nanotechnology: 8, 277 C2010B1063

Hwang, Y., Nguyen, B.M., Dayeh, S. (2013) "Atomic Layer Deposition of Platinum with Enhanced Nucleation and Coalescence by Trimethylaluminum Pre-Pulsing". Applied Physics Letters: 103, 263115

Jun, Y.C., Reno, J.L., Ribaudo, T., Shaner, E., Greffet, J.J., Vassant, S., Marquier, F., Sinclair, M., Brener, I., (2013) "Epsilon-near-zero strong coupling in metamaterial-semiconductor hybrid structures," *Nano Letters*: 13, 5391 C2010A972

Kim, I., Jiao, L., Khatkhatay, F., Martin, M.S., Lee, J., Shao, L., Zhang, X., Swadener, J.G., Wang, Y.Q., Gan, J., Cole, J., Wang, H. (2013) "Size-dependent radiation tolerance in ion irradiated TiN/AlN nanolayer films" Journal of Nuclear Materials: 441, 47-53

Kloosterman, J.L., Hayton, D.J., Ren, Y., Kao, T.Y., Hovenier, J.N., Gao, J.R., Klapwijk, T.M., Hu, Q., Walker, C.K., Reno, J.L. (2013) "Hot electron bolometer heterodyne receiver with a 4.7 THz quantum cascade laser as a local oscillator" Applied Physics Letters: 102, 011123 C2010B1033

Koecher, M., Yeager, J.D., Park, T., Fullwood, D., Colton, J.S., Mara, N., Hansen, N. (2013) "Characterization of nickel nanostrand nanocomposites through dielectric spectroscopy and nanoindentation" Polymer Engineering and Science: 53, 12, 2666-2673 C2010A915

Li, W.W., Zhao, R., Wang, L., Tang, R.J., Zhu, Y.Y., Lee, J.H., Cao, H.X., Cai, T.Y., Guo, H.Z., Wang, C., Ling, L.S., Pi, L., Jin, K.J., Zhang, Y.H., Wang, H.Y., Wang, Y.Q., Ju, S., Yang, H. (2013) "Oxygen-vacancy-induced antiferromagnetism to ferromagnetism transformation in Eu0.5Ba0.5TiO32d multiferroic thin films" Scientific Reports: 3, 2618

Liang, W., Yang, H., Fan, F., Liu, Y., Liu, X.H., Huang, J.Y., Zhu, T., Zhang, S. (2013) "Tough Germanium Nanoparticles under Electrochemical Cycling" ACS Nano: 7, 3427 C2012A0033

Liu, R., Antoniou, A. (2013) "A relationship between the geometrical structure of a nanoporous metal foam and its modulus". Acta Materialia: 61(7):2390-402. C2010B1054

Liu, R., Zheng, S., Baldwin, K.J., Kuthuru, M., Mara, N., Antoniou, A. (2013) "Synthesis and mechanical behavior of nanoporous nanotwinned copper" Applied Physics Letters: 103(24). U2012A0107

Liu, Y., Liu, X.H., Nguyen, B.M., Yoo, J., Sullivan, J.P., Picraux, S.T., Huang, J.Y, Dayeh, S.A. (2013) "Tailoring Lithiation Behavior by Interface and Bandgap Engineering at the Nanoscale" Nano Letters: 13,4876 C2012A0014

Lotfian, S., Rodriguez, M., Yazzie, K.E., Molina-Aldareguia, J.M., Chawla, N., Lorca, J.L. (2013) "High Temperature Micropillar Compression of Al/SiC Nanolaminates" Acta Materialia: 61, 4439-4451 U2012B0013

Mann, J., Sun, D., Ma, Q., Chen, J.R., Preciado, E., Ohta, T., Diaconescu, B., Yamaguchi, K., Tran, T., Wurch, M.A., Magnone, K.M., Heinz, T.F., Kellogg, G.L., Kawakami, R., Bartels, L. (2013) "Facile growth of monolayer MoS2 on SiO2" European Phyical Journal B: 86, 226 C2011A1026

Mara, N.A., Crapps, J., Wynn, T., Clarke, K., Antoniou, A., Dickerson, P., Dombrowski, D.E., Mihaila, B. (2013) "Defining Strength of Metallic Bonded Interfaces via Microcantilever Bend Testing" Philosophical Magazine: 93, 2749-2758 C2010B1054

Martin, K.E., Tian, Y., Busani, T., Medforth, C.J., Franco, R., van Swol, F., Shelnutt, J.A. (2013) "Charge effects on the structure and composition of porphyrin binary ionic solids: ZnTPPS/SnTMePyP nanomaterials" Chemistry of Materials: 25, 441 U2012A0117

McCombe, B.D., Thomas, D., Einhorn, M., Reno, J.L., Strasser, G., Bird, J.P. (2013) "Terahertz detection with nanoscale semiconductor rectifiers" IEEE Sensors Journal: 13, 24 C2012A0038

Monclus, M.A., Zheng, S.J., Mayeur, J.R., Beyerlein, I.J., Mara, N.A., Polcar, T., Lorca, J., Molina-Aldareguia, J.M. (2013) "Optimum high temperature strength of two-dimensional nanocomposites" Applied Physics Letters Materials: 1, 5

Mook, W.M., Raghavan, R., Baldwin, J.K., Frey, D., Michler, J., Mara, N.A., Misra, A., Zheng, S. (2013) "Indentation fracture response of Al-TiN nanolaminates" Materials Research Letters: 1-7 RA2012A0023

Nguyen, B.M., Yoo, J., Dayeh, S.A., Schuele, P., Evans, D., Picraux, S.T. (2013) "Design of Radial p–i–n Silicon Nanowires for High-Performance Solar Cells" The Wonder of Nanotechnology: Quantum Optoelectronic Devices and Applications M. Razeghi. L. Esaki, and K. von Klitzing, Eds., SPIE Press, Bellingham, WA, pp. 823-842 C2012A0014

Prenzel, T., Mehner, A., Lucca, D.A., Qi, Y., Harriman, T.A., Mutlugünes, Y, Shojaee, S.A., Wang, Y.Q., Williams, D., Nastasi, M., Zoch, H.-W., Swiderek, P. (2013) "Chemical and mechanical properties of silica hybrid films from NaOH catalyzed sols for micromachining with diamond cutting tools" Thin Solid Films: 531, 208-216. C2010B1100

Qin, Q., Han, N., Kao, W., Reno, J.L., Hu, Q., (2013) "An effective mode selector for tunable terahertz wire-lasers," Optics Letters: 38, 407. C2010B1033

Ran, L., Antoniou, A. (2013) "A relationship between geometrical structure of nanoporous metal foam and its modulus" Acta Materialia: 61, 7, 2390 U2012A0107

Rivadulla, F., Bi, Z.X., Bauer, E., Murias, B.R., Vila-Fungueirino, J.M., Jia, Q.X. (2013) "Strain-induced ferromagnetism and magnetoresistance in epitaxial thin films of $LaCoO_3$ prepared by polymer assisted deposition," Chemistry of Materials: 25, 55-58 U2011B104

Rui, C., Chen, R., Song, J., Jungwoo, S., et al. (2013) "Terahertz detection with nanoscale semiconductor rectifiers" IEEE Sensors Journal: 13, 1 C2012A0038

Seo, M.A., Yoo, J., Perea, D.E., Dayeh, S.A., Picraux, S.T., Taylor, A.J., Prasankumar, R.P. (2013) "Tracking ultrafast dynamics in molecules, nanostructures, and interfaces" 18^{th} International Conference on Ultrafast Phenomena, M. Chergui, A. J. Taylor eds, Oxford University Press: p. 04030

Shelnutt, J.A., Tian, Y., Martin, K.M., Medforth, C.J. (2013) "Binary ionic porphyrin nanomaterials for energy from sunlight" Handbook of porphyrin science: 2 C2011A1013

Su, Q., Yoon, D., Sisman, Z., Khatkhatay, F., Jia, Q.X., Manthiram, A., Wang, H. (2013) "Vertically aligned nanocomposite $La_{0.8}Sr_{0.2}MnO_{3-d}/Zr_{0.92}Y_{0.08}O_{1.96}$ thin films as electrode/electrolyte interfacial layer for solid oxide reversible fuel cells," International Journal of Hydrogen Energy: 38, 16320-16327 C2010B1039

Sun, C., Bufford, D., Chen, Y.X., Kirk, M., Wang, Y.Q., Li, M.M., Wang, H.Y., Maloy, S., Zhang, X.H. (2013) "In situ study of defect migration kinetics in nanoporous Ag with enhanced radiation tolerance" Scientific Reports: 4, 3737 C2013A0005

Sun, Y., Padbury, R.P., Akyildiz, H.I., Goertz, M.P., Palmer, J.A., Jur, J.S. (2013) "Influence of subsurface hybrid material growth on the mechanical properties of atomic layer deposited thin films on polymers" Chemical Vapor Deposition: 19, 134-141 U2011A1059

Tang, W., Dayeh, S.A., Picraux, S.T., Huang, J., Tu, K.N. (2013) "Nucleation and Atomic Layer Reaction in Nickel Silicide for Defect-engineered Si Nanochannels" Nano Letters: 13,2748 C2011A1023

Tang, W., Dayeh, S.A., Picraux, S.T., Liu, X., Huang, J., Tu, K.N. (2013) "Gold Catalyzed Ni Disilicide Formation in Si Nanowires: A New Solid-Liquid-Solid (SLS) Phase Growth Mechanism" Nano Letters:13, 6009 C2011A1023

Wang, J.W., He, Y., Fan, F., Liu, X.H., Xia, S., Liu, Y., Harris, C.T., Li, H., Huang, J.Y., Mao, S.X., Zhu, T. (2013) "Two-Phase Electrochemical Lithiation in Amorphous Silicon" Nano Letters: 13, 709 C2012A0045

Wang, J.W., Narayanan, S., Huang, J.Y., Liu, Y., Sun, S., Zhang, Z., Mao, S.X. (2013) "Atomic-scale dynamic process of deformation-induced stacking fault tetrahedral in gold nanocrystals" Nature Communications: 4, 2340 C2010B1063

Wang, J.W., Sansoz, F., Huang, J.Y., Zhang, Z., Zhu, T., Mao, S.X. (2013) "Near-ideal theoretical strength in gold nanowires containing angstrom scale twins" Nature Communications: 4, 1742 C2010B1063

Xiao, S., Xiang, S., et al. (2013) "Talking through the continuum: new manifestations of Fano-resonance phenomenology realized with mesoscopic nanostructures" Fortschritte DerPhysik- Progress of Physics: 61, 2-3 C2012A0038

Xu, Y., Chen, G., Fu, E., Zhou, M., Dunwell, M., Fei, L., Deng, S.G., Andersen, P., Wang, Y.Q., Jia, Q.X., Civale, L. (2013) "Nickel substituted $LiMn_2O_4$ cathode with durable high-rate capability for Li-ion batteries," Royal Society of Chemistry Advances: 3, 18441-18445 C2011B101

Yang, Z.B., Chen, T., He, R.X., Li, H.P., Lin, H.J., Li, L., Zou, G.F., Jia, Q.X., Peng, H.S. (2013) "A novel carbon nanotube/polymer composite film for counter electrodes of dye-sensitized solar cells," Polymer Chemistry: 4, 1680-1684 U2010A895

Yoo, J., Dayeh, S.A., Tang, W., Picraux, S.T. (2013) "Epitaxial growth of radial Si p-i-n junctions for photovoltaic applications" Applied Physics Letters: 102, 093113

Yoo, J., Ma, X., Tang, W., Yi, G.C. (2013) "Metal-lined semiconductor nanotubes for surface plasmon-mediated luminescence enhancement" Nano Letters: 13, 2134-2140

Yu, K. Y., Bufford, D., Chen, Y., Liu, Y., Wang, H., Zhang, X., (2013) "Basic criteria for formation of growth twins in high stacking fault energy metals." Applied Physics Letters: 103 (18), 181903. C2013B0013.

Yu, K., Liu, Y., Fu, E., Wang, Y., Myers, M., Wang, H., Shao, L., Zhang, X. (2013) "Comparisons of radiation damage in He ion and proton irradiated immiscible Ag/Ni nanolayers" Journal of Nuclear Materials: 440, 310 U2012A0032

Zaslavsky, A., Wan, J., Le, S.T., Jannaty, P., Cristoloveanu, S., Le Royer, C., Perea, D.E., Dayeh, S.A., Picraux, S.T. (2013) "Sharp-switching high-current tunneling devices" Electrochemical Society Transcripts: 53, 5, 63-74 C2011A1067

Zhong, L., Mitchell, R.R., Liu, Y., Gallant, B.M., Thompson, C.V., Huang, J.Y., Mao, S.X., Shao-Horn, Y. (2013) "In situ Transmission Electron Microscopy Observations of Electrochemical Oxidation Li2O2" Nano Letters: 13, 2209 C2010B1063

Zhu, Y.Y., Chen, A., Zhou, H., Zhang, W., Narayan, J., MacManus-Driscoll, J.L., Jia, Q.X., Wang, H. (2013) "Research updates: Epitaxial strain relaxation and associated interfacial reconstructions: The driving force for creating new structures with integrated functionality," APL Materials: 1, 050702 U2011B3

Zhu, Y., Wang, J. W., Liu, Y., Liu, X., Kushima, A., Liu, Y., Xu, Y., Mao, S. X., Li, J., Wang, C., Huang, J. Y. (2013) "In Situ Atomic-Scale Imaging of Phase Boundary Migration in $FePO_4$ Microparticles During Electrochemical Lithiation" Advanced Materials: 25: 5461–5466. U2010B1073

Zou, G.F., Zhao, J., Luo, H.M., McCleskey, T.M., Burrell, A.K., Jia, Q.X. (2013) "Polymer-assisted-deposition: a chemical solution route for a wide range of materials" Chemical Society Review: 42, 439 U2012B0011

Citations for 2014 (115) total

CINT Science (12)

Dowden, P.C., Bi, Z., Jia, Q.X. (2014) "Method for controlling energy density for reliable pulsed laser deposition of thin films" Review of Scientific Instruments: 85, 025111

Lei, Q.Y., Golalikhani, M., Yang, D., Withanage, W., Rafti, A., Qiu, J., Hambe, M., Bauer, E., Ronning, F., Jia, Q.X., Weiss, J., Hellstrom, E., Wang, X., Chen, X.H., Williams, F., Yang, Q., Temple, D., Xi, X.X. (2014) "Structural and transport properties of epitaxial Ba(Fe1-xCox)2As2 thin films on various substrates" Superconducting Science and Technology: 27, 115010

McCleskey, T.M., Shi, P., Bauer, E., Highland, M.J., Eastman, J.A., Bi, Z.X., Fuoss, P.H., Baldo, P.M., Ren, W., Scott, B.L., Burrell, A.K., Jia, Q.X. (2014) "Nucleation and growth of epitaxial metal-oxide films based on polymer-assisted deposition" Chemical Society Review: 43, 2141

Paranthaman, M.P., Aytug, T., Stan, L., Jia, Q.X., Cantoni, C., Wee, S.H. (2014) "Chemical solution derived planarization layers for highly aligned IBAD-MgO templates" Superconducting Science and Technology: 27, 022002

Sheu, Y.M., Trugman, S.A., Yan, L., Qi, J., Jia, Q.X., Taylor, A.J., Prasankumar, R.P. (2014) "Polaronic transport induced by competing interfacial magnetic order in a La.7Ca.3MnO3/BiFeO3 heterostructure" Physical Review X: 4, 021001

Sheu, Y.M., Trugman, S.A., Yan, L., Jia, Q.X., Taylor, A.J., Prasankumar, R.P. (2014) "Using ultrafast optical pulses to couple ferroelectric and ferromagnetic order in an oxide heterostructure" Nature Communications: 5, 5832

Staruch, M., Cil, K., Silva, H., Xiong, J., Jia, Q.X., Jain, M. (2014) "Effect of Mn doping on the properties of sol-gel derived Pb0.3Sr0.7TiO3 thin films" Ferroelectrics: 470, 227

Sutter, E., Jungjohann, K., Bliznakov, S., Courty, A., Maisonhaute, E., Tenney, S., Sutter, P. (2014) "In situ liquid-cell electron microscopy of silver-palladium galvanic replacement reactions on silver nanoparticles" Nature Communications: 5, 4946

Watkins, E.B., Kashinath, A., Wang, P., Baldwin, J.K., Majewski, J., Demkowicz, M.J. (2014) "Characterization of a Fe/Y2O3 metal/oxide interface using neutron and x-ray scattering" Applied Physics Letters: 105, 041601

Xiong, J., Matias, V., Tao, B.W., Li, Y.R., Jia, Q.X. (2014) " Ferroelectric and ferromagnetic properties of epitaxial BiFeO3-BiMnO3 films on ion-beam-assisted deposited TiN buffered flexible Hastelloy" Journal of Applied Physics: 115, 17

Zhang, J., Zhang, Y., Mara, N.A., Nicola, L., Lou, J. (2014) "Nanoimprinting of single crystalline gold: experiments and dislocation simulations" Applied Surface Science: 290, 301

Zhernenkov, M., Gill, S., Stanic, V., DiMasi, E., Kisslinger, K., Baldwin, J.K., Misra, A., Demkowicz, M.J., Ecker, L. (2014) "Design of radiation resistant metallic multilayers for advanced nuclear systems" Applied Physics Letters: 104, 241906

CINT User Science - Internal (33)

Aguiar, J.A., Dholabhai, P.P., Bi, Z., Jia, Q.X., Fu, E., Wang, Y., Aoki, T., Zhu, J. (2014) "Probing defect-boundary interactions at oxide interfaces" Journal of Materials Research: 29, 1699-1710

Aguiar, J.A., Dholobhai, P.P., Bi, Z., Jia, Q.X., Fu, E.G., Wang, Y.Q., Aoki, T., Zhu, J., Misra, A., Uberuaga, B.P. (2014) "Linking interfacial step structure and chemistry with locally enhanced radiation-induced amorphization at oxide heterointerfaces" Advanced Material Interfaces: 1, 1300142

Aguiar, J.A., Zhuo, M., Bi, Z., Fu, E., Wang, Y., Dholabhai, P.P., Misra, A., Jia, Q., Uberuaga, B.P. (2014) "Orientation-specific amorphization and intercalated recrystallization at ion-irradiated

SrTiO3/MgO interfaces" Journal of Materials Research: 10, 1557

Ardeljan, M., Knezevic, M., Nizolek, T., Beyerlein, I.J., Zheng, S.J., Carpenter, J.S., McCabe, R.J., Mara, N.A., Pollock, T.M. (2014) "A multi-scale model for texture development in Zr/Nb nanolayered composites processed by accumulative roll bonding" Materials Science and Engineering: 63, 012170. U2011B27

Beyerlein, I.J., Mayeur, J.R., McCabe, R.J., Zheng, S.J., Carpenter, J.S., Mara, N.A. (2014) "Influence of slip and twinning on the crystallographic stability of bimetal interfaces in nanocomposites under deformation" Acta Materialia: 72, 137-147

Branch, B., Dubey, M., Anderson, A.S., Artyushkova, K., Baldwin, J. K., et al. (2014) "Investigating phosphonate monolayer stability on ALD oxide surfaces" Applied Surface Science 288, 98-108

Bussmann, E., Rudolph, M., Subramania, G., Misra, S., Carr, S.M., Langlois, E., Dominguez, J., Ten Eyck, G., Pluym, T., Lilly, M., Carroll, M.S. (2014) "Scanning capacitance microscopy registration of buried atomic-precision donor devices" Nanotechnology: 26, 085701 U2013B0148

Caro, M., Mook, W.M., Fu, E.G., Wang, Y.Q., Sheehan, C., Martinez, E., Caro, A. (2014) "Radiation induced effects on mechanical properties of nanoporous gold foams" Applied Physics Letters: 104, 23

Carpenter, J.S., McCabe, R.J., Zheng, S.J., Wynn, T.A., Mara, N.A., Beyerlein, I.J. (2014) "Processing parameter influence on texture and microstructural evolution in Cu-Nb multilayer composites fabricated via accumulative roll bonding" Metallurgical and Materials Transactions A: 45, 4 RA2012B0013

Carpenter, J.S., Nizolek, T., McCabe, R.J., Zheng, S.J., Scott, J., Vogel, S.C., Mara, N.A., Pollock, T., Beyerlein, I.J. (2014) "The suppression of instabilities via biphase interfaces during bulk fabrication of nanograined Zr" Materials Research Letters: 10.1080 U2013B0110

Cobb, J., Vachhani, S., Dickerson, R.M., Dickerson, P.O., Han, W.Z., Mara, N.A., Schneider, J. (2014) "Layer stability and material properties of friction stir welded Cu-Nb nanolamellar composite plates" Materials Research Letters: 1, 1-6 RA2014A0000

Dyer, G.C., Aizin, G.R., Allen, S.J., Grine, A.D., Bethke, D., Reno, J.L., Shaner, E.A. (2014) "Coherent phenomena in terahertz 2d plasmonic structures: strong coupling, plasmonic crystals, and induced transparency by coupling of localized modes" Terahertz physics, devices, and systems VIII: Advanced Applications in Industry and Defense: 9102 U2013B0053

Dyer, G.C., Aizin, G.R., Allen, S.J., Grine, A.D., Bethke, D., Reno, J.L., Shaner, E.A. (2014) "Interferometric measurement of far infrared plasmons via resonant homodyne mixing" Optics Express: 22, 13 RA2009B068

Eftink, B.P., Mara, N.A., Kingstedt, O.T., Safarik, D.J., Lambros, J., Robertson, I.M. (2014) "Anomalous deformation twinning in coarse-grained Cu in Ag60Cu40 composites under high strain-rate compressive loading" Materials Science & Engineering A: 618, 254

Ekiz, H.E., Lach, T., Averback, R.S., Mara, N.A., Beyerlein, I.J., Pouryazdan, M., Hahn, H., Bellon, P. (2014) "Microstructural evolution of nanolayered Cu-Nb composites subjected to high pressure torsion" Acta Materialia: 72, 178

Gao, Y., Roslyak, O., Dervishi, E., Karan, N.S., Ghosh, Y., Sheehan, C.J., Wang, F., Gupta, G., Mohite, A., Dattelbaum, A.M., Doorn, S.K., Hollingsworth, J.A., Piryatinski, A., Htoon, H. (2014) " Hybrid graphene-giant nanocrystal quantum dot assemblies with highly efficient biexciton emission" Advanced Optical Materials: 10.1002 U2013B0037

Hensley, J., Cederberg, J.G., Bethke, D.T., Grine, A.D., Shaner, E.A. (2014) "Heterogenous metasurface for high temperature selective emission" Applied Physics Letters: 105, 8

Knezevic, M., Nizolek, T., Ardeljan, M., Beyerlein, I.J., Mara, N.A., Pollock, T.M. (2014) "Texture evolution in two-phase Zr/Nb lamellar composites during accumulative roll bonding" International Journal of plasticity: 57, 16-28

Li, N., Hattar, K., Misra, A. (2013) "In situ Probing of the Evolution of Irradiation-Induced Defects in Copper", Journal of Nuclear Materials: 439, 185. C2013A0036.

Li, N., Wang, J., Wang, Y.Q., Serruys, Y., Nastasi, M., Misra, A. (2013) "Σ3 Grain Boundary Migration Induced by Ion Irradiation", Journal of Applied Physics: 113, 023508. C2013A0036.

Liontas, R., Gu, X.W., Fu, E., Wang, Y., Li, N., Mara, N.A., Greer, J.R. (2014) "Effects of Helium Implantation on the tensile properties and microstructure of Ni73P27 Metallic glass nanostructures" Nano Letters: 14, 5176

Mara, N.A., Beyerlein, I.J. (2014) "Review: Effect of bimetal interface structure on the mechanical behavior of Cu/Nb nanolayered composites" Journal of Materials Science: 49, 6497 U2008B092 419

McCabe, R.J., Beyerlein, I.J., Carpenter, J.S., Mara, N.A., (2014) "The critical role of grain orientation and applied stress in nanoscale twinning" Nature Communications: 5, 3806

Nizolek, T., Mara, N.A., Beyerlein, I.J., Avallone, J.T., Scott, J.E., Pollock, T.M. (2014) "Processing and deformation behavior of bulk Cu-Nb nanolaminates" Metallography, Microstructure, and Analysis: 3, 6

Pena-Rodriguez, O., Caro, M., Rivera, A., Olivares, J., Perlado, J.M., Caro, A. (2014) "Optical properties of Au-Ag alloys: An ellipsometric study" Optical Materials Express: 4, 2 C2012A0092

Quan, Z., Xu, H., Wang, C., Wen, X., Wang, Y., Zhu, J., Li, R., Sheehan, C.J., Wang, Z., Smilgies, D., Luo, Z., Fang, J. (2014) "Solvent-mediated self-assembly of nanocube superlattices" Journal of the American Chemical Society: 136, 1352-1359 RA2014A0006

Ribaudo, T., Taylor, A.J., Nguyen, B.M., Bethke, D., Shaner, E.A. (2014) "High Efficiency Reflective Wave Plates in the Midwave Infrared" Optics Express: 22, 3, 2821 C2013A0099

Rudolph, M., Carr, S.M., Subramania, G., Ten Eyck, G., Dominguez, J., Pluym, T., Lilly, M.P., Carroll, M.S., Bussmann, E. (2014) "Probing limits of STM field emission patterned Si:P-doped devices" Applied Physics Letters: 105, 163110 C2013B0052

Selby, N.S., Crawford, M., Tracy, L., Reno, J.L., Pan, W. (2014) "In-situ biaxial rotation at low-temperatures in high magnetic fields" Review of Scientific Instruments: 85, 9 U2012B0085

Tracy, L.A., Hargett, T.W., Reno, J.L. (2014) "Few-hole double quantum dot in an undoped GaAs/AlGaAs heterostructure" Applied Physics Letters: 104, 123101 U2011A1019

Yablinsky, C.A., Tippey, K.E., Vaynman, S., Anderoglu, O., Fine, M.E., Chung, Y.W., Speer, J.G., Findley, K.O., Dogan, O.N., Jablonski, P.D., Hackenberg, R.E., Clarke, A.J., Clarke, K.D. (2014) "Concepts for the development of nanoscale stable precipitation-strengthened steels manufactured by conventional methods" JOM: 66, 12 C2010A988

Zheng, S.J., Capenter, J.S., McCabe, R.J., Beyerlein, I.J., Mara, N.A. (2014) "Engineering stable interfaces in bulk nanostructured metals" Scientific Reports: 4, 4226 C2013A0022

Zheng, S.J., Wang, J., Carpenter, J.S., Mook, W.M., Dickerson, P.O., Mara, N.A., Beyerlein, I.J. (2014) "Plastic instability mechanisms in bimetallic nanolayered composites" Acta Materialia: 79, 282-291 C2013A0022

CINT User Science - External (70)

Alberi, K., Mialitsin, A.V., Fluegel, B., Crooker, S.A., Reno, J.L., Mascarenhas, A. (2014) " Magnetic field-induced direct-indirect crossover in AlxGa1-Xas" Applied Physics Express: 7, 11 C2012B0045

Bi, Z., Uberuaga, B.P., Vernon, L.J., Aguiar, J.A., Fu, E., Zheng, S., Zhang, S., Wang, Y., Misra, A., Jia, Q.X. (2014) "Role of the interface on radiation damage in the SrTiO3/LaAIO3 heterostructure under Ne2+ ion irradiation" Journal of Applied Physics: 115, 124315 U2013A0039

Browning, J.F., Baggetto, L., Jungjohann, K., Wang, Y., Tenhaeff, W., Keum, J.K., Wood, D.L., Veith, G.M. (2014) "In situ determination of the liquid/solid interface thickness and composition for the Li-Ion cathode LiMn1.5Ni0.5O4" ACS Applied Materials and Interfaces: 10.1021 U2013A0019

Bufford, D., Liu, Y., Wang, J., Wang, H., Zhang, X., (2014) "In situ nanoindentation study on plasticity and work hardening in aluminium with incoherent twin boundaries." Nature Communications: *5*. C2013B0013.

Burghoff, D., Kao, T.Y., Han, N.R., Chan, C.W.I., Cai, X.W., Yang, Y., Hayton, D.J., Gao, J.R., Reno, J.L., Hu, Q. (2014) "Terahertz laser frequency combs" Nature Photonics: 8, 6 C2013A0020

Chason, E. Shin, J.W., Chen, C-H., Engwall, A.M., Miller, C.M., Hearne, S.J., Freund, L.B. "Growth of patterned island arrays to identify origins of thin film stress" Journal of Applied Physics 115(12) 123519

Chen, A., Weigand, M., Bi, Z., Zhang, W., Lu, X., Dowden, P., MacManus-Driscoll, J.L., Wang, H., Jia, Q.X. (2014) "Evolution of microstructure, strain and physical properties in oxide nanocomposite films" Scientific Reports: 4, 5426 C2013A0005

Chen, A., Bi, Z., Zhang, W., Jian, J., Jia, Q.X., Wang, H. (2014) "Textured metastable VO2 (B) thin films on SrTiO3 substrates with significantly enhanced conductivity" Applied Physics Letters: 104, 071909 C2013A0005

Chen, Y., Jiao, L., Sun, C., Song, M., Yu, K. Y., Liu, Y., Kirk, M., Li, M., Wang, H., Zhang, X., (2014) "In situ studies of radiation induced crystallization in Fe/a-Y2O3 nanolayers." Journal of Nuclear Materials: 452 (1–3), 321-327. C2013B0013.

Choi, E.M., Fix, T., Kursumovic, A., Kinane, C.J., Arena, D., Sahonta, S.L., Bi, Z., Xiong, J., Yan, L., Lee, J.S., Wang, H., Langridge, S., Kim, Y.M., Borisevich, A.Y., MacLaren, I., Ramasse, Q.M., Blamire, M.G., Jia, Q.X., MacManus-Driscoll, J.L. (2014) "Room temperature ferrimagnetism and ferroelectricity in strained, thin films of BiFe0.5Mn0.5O3" Advanced Functional Materials: 24, 7478 U2012B0069

Fan, Z., Jian, J., Liu, Y., Chen, Y., Song, M., Jiao, L., Wang, H., Zhang, X., "In situ studies on superior thermal stability of bulk FeZr nanocomposites." Acta Materialia 101, 125-135. C2015A0021

Fransson, J., Kang, M.G., Yoon, Y., Xiao, S., Ochiai, Y., Reno, J.L., Aoki, N., Bird, J.P. (2014) "Tuning the Fano resonance with an intruder continuum" Nano Letters: 14, 788 C2012A0038

Fu, E.G., Fang, Y., Zhuo, M.J., Zheng, S.J., Bi, Z.X., Wang, Y.Q., Tang, M., Ding, X., Han, W.Z., Luo, H.M., Baldwin, J.K., Misra, A., Nastasi, M. (2014) “Interface structure of Nb films on single crystal MgO(100) and MgO(111) substrates” Acta Materialia: 64, 100-112 U2012B0011

Gao, W., Wu, G., Janicke, M.T., Cullen, D.A., Mukundan, R. (2014) “Proton conducting ozonated graphene oxide membrane” Angewandte Chemie International Edition: 53, 14 RA2012A0009

Gao, W., Wu, G., Janicke, M.T., Cullen, D.A., Mukundan, R et al. (2014) “Ozonated graphene oxide film as a proton-exchange membrane” Angewandte Chemie International Edition: 53, 14 RA2012A0009

Gao, X., Mamaluy, D., Nielsen, E., Young, R.W., Shirkhorshidian, A., Lilly, M.P., Bishop, N.C., Carroll, M.S., Muller, R.P. (2014) “Efficient self-consistent quantum transport simulator for quantum devices” Journal of Applied Physics: 115, 133707 U2011A1066

Han, N.R., de Geofroy, A., Burghoff, D.P., Chan, C.W.I., Lee, A.W.M., Reno, J.L., Hu, Q. (2014) “Broadband all-electronically tunable mems terahertz quantum cascade lasers” Optics Letters: 39, 12 C2012A0006

Han, X., Liu, Y., Jia, Z., Chen, T.C., Wan, J., Weadock, N., Gaskell, K.J., Li, T., Hu, L. (2014) “Atomic-layer-deposition oxide nano-glue for sodium ion batteries” Nano Letters: 14, 139

Hayton, D.J., Kloosterman, J.L., Ren, Y., Gao, J.R., Klapwijk, T.M., Hu, Q., Walker, C.K., Reno, J.L. (2014) “A 4.7 THz heterodyne receiver for a balloon borne telescope” Proceedings of SPIE: 9153 C2013A0020

Hong, M., Wang, Y., Ren, F., Zhang, H., Fu, D., Yang, B., Xiao, X., Jiang, C. (2014) “Helium release and amorphization resistance in ion irradiated nanochannel films” Europhysics Letters: 106, 12001 U2011B13

Huang, H.Y.S., Subramanian, A. (2014) “Special section on spectroscopy, scattering, and imaging, techniques for nanostructured materials” ASME Journal of Nanotechnology in Engineering and Medicine: 5, 2 C2012B0030

Ji, Y., Zhang, Y., Gao, M., Yuan, Z., Xia, Y., Jin, C., Tao, B., Chen, C., Jia, Q.X., Lin, Y. (2014) “Role of microstructures on the M1-M2 phase transition in epitaxial VO2 thin films” Scientific Reports: 4, 4854 U2012B0070

Kao, T.Y., Cai, X., Hu, Q., Reno, J.L. (2014) “Microstrip-antenna-coupled distribute feedback terahertz quantum-cascade lasers” Quantum Sensing and Nanophotonic Devices: 8993 C2012A0006

Karl, N., Reichel, K., Chen, H.T., Taylor, A.J., Brener, I., Benz, A., Reno, J.L., Mendis, R., Mittleman, D.M. (2014) “An electrically driven terahertz modulator with over 20 dB of dynamic range” Applied Physics Letters: 104, 091115 C2013B0008

Khanal, S., Zhao, L., Reno, J.L., Kumar, S. (2014) “Temperature performance of terahertz quantum-cascade lasers with resonant-phonon active-regions” Journal of Optics: 16, 9 U2012A0041

Laroche, D., Gervais, G., Lilly, M.P., Reno, J.L. (2014) “1D-1D Coulomb Drag Signature of a Luttinger Liquid” Science: 343, 631 C2012B0019

Lee, J., Han, J.E., Xiao, S., Song, J., Reno, J.L., Bird, J.P. (2014) “Formation of a protected sub-band for conduction in quantum point contacts under extreme biasing” Nature Nanotechnology: 9, 101. C2013B0022

Lee, S., Sangle, A., Lu, P., Chen, A., Zhang, W., Lee, J.S., Wang, H., Jia, Q.X., MacManus-Driscoll, J.L. (2014) "Novel electroforming-free nanoscaffold memristor with very high uniformity, tenability, and density" Advanced Materials: 26, 6284 U2012B0069

Li, N., Wang, H., Misra, A., Wang, J. (2014) "In situ Nanoindentation Study of Plastic Co-deformation in Al-TiN Nanocomposites" Scientific Reports: 4, 6633 U2014A0085.

Liang, W., Li, Z., Bi, Z., Nan, T., Du., H., Nan, C., Chen, C., Jia, Q.X., Lin, Y. (2014) "Role of the interface on the magnetoelectric properties of BaTiO3 thin films deposited on polycrystalline Ni foils" Journal of Materials Chemistry C: 2, 708 U2012B0070

Liu, Y., Jian, J., Chen, Y., Wang, H., Zhang, X., (2014) "Plasticity and ultra-low stress induced twin boundary migration in nanotwinned Cu by in situ nanoindentation studies." Applied Physics Letters: 104 (23), 231910. C2013B0013.

Liu, Y., Liu, X.H., Nguyen, B.M., Yoo, J., Sullivan, J.P., Picraux, S.T., Dayeh, S.A. (2014) "In-situ transmission electron microscopy (TEM) study on the lithium ion transport in Si-Ge heterostructures nanowires" Microscopy and Microanalysis: 20, 1534

Liu, Y., Ren, F., Cai, G., Zhou, X., Hong, M., Li, W., Xiao, X., Wu, W., Jiang, C. (2014) "Energy dependence on formation of TiO2 nanofilms by Ti Ion implantation and annealing" Materials Research Bulletin: 51, 376 C2013B0011

Liu, Y., Fan, F., Wang, J., Liu, Y., Chen, H., Jungjohann, K.L., Xu, Y., Zhu, Y., Bigio, D., Zhu, T., Wang, C. (2014) "In situ transmission electron microscopy study of electrochemical sodiation and potassiation of carbon nanofibers" Nano Letters: 14, 3445-3452 C2012B0038

Liu, Y., Zhang, S., Zhu, T. (2014) "Germanium-based electrode materials for lithium ion batteries" ChemElectroChem: 1, 706 C2012A0033

Loftian, S., Mayer, C., Chawla, N., Llorca, J., Misra, A., Baldwin, J.K., Molina-Aldareguia, J.M. (2014) "Effect of layer thickness on the high temperature mechanical properties of Al/SiC nanolaminates" Thin Solid Films: 10, 1016 U2012B0013

Lu, P., Romero, E., Lee, S., MacManus-Driscoll, J.L., Jia, Q.X. (2014) "Chemical quantification of atomic-scale EDS maps under thin specimen conditions" Microscopy and Microanalysis: 20, 1782 U2012B0069

Lu, X., Wang, G., Howard, J.W., Chen, A., Zhao, Y., Daemen, L.L., Jia, Q.X. (2014) "Li-rich anti-perovskite Li3OCI films with enhanced ionic conductivity" Chemical Communications: 50, 11520-11522 C2012A0024

Macfaden, A.J., Reno, J.L., Brener, I., Mitrofanov, O. (2014) "3UM aperture probes for near-field terahertz transmission microscopy" Applied Physics Letters: 104, 011110 C2012B0064

Macfaden, A.J., Reno, J.L., Brener, I., Mitrofanov, O. (2014) "Terahertz near-field probe incorporating lambda/100 aperture for time-domain spectroscopy and imaging" Quantum Sensing and Nanophotonic Devices: 8993 C2012B0064

Mackay, D.T., Janish, M.T., Sahaym, U., Kotula, P.G., Jungjohann, K.L., Carter, C.B., Norton, M.G. (2014) "Template-free electrochemical synthesis of tin nanostructures" Journal of Materials Science: 49, 4 U2013A0103

Martin, K., Erdman, M., Quintana, H., Shelnutt, J., Nogan, J., Swartzentruber, B., Martinez, J., Lavrova, O., Busani, T. (2014) "Bio-hybrid integrated system for wide-spectrum solar energy harvesting" Organic Photonic Materials and Devices: 89831 C2011A1013

Mitrofanov, O., Dominec, F., Kuzel, P., Reno, J.L., Brener, I., Chung, U.C., Elissalde, C., Maglione, M., Mounaix, P. (2014) "Near-field probing of Mie resonances in single TiO2 microspheres at terahertz frequencies" Optics Express: 22, 19 C2012B0064

Nguyen, B.M., Taur, Y., Picraux, S.T., Dayeh, S.A. (2014) "Diameter-independent hole mobility in Ge/Si core/shell nanowire field effect transistors" Nano Letters: 14, 2, 585 RA2013A0023

Palapati, N.K.R., Muth, A., Zhu, Y., Wang, C., Subramanian, A. (2014) "Elastic modulus measurements on large diameter nanowires using a nano-assembled platform" ASME Journal of Nanotechnology in Engineering and Medicine: 5, 2 C2012B0030

Paul, J., Dey, P., Tokumoto, T., Reno, J.L., Hilton D.J., Karaiskaj, D. (2014) "Exploring two-dimensional electron gases with two-dimensional fourier transform spectroscopy" Journal of Chemical Physics: 141, 13 U2013B0016

Perng, Y., Cho, J., Sun, Y., Membreno, D., Cirigliano, N., Dunn, B., Chang, J.P. (2014) "Synthesis of ion conducting LixAlySizO thin films by atomic layer deposition" Journal of Materials Chemistry A: 2, 9566 U2013B0077

Sanders, C. E., Zhang, C., Kellogg, G.L., Shih, C. K. (2014) "Role of thermal processes in dewetting of epitaxial Ag(111) film on Si(111)" Surface Science: 630, 168-173

Schoeppner, R.L., Abdolrahim, N., Salehinia, I., Zbib, H.M., Bahr, D.F. (2014) "Elevated temperature dependence of hardness in tri-metallic nano-scale metallic multilayer systems" Thin Solid Films: 10.1016 U2013A0056

Scott, B.L., Joyce, J.J., Durakiewicz, T.D., Martin, R.L., McCleskey, T.M., Bauer, E., Luo, H., Jia, Q.X. (2014) "High quality epitaxial thin films of actinide oxides, carbides, and nitrides: Advancing understanding of electronic structure of f-element materials" Elsevier: 266-267, 137-154 U2012B0011

Singh, S., Haraldsen, J.T., Xiong, J., Choi, E.M., Lu, P., Yi, D., Wen, X.D., Liu, J., Wang, H., Bi, Z., Yu, P., Fitzsimmons, M.R., MacManus-Driscoll, J.L., Ramesh, R., Balatsky, A.V., Zhu, J.X., Jia, Q.X. (2014) "Induced Magnetization in La .7 Sr.3MnO3/BiFeO3 Superlattices" Physical Review Letters: 113, 047204 U2013B0009

Soni, S.K., Sheldon, B.W., Hearne, S.J (2014). "Origins of saccharin-induced stress reduction based on observed fracture behavior of electrodeposited Ni films" Journal of Materials Science 49 (3)1399-1407

Su, Q., Gong, W., Yoon, D., Jacob, C., Jia, Q.X., Manthiram, A., Jacobson, A.J., Wang, H. (2014) "Interlayer Effects on Oxygen Reduction Kinetics in Porous Electrodes of La.5Sr.5C0O3" Journal of the Electrochemical Society: 161, 398-404 C2013A0005

Subramanian, A., Hudak, N.S., Huang, J.Y., Zhan, Y., Lou, J., Sullivan, J.P. (2014) "On-chip lithium cells for electrical and structural characterization of single nanowire electrodes" Nanotechnology: 25, 265402 C2012B0030

Sun, C., Bufford, D., Chen, Y., Kirk, M.A., Wang, Y.Q., Li, M., Wang, H., Maloy, S., Zhang, X. (2014) "In situ study of defect migration kinetics in nanoporous Ag with enhanced radiation tolerance" Nature Scientific Report: 4, 3737 C2012A0017

Tang, W., Nguyen, B.M., Chen, R., Dayeh, S.A. (2014) "Solid-state reaction of nickel silicide and germanide contacts to semiconductor nanochannels" Semiconductor Science and Technology: 29, 5

Vetterick, G., Baldwin, J.K., Misra, A., Taheri, M.L. (2014) "Texture evolution in nanocrystalline iron films deposited using biased magnetron sputtering" Journal of Applied Physics: 116, 233503

Wan, J., Bao, W., Liu, Y., Dai, J., Shen, F., Zhou, L., Cai, X., Urban, D., Li, Y., Jungjohann, K., Fuhrer, M.S., Hu, L. (2014) "Rapid first-cycle lithiation strategy for enhanced performance of Li-MoS2 batteries as identified by in situ studies" Advanced Energy Materials: 1401742 U2012A0007

Wang, J., Fan, F., Liu, Y., Jungjohann, K.L., Lee, S.W., Mao, S.X., Liu, X., Zhu, T. (2014) "Structural evolution and pulverization of tin nanoparticles during lithiation-delithiation cycling" Journal of Electrochemical Society: 161, 11 U2012B0018

Wood, R.M., Saha, D., McCarthy, L.A., Tokarski, J.T., Sanders, G.D., Kuhns, P.L., McGill, S.A., Reyes, A.P., Reno, J.L., Stanton, C.J., Bowers, C.R. (2014) "Effects of strain and quantum confinement in optically pumped nuclear magnetic resonance in GaAs: Interpretation guided by spin-dependent band structure calculations" Physical Review B: 90, 15 U2013B0045

Wright, J.B., Campione, S., Liu, S., Martinez, J.A., Xu, H., Luk, T.S., Wang, G.T., Swartzentruber, B.S., Lester, L.F., Brener, I. (2014) "Distributed feedback gallium nitride nanowire lasers" Applied Physics Letters: 104, 041107 U2012A0040

Xing, Z., Shen, S., Wang, M., Ren, F., Liu, Y., Zheng, X., Liu, Y., Xiao, X., Wu, W., Jiang, C. (2014) "Efficient enhancement of solar-water-splitting by modified 'Z-scheme' structural WO3-W-Si photoelectrodes" Applied Physics Letters: 105, 143902 C2013B0011

Yoo, J., Dayeh, S.A., Bartelt, N.C., Tang, W.Findikoglu, A.T., Picraux, S.T. (2014) "Size-dependent silicon epitaxy in mesoscale dimensions" Nano Letters: 14, 11

Zhao, R., Li, W., Lee, J.H., Choi, E.M., Liang, Y., Zhang, W., Tang, R., Wang, H., Jia, Q.X., MacManus-Driscoll, J.L., Yang, H. (2014) "Precise Tuning of (YBa 2 Cu 3 O 7-δ) 1-x :(BaZrO 3) x Thin Film Nanocomposite Structures" Advanced Functional Materials: 24, 5240-5245 U2011B13

Zhang, H., Ren, F., Hong, M., Xiao, X., Cai, G., Jiang, C. (2014) "Structure and growth mechanism of V/Ag multilayers with different period fabricated by magnetron sputtering deposition" Journal of Material Science & Technology: 30, 1012 C2013B0011

Zhang, H., Ren, F., Wang, Y., Hong, M., Xiao, X., Liu, D., Qin, W., Zheng, X., Liu, Y., Jiang, C. (2014) "Enhanced radiation tolerance of nanochannel V films through defects release" Nuclear Instruments and Methods in Physics Research B: 334, 1-7 U2011B13

Zhang, Q., Arikawa, T., Kato, E., Reno, J.L., Pan, W., Watson, J.D., Manfra, M.J., Zudov, M.A., Tokman, M., Erukhimova, M., Belyanin, A., Kono, J. (2014) "Superradiant decay of cyclotron resonance of two-dimensional electron gases" Physical Review Letters: 113, 4 C2010B1057

Zhang, W., Chen, A., Bi, Z., Jia, Q.X., MacManus-Driscoll, J.L., Wang, H. (2014) "Interfacial coupling in heteroepitaxial vertically aligned nanocomposite thin films: From lateral to vertical control" Elsevier: 18, 6-18 C2013A0005

Zhang, W., Jian, J., Chen, A., Jiao, L., Khathatay, F., Li, L., Chu, F., Jia, Q.X., MacManus-Driscoll, J.L., Wang, H. (2014) "Strain relaxation and enhanced perpendicular magnetic anisotropy in BiFeO3:CoFe2O4 vertically aligned nanocomposite thin films" Applied Physics Letters: 104, 062402 C2013A0005

Zheng, X.D., Ren, F., Cai, G.X., Hong, M.Q., Xiao, X.H., Wu, W., Liu, Y.C., Li, W.Q., Ying, J.J., Jiang, C.Z. (2014) "Formation of TiO2 Nanorods by Ion Irradiation" Journal of Applied Physics: 115, 184306 C2013B0011

Citations for 2015 (98 Total)

CINT Science (4)

Driscoll, J.L., Lee, S.B., Jia, Q.X. (2015) "Memristor comprising film with comb-like structure of nanocolumns of metal oxide embedded in a metal oxide matrix" US Patent: No. 9,029,985

Leenheer, A.J., Sullivan, J.P., Shaw, M., Harris, C.T. (2015) "A sealed liquid cell for in-situ transmission electron microscopy of controlled electrochemical processes" Journal of Microelectromechanical Systems: 24, 4

Nan, C.W., Jia, Q.X. (2015) "Obtaining ultimate functionalities in nanocomposites: Design, control, and fabrication" MRS Bulletin: 40, 719

Park, Y., Choi, J.S., Choi, T., Lee, M.J., Jia, Q.X., Park, M., Lee, H., Park, B.H. (2015) "Configuration of ripple domains and their topological defects formed under local mechanical stress on hexagonal monolayer graphene" Scientific Reports: 5, 9390

CINT User Science - Internal (22)

Bussmann, E., Rudolph, M., Subramania, G.S., Misra, S., Carr, S.M., Langlois, E., Dominguez, J., Pluym, T., Lilly, M.P., Carroll, M.S. "Scanning capacitance microscopy registration of buried atomic-precision donor devices" Nanotechnology: 26, 085701

Carpenter, J.S., Nizolek, T., McCabe, R., Knezevic, M., Zheng, S., Eftink, B., Scott, J., Vogel, S., Pollock, T., Mara, N.A., Beyerlein, I.J. (2015) "Bulk texture evolution of nanolamellar Zr-Nb composites processed via accumulative roll bonding" Acta Materialia: 92, 97-108 C2013A0022

Chen, A., Poudyal, N., Xiong, J., Liu, J.P., Jia, Q.X. (2015) "Modification of structure and magnetic anisotropy of epitaxial CoFe2O4 films by hydrogen reduction" Applied Physics Letters: 106, 111907 U2014A0041

Chou, S.S., Huang, Y.K., Kim, J., Kaehr, B., Foley, B.M., Lu, P., Dykstra, C., Hopkins, P.E., Brinker, C.J., Huang, J., Dravid, V.P. (2015) "Controlling the metal to semiconductor transition of MoS2 and WS2 in solution" Journal of the American Chemical Society: 137, 5 U2014B0071

Curry, M.J., England, T.D., Bishop, N.C., Ten-Eyck, G., Wendt, J.R., Pluym, T.P., Lilly, M.P., Carr, S.M., Carroll, M.S. (2015) "Cryogenic preamplification of a single-electron-transistor using a silicon-germanium heterojunction-bipolar-transistor" Applied Physics Letters: 106, 203505 U2013B0148

Jain, P., Wang, Q., Roldan, M., Glavic, A., Lauter, V., Urban, C., Bi, Z., Ahmed, T., Zhu, J.X., Varela, M., Jia, Q.X., Fitzsimmons, M.R. (2015) "Synthetic magnetoelectric coupling in a nanocomposite multiferroic" Scientific Reports: 5, 9089 U2013B0097

Kamaraju, N., Pan, W., Ukenberg, U., Gvozdic, D.M., Boubanga-Tombet, S., Upadhya, P.C., Reno, J., Taylor, A.J., Prasankumar, R.P. (2015) "Terahertz magneto-optical spectroscopy of a two-dimensional hole gas" Applied Physics Letters: 106, 031902 U2012B0010

Leenheer, A.J., Jungjohann, K.L., Zavadil, K.R., Sullivan, J.P., Harris, C.T. (2015) “Lithium electrodeposition dynamics in aprotic electrolyte observed in situ via transmission electron microscopy” ACS Nano: 9, 4

Ma, X., Baldwin, J.K.S., Hartmann, N.F., Doorn, S.K., Htoon, H. (2015) “Solid-state approach for fabrication of photostable oxygen-doped carbon nanotubes” Advanced Functional Materials: 25, 6157 U2012B0040

Mara, N.A., Beyerlein, I.J. (2015) “Interface-dominant multilayers fabricated by severe plastic deformation: Stability under extreme conditions” Current Opinions in Solid State and Materials Science: 19, 5 U2014A0085

Mayer, C., Li, N., Mara, N., Chawla, N. (2015) “Micromechanical and in situ shear testing of Al-SiC nanolaminate composites in a transmission electron microscope (TEM)” Materials Science and Engineering A: 621, 229 U2014A0085

Moore, S.G., Stevens, M.J., Grest, G.S. (2015) “``Liquid-vapor interface of the Stockmayer fluid in a uniform external field” Physical Review E 91, 022309

Nizolek, T., Avallone, J., Pollock, T., Mara, N., Beyerlein, I. (2015) “High strength bulk metallic nanolaminates” Advanced Materials and Processes: 173, 2 C2013A0022

Nizolek, T., Avallone, J., Mara, N.A., Beyerlein, I.J. (2015) “Enhanced plasticity via kinking in cubic metallic nanolaminates” Advanced Engineering Materials: 17, 6 C2013A0022

Pathak, S, Kalidindi, S.R. (2015) “Spherical nanoindentation stress–strain curves” Materials Science and Engineering: R: Reports. 91, 1-36

Roehling, D., Perron, A., Fattebert, J-L, Coughlin, D.R, Gibbs, P.J., Gibbs, J.W., Imhoff, S.D., Tourret, D., Baldwin, J.K., Clarke, A.J., Turchi, P.E.A., McKeown, J.T. (2015) “Imaging the rapid solidification of metallic alloys in the TEM”, Microscopy and Microanalysis: 21(S3):469-470 U2014A0006.

Shirkhorshidian, A., Bishop, N., Dominguez, J., Wendt, J., Lilly, M.P., Carroll, M.S. (2015) “Transport spectroscopy of low disorder silicon tunnel barriers with and withour Sb implants” Nanotechnology: 26, 205703 U2013B0148

Sun, C., Kirk, M., Li, M., Hattar, K., Wang, Y., Anderoglu, O., Valdez, J., Uberugga, B.P., Dickerson, R., Maloy, S.A. (2015), Microstructure, chemistry and mechanical properties of Ni-based superalloy Rene N4 under irradiation at room temperature, Acta Materialia, 95, 357-365. U2014A0061

Wang, G., Zhang, M., Liu, S., Xie, X.M., Ding, G.Q., Wang, Y.Q., Chu, P.K., Heng, G., Ren, W., Yuan, Q.H., Zhang, P.H., Wang, X., Di, Z.F (2015) “Synthesis of layer-tunable graphene: A combined kinetic implantation and thermal ejection approach” Advanced Functional Materials: 25, 3666-3675 U2014A0013

Wang, F., Karan, N. S., Nguyen, H. M., Ghosh, Y., Sheehan, C. J., Hollingsworth, J. A. & Htoon, H. “Correlated structural-optical study of single nanocrystals in a gap-bar antenna: effects of plasmonics on excitonic recombination pathways.” Nanoscale **7**, 9387-9393, (2015). U2013B0037

Wang, F., Karan, N. S., Nguyen, H. M., Ghosh, Y., Sheehan, C. J., Hollingsworth, J. A. & Htoon, H. "Quantum Optical Signature of Plasmonically Coupled Nanocrystal Quantum Dots." Small **11**, 5028-5034, (2015) (Back Cover) U2013B0037

Gupta, G., Staggs, K., Mohite, A. D., Baldwin, J. K. ; Iyer, S., et al. (2015) "Irradiation-induced formation of a spinel phase at the FeCr/MgO interface" Acta Materialia ; 93, 87-94

CINT User Science - External (72)

Aguiar, J.A., Anderoglu, O., Choudhury, S., Baldwin, J.K., Wang, Y., Misra, A., Uberuagapril, B.P. (2015) "Nanoscale morphologies at alloyed and irradiated metal-oxide bilayers" Journal of Materials Science: 50, 7 U2014B0058

Bennaceur, K., Schmidt, B.A., Gaucher, S., Laroche, D., Lilly, M.P., Reno, J.L., West, K.W., Pfeiffer, L.N., Gervais, G. (2015) "Mechanical flip chip for ultra-high electron mobility devices" Scientific Reports: 5, 13494 U2014A0003

Bilodeau, R.A., Fullwood, D.T., Colton, J., Yeager, J.D., Bowden, A.E., Park, T. (2015) "Evolution of nanojunctions in piezoresistive nanostrand composites" Composites Part B: 72, 45 C2013A0091

Budiman, A.S., Narayanan, K.R., Li, N., Wang, J., Tamura, N., Kunz, M., Misra, A., (2015) "Plasticity evolution in nanoscale Cu/Nb single-crystal multilayers as revealed by synchrotron X-ray microdiffraction" Materials Science and Engineering: A: 635, 6 U2013B0018

Burghoff, D., Yang, Y., Hayton, D.J., Gao, J.R., Reno, J.L., Hu, Q. (2015) "Evaluating the coherence and time-domain profile of quantum cascade laser microcombs" Optics Express: 23, 1190 C2013B0004

Chason, E. Engwall, A.M., Miller, C.M., Chen, C-H., Bhandari, A. Soni, S.K., Hearne, S.J., Freund, L.B., Sheldon, B.W. (2015) "Stress evolution during growth of 1-D island arrays: Kinetics and length scaling" Scripta Materialia 97, 33-36.

Cheaito, R., Hattar, K., Gaskins, J.T., Yadav, A.K., Duda, J.C., Beechem, T.E., Ihlefeld, J.F., Piekos, E.S., Baldwin, J.K., Misra, A., Hopkins, P.E. (2015) "Thermal flux limited electron Kapitza conductance in copper-niobium multilayers" Applied Physics Letters: 093114 U2014B0058

Chen, L.Y., He, M., Shin, J., Richter, G., Gianola, D.S. (2015) "Measuring surface dislocation nucleation in defect-scarce nanostructures" Nature Materials: 10.1038 C2013A0009

Chen, R., Dayeh, S.A. (2015) "Size and orientation effects on the kinetics and structure of nickelide contacts to InGaAs fin structures" Nano Letters: 15, 6 U2013B0062

Chen, Y., Fu, E., Yu, K., Song, M., Liu, Y., Wang, Y., Wang, H., Zhang, X., (2015)"Enhanced radiation tolerance in immiscible Cu/Fe multilayers with coherent and incoherent layer interfaces." Journal of Materials Research: 30 (09), 1300-1309. C2015A0021.

Chen, Y., Liu, Y., Fu, E. G., Sun, C., Yu, K. Y., Song, M., Li, J., Wang, Y. Q., Wang, H., Zhang, X., (2015) "Unusual size-dependent strengthening mechanisms in helium ion-irradiated immiscible coherent Cu/Co nanolayers." Acta Materialia *84*, 393-404. C2015A0021.

Chen, Y., Yu, K.Y., Liu, Y., Shao, S., Wang, H., Kirk, M.A., Wang, J., Zhang, X., (2015)"Damage-

tolerant nanotwinned metals with nanovoids under radiation environments." Nature Communications: 6. C2015A0021

Cole, W.T.S., Hlavacek, N.C., Lee, A.W.M., Kao, T.Y., Hu, Q., Reno, J.L., Saykally, R.J. (2015) "Terahertz Vrt spectrometer employing quantum cascade lasers" Chemical Physics Letters: 638, 144-148 C2013B0004

Dhara, S., Mele, E., Agarwal, R. (2015) "Voltage-tunable circular photogalvanic effect in silicon nanowires" Sciencexpress: 10, 1126 U2013B0054

Fluegel, B., Mialitsin, A.V., Beaton, D.A., Reno, J.L., Mascarenhas, A. (2015) "Electronic Raman Scattering as an ultra-sensitive probe of strain effects in semiconductors" Nature Communications: 6 C2012B0045

Fluegel, B., Alberi, K., Reno, J., Mascarenhas, A. (2015) "Spectroscopic determination of the bandgap crossover composition in Mbe-grown AlxGa1-Xas" Japanese Journal of Applied Physics: 54, 4 C2012B0045

Frolova, L.V., Magedov, I.V., Harper, A., Jha, S.K., Ovezmyradov, M., Chandler, G., Garcia, J., Bethke, D., Shaner, E.A., Vasiliev, I., Kalugin, N.G. (2015) "Tetracyanothylene oxide-functionalized graphene and graphite characterized by Raman and Auger spectroscopy" Carbon: 81, 216 C2013A0099

Gao, Y., Roslyak, O., Dervishi, E., Karan, N.S., Ghosh, Y., Sheehan, C.J., Wang, F., Gupta, G., Mohite, A., Dattelbaum, A.M., Doorn, S.K., Hollingsworth, J.A., Piryatinski, A., Htoon, H. (2015) "Hybrid graphene-giant nanocrystal quantum dot assemblies with highly efficient biexciton emission" Advanced Optical Materials: 3, 39 RA2014A0017

Hong, M., Ren, F., Wang, Y.Q., Zhang, H., Xiao, X., Fu, D., Yang, B., Jiang, C. (2015) "Size-dependent radiation tolerance and corrosion resistance in ion irradiated CrN/AlTiN nanofilms" Nuclear Instruments and Methods in Physics Research B: 342, 137 C2013B0011

Hong, Y.J., Lee, C.H., Yoo, J., Kim, Y.J., Jeong, J., Kim, M., Yi, G.C. (2015) "Emission color-tuned light-emitting diode microarrays of nonpolar InxGa1-xN/GaN multishell nanotube heterostructures" Scientific Reports: 5, 18020 U2014B0041

Janish, M.T., Carter, C.B. (2015) "In-situ TEM observations of the lithiation of molybdenum disulfide" Scripta Materialia: 107, 22-25 U2013A0103

Janish, M.T., Mackay, D.T., Liu, Y., Jungjohann, K.L., Carter, C.B., Norton, M.G. (2015) "TEM in situ lithiation of tin nanoneedles for battery applications" Journal of Material Sciences: 10.1007 U2013A0103

Janish, M.T., Kotula, P.G., Boyce, B.L., Carter, C.B. (2015) "Observations of fcc and hcp tantalum" Journal of Materials Science: 50, 10 U2013A0103

Janish, M.T., Mook, W.M., Carter, C.B. (2015) "Nucleation of face-centered cubic Ta when heating thin films" Scripta Materialia: 96, 21-24 U2013A0103

Johnson, P.E., Muttil, P., Mackenzie, D., Carnes, E.C., Pelowitz, J., Mara, N.A., Mook, W.M., Jett, S.D., Dunphy, D.R., Timmins, G.S., Brinker, C.J. (2015) "Spray-dried multiscale nano-biocomposites containing living cells" ACS Nano: 9, 7 C2013B0007

Keyan-Bennaceur, J., Schmidt, B.A., Gaucher, S., Laroche, D., Lilly, M.P., Reno, J.L., West, K.W., Pfeiffer, L.N., Gervais, G. (2015) "Mechanical flip-chip for ultra-high electron mobility devices" Scientific Reports: 5, 13494 U2014A0003

Khromova, I., Navarro-Cia, M., Brener, I., Reno, J.L., Ponomarev, A., Mitrofanov, O. (2015) "Dipolar resonances in conductive carbon micro-fibers probed by near-field terahertz spectroscopy" Applied Physics Letters: 107, 021102 C2012B0064

Kim, H., Lee, J.T., Magasinski, A., Zhao, K., Liu, Y., Yushin, G. (2015) "In-situ TEM observation of electrochemical lithiation of sulfur confined within inner cylindrical pores of carbon nanotubes" Advanced Energy Materials: 10, 1002 C2013A0021

Koechner, M.C., Pande, J.H., Merkley, S., Henderson, S., Fullwood, D.T., Bowden, A. (2015) "Remote in situ strain sensing of carbon fiber structures using embedded conductive materials" Composites Part B: 69, 534 C2013A0091

Kraehnert, R., Ortel, E., Paul, B., Eckhardt, B., Kanis, M., Liu, R., Antoniou, A. (2015) "Electrochemically dealloyed platinum with hierarchical pore structure as highly active catalytic coating" Catalysis Science and Technology: 5, 206 U2014A0082

Laroche, D., Huang, S.H., Nielsen, E., Chuang, Y., Li, J.Y., Liu, C.W., Lu, T.M. (2015) "Scattering mechanisms in shallow undoped Si/SiGe quantum wells" AIP Advances: 5, 107106 C2012B0019

Laroche, D., Huang, S.H., Nielsen, E., Liu, C.W., Li, J.Y., Lu, T.M. (2015) "Magneto-transport of an electron bilayer system in an undoped Si/SiGe double-quantum-well heterstructure" Applied Physics Letters: 106, 143503 C2012B0019

Lee, S., Zhang, W., Khatkhatay, F., Wang, H., Jia, Q.X., MacManus-Driscoll, J.L. (2015) "Ionic conductivity increased by two orders of magnitude in micrometer-thick vertical yttria-stabilized ZrO2 nanocomposite films" Nano Letters: 15, 7362 C2013A0005

Lee, S., Zhang, W., Jia, Q.X., Wang, H., MacManus-Driscoll, J.L. (2015) "Strain tuning and strong enhancement of ionic conductivity in SrZrO3-RE2O3 (RE=Sm, Eu, Gd, Dy, and Er) nanocomposite films" Advanced Functional Materials: 25, 4238 C2013A0005

Leonard, F., Song, E., Li, Q., Swartzentruber, B., Pan, W., Martinez, J., Wang, G. (2015) "Simultaneous thermoelectric and optoelectronic characterization of individual nanowires" Nano Letters: 15, 8129 C2013B0112

Li, J., Yu, K. Y., Chen, Y., Song, M., Wang, H., Kirk, M. A., Li, M., Zhang, X., (2015) "In Situ Study of Defect Migration Kinetics and Self-Healing of Twin Boundaries in Heavy Ion Irradiated Nanotwinned Metals. Nano Letters: 15 (5), 2922-2927. C2015A0021.

Li, N., Demkowicz, M., Mara, N., Wang, Y.Q., Misra, A. (2015) "Hardening due to interfacial He bubbles in nanolayered composites" Materials Research Letters: DOI: 10.1080/21663831.2015.1110730. U2013B0018

Li, N., Misra, A., Shao, S., Wang, J. (2015) "Experimental Quantification of Resolved Shear Stresses for Dislocation Motion in TiN" Nano Letters: 15, 4434 U2014A0085.

Li, N., Yadav, S., Liu, X.Y., Wang, J., Hoagland, R., Mara, N.A., Misra, A. (2015) "Growth and stress-induced transformation of zinc blended AIN layers in Al-AlN-TiN multilayers" Scientific Reports: 5, 18554 U2014B0058

Li, N., Yadav, S., Liu, X.Y., Wang, J., Hoagland, R., Mara, N.A., Misra, A. (2015) "Quantification of dislocation nucleation stress in TiN through high-resolution in situ indentation experiments and first principles calculations" Scientific Reports: 5, 15813 U2014B0058

Li, Z., Tan, X., Kalisvaart, P., Janish, M.T., Mook, W.M., Jungjohann, K.L., Carter, C.B., Mitlin, D. (2015) "Coupling in-situ TEM and ex-situ analysis to understand heterogeneous sodiation of antimony" Nano Letters: 15, 10 U2013B0051

Liu, Y., Vishniakou, S., Yoo, J., Dayeh, S.A. (2015) "Engineering heteromaterials to control lithium ion transport pathways" Scientific Reports: 5, 18482 U2013B0062

Liu, Y., Wang, H., Zhang, X., (2015) "In Situ TEM Nanoindentation Studies on Stress-Induced Phase Transformations in Metallic Materials." JOM: the journal of the Minerals, Metals & Materials Society: 68 (1), 226-234. C2013B0013.

Ma, X., Hartmann, N.F., Baldwin, J.K.S., Doorn, S. K., Htoon, H. (2015) "Room-temperature single-photon generation from solitary dopants of carbon nanotubes" Nature Nanotechnology 10, 671-675

MacManus-Driscoll, J.L., Suwardi, A., Kursumovic, A., Bi, Z., Tsai, C.F., Wang, H., Jia, Q.X., Lee, Q.J. (2015) "New strain states and radical property tuning of metal oxides using a nanocomposite thin film approach" APL Material: 3, 062507 U2012B0069

Maksud, M., Yoo, J., Harris, C.T., Palapati, N.K.R., Subramanian, A. (2015) "Young's modulus of [111] germanium nanowires" APL Materials: 3, 116101 U2014A0084

Mayer, C., Li, N., Mara, N.A., Chawla, N. (2015) "Micromechanical and in situ shear testing of Al-SiC nanolaminate composites in a transmission electron microscope (TEM)" Materials Science and Engineering A: 621, 229-235 C2014A0011

Mitrofanov, O., Luk, T.S., Brener, I., Reno, J.L. (2015) "Plasmonic enhancement of sensitivity in terahertz (Thz) photo-conductive detectors" Terahertz Emitters, Receivers, and Applications: 9585 U2014A0072

Mitrofanov, O., Luk, T.S., Brener, I., Reno, J.L. (2015) "Photoconductive terahertz near-field detector with a hybrid nanoantenna array cavity" ACS Photonics: 2, 12 U2014A0072

Nguyen, B.M., Swartzentruber, B.S., Ro, Y.G., Dayeh, S.A. (2015) "Facet-selective nucleation and conformal epitaxy of Ge shell on Si Nanowires" Nano Letters: 15, 11 U2013B0062

Ovezmyradov, M., Magedov, I.V., Frolova, L.V., Chandler, G., Garcia, J., Bethke, D., Shaner, E.A., Kalugin, N.G. (2015) "Chemical vapor deposition of phosphorous- and boron-doped graphene using phenyl-containing molecules" Nanoscience and Nanotechnology: 15, 7 C2013A0099

Parashar, V., Durand, C.P., Hap, B., Amorim, R.G., Pandey, R., Tiwari, B., Zhang, D., Liu, Y., Li, A.P., Yap, Y.K. (2015) "Switching behaviors of graphene-boron nitride nanotube heterojunctions" Scientific Reports: 5, 12238 U2014B0070

Pathak, S., Li, N., Mook, W.M., Hoagland, R.G., Baldwin, J.K., Misra, A., Wang, J., Mara, N.A. (2015) "On the origins of hardness in Cu-TiN nanolayered composites" Scripta Materialia: 109, 48-51 U2014B0058

Song, E., Li, Q., Swartzentruber, B.S., Pan, W., Wang, G.T., Martinez, J.A. (2015) "Enhanced thermoelectric transport in modulation-doped GaN/AlGaN Core/Shell nanowires" Nanotechnology: 27, 015204 C2013B0112

Sukrittanon, S., Liu, R., Ro, Y.G., Pan, J.L., Jungjohann, K.L., Tu, C.W., Dayeh, S.A. (2015) "Enhanced conversion efficiency in wide-bandgap GaNP solar cells" Applied Physics Letters: 107, 153901 U2013B0062

Sun, C., Zheng, S., Wei, C. C., Wu, Y., Shao, L., Yang, Y., Hartwig, K. T., Maloy, S. A., Zinkle, S. J., Allen, T. R., Wang, H., Zhang, X., (2015) "Superior radiation-resistant nanoengineered austenitic 304L stainless steel for applications in extreme radiation environments." Scientific Reports: *5*, 7801. C2015A0021.

Tanaka, A., Chen, R., Jungjohann, K., Dayeh, S. (2015) "Strong geometrical effects in submillimeter selective area growth and light extraction of GaN light emitting diodes on sapphire" Scientific Reports: 5, 17314 U2013B0062

Tian, M., Wang, W., Liu, Y., Jungjohann, K.L., Harris, C.T., Lee, Y.C., Yang, R. (2015) "A Three-dimensional carbon nano-network for high performance lithium ion batteries" Nano Energy: 11, 500-509 C2013B0134

Upadhya, P.C., Martinez, J.A., Li, Q., Wang, G.T., Swartzentruber, B.S., Taylor, A.J., Prasankumar, R.P. (2015) "Space and time resolved spectroscopy of sing GaN nanowires" Applied Physics Letters: 106, 263103 C2013B0093

Wang, X., Fan, F., Wang, J.W., Wang, H., Tao, S., Yang, A., Liu, Y., Chew, H.B., Mao, S.X., Zhu, T., Xia, S. (2015) "High damage tolerance of electrochemically lithiated silicon" Nature Communications: 6, 8417 C2012A0045

Wang, X., Pan, Z., Fan, F., Wang, J.W., Liu, Y., Mao, S.X., Zhu, T., Xia, S. (2015) "Nanoscale deformation measurement with high-resolution transmission electron microscopy and digital image correlation" Journal of Applied Mechanics, Transactions ASME: 82, 121001 C2012A0045

Xu, E.Z., Li, Z., Martinez, J.A., Sinitsyn, N., Htoon, H., Li, N., Swartzentruber, B., Hollingsworth, J.A., Wang, J., Zhang, S.X. (2015) "Diameter dependent thermoelectric properties of individual SnTe nanowires" Nanoscale: 7, 2869 C2013A0093

Xu, Y., Aguiar, J.A., Yadav, S.K., Anderoglu, O., Baldwin, J.K., Wang, Y.Q., Valdez, J.A., Misra, A., Luo, H.M., Uberuaga, B.P., Li, N. (2015) "Solute redistribution and phase stability at FeCr/TiO2-x interfaces under ion irradiation" Acta Materialia: 89, 364-373 U2014B0058

Xu, Y., Yadav, S.K., Aguiar, J.A., Anderoglu, O., Baldwin, J.K., Wang, Y.Q., Misra, A., Luo, H., Uberuaga, B.P., Li, N. (2015) "Irradiation-induced formation of a spinel phase at the FeCr/MgO interface" Acta Materialia: 93, 87 U2013B0018.

Xue, S., Fan, Z., Chen, Y., Li, J., Wang, H., Zhang, X., (2015) "The formation mechanisms of growth twins in polycrystalline Al with high stacking fault energy" Acta Materialia: 101, 62-70. C2015A0021

Yang, S.M., Lee, S., Jian, J., Zhang, W., Jia, Q.X., Wang, H., Noh, T.W., Kalinin, S.V., MacManus-Driscoll, J.L. (2015) "Strongly enhanced oxygen ion transport through Sm-doped CeO2 nanopillars in nanocomposite films" Nature Communications: 6, 8588

Yoo, J., Nguyen, B.M., Campbell, I.H., Dayeh, S.A., Schuele, P., Evans, D., Picraux, S.T. (2015) "Si radial p-i-n junction arrays for photovoltaics with built-in light concentrators" ACS Nano: 9, 5 U2013B0062

Yu, K. Y., Fan, Z., Chen, Y., Song, M., Liu, Y., Wang, H., Kirk, M. A., Li, M., Zhang, X., (2015) "In situ Observation of Defect Annihilation in Kr Ion-Irradiated Bulk Fe/Amorphous-Fe2Zr Nanocomposite Alloy." Materials Research Letters: 3 (1), 35-42. C2013B0013.

Zhang, W., Fan, M., Li, L., Chen, A., Su, Q., Jia, Q.X., MacManus-Driscoll, J.L., Wang, H. (2015) "Heterointerface design and strain tuning in epitaxial BiFeO3:CoFe2O4 nanocomposite films" Applied Physics Letters: 107, 21290 U2012B0069

Zhang, W., Li, L., Lu, P., Fan, M., Su, Q., Khatkhatay, F., Chen, A., Jia, Q.X., Zhang, X., MacManus-Driscoll, J.L., Wang, H. (2015) "Perpendicular exchange biased magnetotransport at the vertical La0.7Sr0.3MnO3-NiO heterointerface" Nanoscale: 7, 13808 U2012B0069

Zheng, S., Shao, S., Zhang, J., Wang, Y., Demkowicz, M., Beyerlein, I., Mara, N.A. (2015) "Adhesion of voids to interfaces with non-uniform energies" Scientific Reports: 5, 15428 U2008A119

Zheng, X., Shen, S., Ren, F., Cai, G., Xing, Z., Liu, Y., Liu, D., Zhang, G., Xiao, X., Wu, W., Jiang, C. (2015) "Irradiation-induced TiO2 nanorods for photoelectrochemical hydrogen production" International Journal of Hydrogen Energy: 10.1016 C2013B0011

8.0 Biographical Sketches

BRIAN S. SWARTZENTRUBER
Principal Member of Technical Staff
Nanostructure Physics Department Phone 505-844-6393
Sandia National Laboratories Fax 505-284-7778
Albuquerque, NM 87185-1303 E-mail bsswart@sandia.gov

Education

Undergraduate: Goshen College Physics/Mathematics, B.A. 1983
Graduate: University of Wisconsin-Madison Physics, PhD 1992

Professional Experience

Principal Member of Technical Staff, Sandia National Laboratories, 1992 – present
Research Associate, University of Wisconsin-Madison, 1986 – 1992
Senior Technical Associate, AT&T Bell Laboratories, Murry Hill, NJ, 1983 – 1986

Relevant Publications

Enhanced Thermoelectric Transport in Modulation-Doped GaN/AlGaN Core/Shell Nanowires, Erdong Song, Qiming Li, Brian Swartzentruber, Wei Pan, George T. Wang, Julio A. Martinez, Nanotechnology **27**, 015204 (2016).

Simultaneous Thermoelectric and Optoelectronic Characterization of Individual Nanowires, Francois Léonard, Erdong Song, Qiming Li, Brian Swartzentruber, Wei Pan, Julio Martinez, and George Wang, Nano Letters **15**, 8129 (2015).

Facet-Selective Nucleation and Conformal Epitaxy of Ge Shell on Si Nanowires, Binh-Minh Nguyen, Brian Swartzentruber, Yun Goo Ro, and Shadi A. Dayeh, Nano Letters **15**(11), 7258 (2015).

Diameter Dependent Thermoelectric Properties of Individual SnTe Nanowires, E. Z. Xu, Z. Li, J. A. Martinez, N. Sinitzyn, H. Htoon, Nan Li, B. S. Swartzentruber, J. Hollingsworth, Jian Wang, and S. X. Zhang, Nanoscale, **7**, 2869 (2015).

Space-and-Time-Resolved Spectroscopy of Single GaN Nanowires, Prashanth C. Upadhya, Julio A. Martinez, Qiming Li, George T. Wang, Brian S. Swartzentruber, Antoinette J. Taylor, and Rohit P. Prasankumar, Appl. Phys. Lett. **106**(26), 263103 (2015).

Distributed Feedback Gallium Nitride Nanowire Lasers, Jeremy B. Wright, Salvatore Campione, Sheng Liu, Julio A. Martinez, Huiwen Xu, Ting S. Luk, Qiming Li, George T. Wang, Brian S. Swartzentruber, Luke F. Lester, and Igal Brener, Appl. Phys. Lett. **104**, 041107 (2014).

Measurement of Electronic States of PbS Nanocrystal Quantum Dots Using Scanning Tunneling Spectroscopy: The Role of Parity Selection Rules in Optical Absorption, B. Diaconescu, L. A. Padilha, P. Nagpal, B. S. Swartzentruber, and V. I. Klimov, Phys. Rev. Lett., **110**, 127406 (2013).

Contribution of Radial Dopant Concentration to the Thermoelectric Properties of Core-Shell Nanowires, Julio A. Martinez, Jeong H. Cho, Xiaohua Liu, Ting S. Luk, Jianyu Huang, S.T. Picraux, John P. Sullivan, and B. S. Swartzentruber, Appl. Phys. Lett. **102**, 103101 (2013).

Cellular Complexity Captured in Durable Silica Biocomposites, Bryan Kaehr, Jason L. Townson, Robin M. Kalinich, Yasmine H. Awad, B. S. Swartzentruber, Darren R. Dunphy, C. Jeffrey Brinker, PNAS, **109**(43), 17336 (2012).

Tuning of Defects in ZnO Nanorod Arrays Used in Bulk Heterojunction Solar Cells, Diana C. Iza, David Munoz-Rojas, Quanxi Jia, B. S. Swartzentruber, and Judith L. MacManus-Driscoll, Nanoscale Research Lett., **7**, 655 (2012).

Awards and Synergistic Activities

2002 Fellow of the American Physical Society

1997 Fellow of the American Vacuum Society
1997 Peter Mark Award, American Vacuum Society
1996 Office of Energy Research's Young Independent Scientist Award, Department of Energy
1991 Wayne B. Nottingham Prize, Physical Electronics Conference
1990 Student Award, American Vacuum Society – Electronic Materials & Processing Division
1990 Dean's Fellowship, UW-Madison
1989 Russell & Sigurd Varian Fellow, American Vacuum Society
Program Committee of the 76th Physical Electronics Conference 2016
Editorial Board of Journal of Scanning Probe Microscopy, 2005-2010
Local Organizing Committee of the 3rd LEEM/PEEM Workshop, 2002
Executive Committee of the Electronic Materials and Processing Division, AVS, 1999-2002
Local Organizing Committee of the 61st Physical Electronics Conference, 2001
Program Committee of the Nanoscale Science and Technology Division, AVS, 1999
Executive Committee of the Nanoscale Science and Technology Division, AVS, 1997-1998

Collaborators: (last 48 months): Y. H. Awad (University of New Mexico), S. Campione (University of California, Irvine), S. A. Dayeh (University of California, San Diego), D. R. Dunphy (University of New Mexico), D. C. Iza (Cambridge), L. F. Lester (University of New Mexico), J. L. MacManus-Driscoll (Cambridge), J. A. Martinez (New Mexico State University), D. Munoz-Rojas (Cambridge), B. M. Nguyen (University of California, San Diego), Y. G. Ro (University of California, San Diego), Erdong Song (New Mexico State University), J. L. Townson (University of New Mexico), P. C. Upadhya (Indian Space Research Organization), E. Z. Xu (Indiana University), H. Xu (University of New Mexico), J. B. Wright (University of New Mexico), S. X. Zhang (Indiana University)

Graduate Advisor: Prof. M. B. Webb, University of Wisconsin - Madison

Graduate Student and Postdoc Sponsor (total: 2 postdocs, 0 students): Past post-docs (current location): Collin Delker (Sandia National Laboratories), Julio Martinez (New Mexico State University)

NATHAN MARA
CINT Scientist
MPA-CINT, Mailstop K771 Phone 505-667-8665
Los Alamos National Laboratory Fax 505-667-5268
Los Alamos, NM 87545 E-mail namara@lanl.gov

Education:
Undergraduate: University of California, Davis, Mech. Eng./Mat. Sci. and Eng. BS 2000
Graduate: University of California, Davis, Materials Science and Engineering PhD 2005

Professional Experience:
Technical staff member, Los Alamos National Lab, March 2008 – present

Current Position: Staff Scientist Level 4, Los Alamos National Laboratory
-Specific research interest in bulk synthesis/nanomechanics of nanomaterials.
-Partner Science Leader, Nanoscale Electronics and Mechanics Thrust at CINT
-Deputy Director, LANL Institute for Materials Science (2014-present).
- Mechanical Thrust experimental team lead, DOE BES Energy Frontiers Research Center: "Center for Materials at Irradiation and Mechanical Extremes". $19.5m/5years PI: Misra (2008-2013).
-PI (August 2015-present) /Co-PI (2014-2015): DOE BES Core program *"Deformation physics of ultra fine scale materials"*
-Experimental team lead and co-PI, LANL Laboratory Directed Research and Development project "Innovative and validated sub-micron to meso-scale modeling of the evolution of interface structure and properties under extreme strains" $1.7m/year over 3 years, PI: Beyerlein
-PI: "Determining the stress-strain response of irradiated metallic materials via spherical nanoindentation". DOE-Nuclear Energy Enabling Technologies, Funded October 2013, $1M total over 3 years.
- Deformation of nanocrystalline materials including rolling, tensile testing, micropillar compression, and nanoindentation.

Director's Postdoctoral Fellow, Los Alamos National Lab, Dec 2005 – March 2008
Graduate student research assistant, University of California, Davis, Apr 2000 – Nov 2005

Relevant Publications: (h-index 30, 2202 citations since 2011 according to Google Scholar)
Publications with a * are students, postdocs, or early career staff mentored by N.A. Mara

N. Li*, S. Yadav, X-Y Liu, J. Wang, R. Hoagland, N.A. Mara, A. Misra, "Quantification of dislocation nucleation stress in TiN through high-resolution in situ indentation experiments and first principles calculations", *Scientific Reports*, Vol. 5, Article 15813, doi:10.1038/srep15813 (2015).

C. Mayer, N. Li, N.A. Mara, N. Chawla, "Micromechanical and in situ shear testing of Al–SiC nanolaminate composites in a transmission electron microscope (TEM)", *Materials Science & Engineering A*, Vol.621, pp.229-235 (2015).

P.E. Johnson, P. Muttil, D. Mackenzie, E.C. Carnes, J. Pelowitz, N.A. Mara, W.M. Mook*, S.D. Jett, D.R. Dunphy, G.S. Timmins, J.C. Brinker, "Spray-dried multiscale nano-biocomposites containing living cells", *ACS nano*, 28 2015, Vol.9(7), pp.6961-77

S. Pathak*, S.R. Kalidindi, N.A. Mara, "Investigations of orientation and length scale effects on micromechanical responses in polycrystalline Zirconium using spherical nanoindentation", *Scripta Materialia*, Vol. 113, pp. 241–245 (2016).

(**invited**) N.A. Mara, N. Li*, A. Misra, J. Wang, "Interface-Driven Plasticity in Metal–Ceramic Nanolayered Composites: Direct Validation of Multiscale Deformation Modeling via In Situ Indentation in TEM", *JOM*, Vol. 68, Issue 1, pp 143-150 (2016).

T. Nizolek*, I.J. Beyerlein, N.A. Mara, J.T. Avallone*, T.M. Pollock, "Tensile Behavior and Flow Stress Anisotropy of Accumulative Roll Bonded Cu-Nb Nanolaminates", accepted to *Applied Physics Letters*

(invited) N.A. Mara, I.J. Beyerlein, "Interface-dominant multilayers fabricated by severe plastic deformation: Stability under extreme conditions", *Current Opinions in Solid State and Materials Science,* Vol 19, Iss 5, pp. 265–276 (2015). DOI: 10.1016/j.cossms.2015.04.002.

(invited, cover) T. Nizolek*, J. Avallone*, T. Pollock, N. Mara, I. Beyerlein, "High Strength Bulk Metallic

Nanolaminates", *Advanced Materials and Processes*, Vol. 173, No. 2, pp. 18-21, (2015).

R. Liontas, X.W. Gu, E. Fu, Y. Wang, N. Li*, N.A. Mara, and J.R. Greer, "Effects of Helium Implantation on the Tensile Properties and Microstructure of Ni73P27 Metallic Glass Nanostructures", *Nano Letters*, 2014, *14* (9), 5176–5183.

(invited) N.A. Mara and I.J. Beyerlein, "Review: Effect of bimetal interface structure on the mechanical behavior of Cu/Nb nano layered composites", *Journal of Materials Science*, Vol.49(19), p .6497-6516 (2014) DOI: 10.1007/s10853-014-8342-9.

Awards and Synergistic Activities:

-**The Minerals, Metals, and Materials Society (TMS)**

-2012 TMS Young Leaders Professional Development Award, Past Chair (March 2013-2015), past Vice-Chair of nanomechanical mat'ls behavior committee, Co-organizer of symposia at 2009, 2012, 2013 Annual Meetings, 2010 MS&T Meeting

-**Reviewer for peer-reviewed journals including:** *Science, Acta Materialia, Applied Physics Letters, Nature Communications, Philosophical Magazine, Materials Science and Engineering A, Thin Solid Films, Journal of Materials Research, Scripta Materialia, Met. Trans., Journal of Alloys and Compounds, International Journal of Plasticity, Journal of Nuclear Materials.*

-**Recipient of 2010 LANL Distinguished Mentor Performance Award**

-**9 Invited talks on interface-driven deformation in the past ~18 months, including**: **a.)** 2015 MRS Fall Meeting, Boston, MA, December 1, 2015. **b.)** invited seminar at Drexel University, Philadelphia, PA, May 13, 2015. **d.)** 2014 Pan American Materials Conference, Sao Paolo, Brazil, July 21-25, 2014. **e.)** Gordon Conference on Thin Films and Small Scale Mechanical Behavior, Bentley College, Waltham, MA, July 13-18, 2014.

Collaborators: Dr. Brent Adams - Brigham Young University, Dr. Antonia Antoniou - Georgia Institute of Technology, Dr. Robert Averback – University of Illinois, Urbana-Champaign, Dr. Katayun Barmak—Colombia University, Dr. Pascal Bellon, University of Illinois, Urbana-Champaign, Dr. Dhriti Bhattacharyya - ANSTO, Australia, Dr. Michael Demkowicz – Massachusetts Institute of Technology, Dr. David Fullwood - Brigham Young University, Dr. Julia Greer – CalTech, Dr. John Hirth - Washington State University, Dr. Peter Hosemann - University of California, Berkeley, Dr. Ibrahim Karaman - Texas A&M University, Dr. Marko Knezevic—University of New Hampshire, Dr. Molly Kennedy – Clemson University, Dr. Javier Llorca – Polytechnic University of Madrid, Dr. Miguel Monclus—Polytechnic University of Madrid, Dr. Jon Molina—Polytechnic University of Madrid, Dr. Don Lucca – Oklahoma State University, Dr. Amit Misra—University of Michigan Dr. Michael Nastasi—University of Nebraska, Dr. Tresa Pollock – University of California, Santa Barbara, Dr. Ian Robertson – University of Illinois, Urbana-Champaign, Dr. Anthony Rollett – Carnegie Mellon University, Dr. Judy Schneider – Mississippi State University, Dr. Raj Vaidyanathan - University of Central Florida, Dr. Xinghang Zhang - Texas A&M University

Graduate and Postdoctoral Advisors: **Postdoctoral Advisors:** Dr. Amit Misra and Dr. Richard G. Hoagland (Los Alamos National Laboratory), **Graduate Advisor:** Dr. Amiya Mukherjee (University of California, Davis)

Thesis Advisor and Postgraduate-Scholar Sponsored by Dr. Mara over past 5 years (10 postdocs, 8 Grad Student):

-LANL Postdocs: Jordan Weaver, Ursula Carvajal-Nunez, Cheng Sun, Youxing Chen, Siddhartha Pathak, LANL Postdoc, now Asst. Prof, U. Nevada-Reno, Shijian Zheng, LANL postdoc, now Asst Prof at Inst. for Metal Research, China, Bill Mook, LANL postdoc, now Sandia Nat'l Laboratories staff, : John Carpenter, Distinguished LANL postdoc, now LANL staff, Weizhong Han, LANL postdoc, now Assistant Professor, Xi'an Jiaotong University, Nan Li, and LANL postdoc, now LANL staff

-Graduate Students: Josef Cobb, PhD student, Mississippi State University, Daniel Savage, PhD Student, University of New Hampshire, Youxing Cheng, PhD Student, Texas A&M University, now LANL postdoc, Ricardo Martinez, Master's Student, UNM, Shraddha Vachhani, PhD Student, Georgia Tech, now at Hyistron, Inc., Thomas Nizolek, PhD student, University of California, Santa Barbara, Ben Eftink, PhD student, University of Illinois, Urbana-Champaign Jon LeDonne, PhD student, Carnegie Mellon University, now at Bettis, Inc.

Total: 10 postdocs, 8 grad students

TOM HARRIS
Senior Member of Technical Staff
Center for Integrated Nanotechnologies
Sandia National Laboratories
Albuquerque, NM 87185
Phone: 505-284-8522
Fax: 505-284-7778
E-mail: ctharri@sandia.gov

Education

Undergraduate:	Vanderbilt University	Mechanical Engineering, B.E.	2000
Graduate:	Vanderbilt University	Mechanical Engineering, M.S.	2003
	Massachusetts Institute of Technology	Electrical Engineering, S.M.	2010
	Massachusetts Institute of Technology	Mechanical Engineering, Ph.D.	2010

Appointments

Senior Member of Technical Staff, Sandia National Laboratories, September 2012 – present
Postdoctoral Research Associate, Sandia National Laboratories, Feb. 2011 – Sept. 2012
Graduate Research Assistant, Massachusetts Institute of Technology, Sept. 2002 – June 2010
Graduate Research Assistant, Vanderbilt University, June 2000 – August 2002

Publications

Lithium Electrodeposition Dynamics in Aprotic Electrolyte Observed in Situ via Transmission Electron Microscopy, Andrew J. Leenheer, Katherine L. Jungjohann, Kevin R. Zavadil, John P. Sullivan, and C. Thomas Harris, ACS Nano, 9(4), Pages 4379–4389, 2015.

A Sealed Liquid Cell for in-situ Transmission Electron Microscopy of Controlled Electrochemical Processes, Andrew Jay Leenheer, John P. Sullivan, Michael Shaw, C. Thomas Harris, Journal of Microelectromechanical Systems, 24(4), Pages 1061-1068, 2015.

A Three-dimensional Carbon Nano-network for High Performance Lithium Ion Batteries, Miao Tian, Wei Wang, Yang Liu, Katherine L. Jungjohann, C. Thomas Harris, Yung-Cheng Lee, Ronggui Yang, Nano Energy, Volume 11, Pages 500–509, 2015.

Two-phase Electrochemical Lithiation in Amorphous Silicon, J. W. Wang, Y. He, F. Fan, X. H. Liu, S. Xia, Y. Liu, C. T. Harris, H. Li, J. Y. Huang, S. X. Mao and T. Zhu, Nano Letters, 13, 709-715, 2013.

Fabrication of a Thermal Property Measurement Platform, C. T. Harris, J. A. Martinez, E. A. Shaner, B. S. Swartzentruber, J. Y. Huang, J. P. Sullivan, and G. Chen, Nanotechnology Vol. 22, pp. 275308, 2011.

Criteria for Cross-Plane Dominated Thermal Transport in Multilayer Thin Film Systems During Modulated Laser Heating, P. E. Hopkins, J. R. Serrano, L. M. Phinney, S. P. Kearney, T. W. Grasser, and C. T. Harris, Journal of Heat Transfer, Vol. 132, No. 8, August 2010, pp. 081302.

A Hot-Wire Probe for Thermal Measurements of Nanowires and Nanotubes Inside a Transmission Electron Microscope, C. Dames, S. Chen, C. T. Harris, J. Y. Huang, Z. F. Ren, M. S. Dresselhaus, and G. Chen, Review of Scientific Instruments, Vol. 78, 104903 (1-13), 2007.

Synergistic Activities

Awards: Pi Tau Sigma, 1999; Exceptional Teaching Award, Vanderbilt University, 2002
Fellowships: Meritor Automotive Fellowship, 1999
Professional Societies: 10+ year member of the Materials Research Society (MRS), 10+ year member of the American Society of Mechanical Engineers (ASME), 10+ year member of the Institute of Electrical and Electronics Engineers (IEEE), 10+ year member of the American Physical Society (APS).

Collaborators (Last 48 months): Gang Chen (MIT), John Cumings (University of Maryland), Chris Dames (UC Berkeley), Horacio Espinosa (Northwestern University), Timothy Fisher (Purdue University), Dan Gianola (University of Pennsylvania), Patrick Hopkins (University of Virginia), Vic Liu (General Motors), Scott Mao (University of Pittsburgh), Gary Rubloff (University of Maryland), Aaron Schmidt (Boston University), Derek

Stewart (Cornell Univ.), Zhu Ting (Georgia Tech.), Yuhaung Wang (University of Maryland), Gleb Yushin (Georgia Tech.)

Graduate and Postdoctoral Advisors: Timothy S. Fisher, M.S. Advisor, Vanderbilt University (Currently at Purdue Univ.); Rajeev J. Ram, S.M. Advisor, Massachusetts Institute of Technology; Gang Chen, Ph.D. Advisor, Massachusetts Institute of Technology; John P. Sullivan, Postdoctoral Advisor, Sandia National Laboratories.

Thesis Advisor and Postgraduate Scholar Sponsor:
Andrew Leenheer (2013-2015), currently SNL staff; Collin Delker (2013-2015), currently SNL staff
Total: 2 postdocs

QUANXI JIA
Center for Integrated Nanotechnologies (CINT)
Materials Physics and Applications Division
Mail Stop K771
Los Alamos, NM 87545

Phone: (505) 667-2716
Fax: (505) 665-9030
E-mail: qxjia@lanl.gov

Education

Undergraduate:	Jiaotong University, Xian, China	Electronic Engineering	B.S. 1982
Other:	Jiaotong University, Xian China	Electronic Engineering	M.S. 1985
Graduate:	SUNY at Buffalo	Electrical Engineering	Ph.D. 1991

Professional Experience

Director & Group Leader, Center for Integrated Nanotechnologies, 2016 - present
Co-Director & Group Leader, Center for Integrated Nanotechnologies, 2015 - 2016
Acting Co-Director, Center for Integrated Nanotechnologies, 2014 - 2015
Thrust Leader, Nanoscale Electronics & Mechanics, CINT, 2009 - 2014
Laboratory Fellow, Los Alamos National Laboratory (LANL), 2003 - present
Team Leader, Electronic Materials & Devices, MPA-STC, LANL, 1996 - 2009
Technical Staff Member, LANL, 1996 - present
Director's Postdoctoral Fellow, LANL, 1993 - 1996
Visiting associate professor, Kumamoto University, Japan, 4/1993 - 12/1993
Research associate, State University of New York (SUNY) at Buffalo, 9/1991 - 8/1993
Teaching assistant, SUNY at buffalo, 9/1988 - 8/1991
Research associate, SUNY at Buffalo, 2/1988 - 8/1988
Assistant professor, Jiaotong University, Xian, China, 12/1987 - 1/1988
Adj. Professor, Jiaotong University, Xian, China, 2008 - present

Relevant Publications (since 2009)

Electrochromatic Carbon Nanotube/Polydiacetylene Nanocomposite Fibers, H. Peng, X. M. Sun, F. J. Cai, X. Chen, G. P. Liao, D. Y. Chen, Q. W. Li, Y. F. Lu, Y. T. Zhu, and Q. X. Jia, *Nature Nanotechnology* **4**, 738 (2009).

Tuning the resonance in high-temperature superconducting terahertz metamaterials, H. T. Chen, H. Yang, R. Singh, J. F. O'Hara, A. K. Azad, S. A. Trugman, Q. X. Jia, and A. J. Taylor, *Phys. Rev. Lett.* **105**, 247402 (2010).

Highly aligned carbon nanotube forests coated by superconducting NbC, G. Zou, H. Luo, S. Baily, Y. Zhang, N. Haberkorn, J. Xiong, E. Bauer, T. McCleskey, A. Burrell, L. Civale, Y. T. Zhu, J. L. MacManus-Driscoll, and Q. X. Jia, *Nature Commun.* **2**, 248 (2011).

Thick lead-free ferroelectric films with high Curie temperatures through nanocomposite-induced strain, S. A. Harrington, J. Zhai, S. Denev, V. Gopalan, H. Wang, Z. Bi, S. A. T. Redfern, S. H. Baek, C. W. Bark, C. B. Eom, Q. X. Jia, M. E. Vickers, and J. L. MacManus-Driscoll, *Nature Nanotechnology* **6**, 491 (2011).

Extremely high tenability and low loss in nanoscaffold ferroelectric films, O. Lee, S. A. Harrington, A. Kursumovic, E. Defay, H. Wang, Z. Bi, C. F. Tsai, L. Yan, Q. X. Jia, and J. L. MacManus-Driscoll, *Nano Lett.* **12**, 4311 (2012).

Polymer-assisted deposition: a chemical solution route for a wide range of materials, G. F. Zou, J. Zhao, H. M. Luo, T. M. McCleskey, A. K. Burrell, and Q. X. Jia, *Chem. Soc. Rev.* **42**, 439 (2013).

Novel electroforming-free nanoscaffold memristor with very high uniformity, tunability and density, S. Lee, A. Sangle, P. Lu, A. Chen, W. Zhang, J. S. Lee, H. Wang, Q. X. Jia, and J. L. MacManus-Driscoll, *Adv. Mater.* **26**, 6284 (2014).

Ultrafast optical manipulation of magnetoelectric coupling at a multiferroic interface, Y. M. Sheu, S. A. Trugman, L. Yan, Q. X. Jia, A. J. Taylor, and R. P. Prasankumar, *Nat. Commun.* **5**, 5832 (2014).

Strongly enhanced oxygen ion transport through samarium-doped CeO_2 nanopillars in nanocomposite films, S. M.

Yang, S. Lee, J. Jian, W. Zhang, Q. X. Jia, H. Wang, T. W. Noh, S. V. Kalinin, and J. L. MacManus-Driscoll, *Nat. Commun.* **6**, 8588 (2015).

Synergistic Activities

Awards:

Fellow of Materials Research Society (MRS), 2014
Fellow of American Association for the Advancement of Science (AAAS), 2011
Postdoctoral Distinguished Mentor Awards, LANL, 2010
Fellow of American Ceramic Society (ACerS), 2010
Fellow of American Physical Society (APS), 2009
The Federal Laboratory Consortium for Technology Transfer Awards for Excellence in Technology Transfer, 2008
The 2008 outstanding Women's Career Development Mentoring Awards, LANL
Asian-American Engineer of the Year award, 2005
Laboratory *Fellow,* Los Alamos National Laboratory, Sept. 2003
Two R&D 100 awards: One for Underground Radio in 1998 and the other one for Flexible Superconducting Tape in 2003
Award for Excellence in Industrial Partnerships at LANL, 1996
National Link Foundation Fellowship award at SUNY in 1990-1991

Publications: 47 US patents issued; more than 400 refereed journal articles; 9 book chapters; and over 60 refereed/un-refereed proceeding articles

Professional Society Office:

Have been as the member of Executive Committee of the Electronics Division, American Ceramic Society (ACerS): Secretary-Elect (2008 - 2009), Secretary (2009 - 2010), Vice-Chair & Program Chair (2010 - 2011), Chair-Elect (2011 - 2012), Chair (2012 - 2013).
Have been as the officers of LANL Fellows: Secretary (2009 - 2010), Deputy Coordinator (2010 - 2011); Coordinator (2011 - 2012)
Editor-in-Chief for *Mater. Res. Lett.*, Taylor & Francis Group, 2013 - present
Editorial Board for *J. Semiconductors*, IOP Publishing, 2010 - present
Int'l Editorial Board for *Trans. Electrical & Electronic Materials*, Korean, 2010 – present
Editorial Board for *Ferroelectrics Letters*, Taylor & Francis Group (2013 – present)
Editorial Board for *Nano Convergence*, Springer (2013 – present)
Served in the organizing committees of many international Symposia/conferences

Recent Collaborators (last 48 months): *The Texas A&M University*: H. Y. Wang; *The University of Cambridge*: J. L. MacManus-Driscoll; *University of Texas at San Antonio*: C. L. Chen and A. Bahlla; *Argonne National Laboratory*: A. K. Burrell

Graduate Advisor: W. A. Anderson, State University of New York at Buffalo
Postdoctoral Advisor: Xini Wu, LANL (currently with Cnano Technol. Limited, CA)

Postdoctoral and Graduate Students Sponsor: Current postdoc scholars: *Erik Enrique* (Univ. of Texas at San Antonio), *Aiping Chen* (Texas A&M Univ.), *Xujie Lu* (Shanghai Institute of Ceramics, CAS, China). Former postdoc scholars currently with: *Jie Xiong* (Univ. of Electronic Sci. & Technol., China), Zhenxing Bi (IBM, NY), *Mujin Zhuo* (Institute of Metal Research, CAS), *Yan Li*, *Marcus Weigand*, and *Binh-Minh Nguyen*.
Total: 9 postdocs.

KATHERINE L. JUNGJOHANN
Senior Member of Technical Staff
Center for Integrated Nanotechnologies
Sandia National Laboratories
Albuquerque, NM 87185-1303
Phone: 505-284-6892
Fax: 505-284-7778
E-mail: kljungj@sandia.gov

Education

Undergraduate:	University of Redlands	Chemistry, B.S.	2008
Graduate:	University of California, Davis	Materials Science, Ph.D.	2012

Appointments

Senior Member of Technical Staff, Sandia National Laboratories, 03/2013 - Present
Postdoctoral Research Associate, Brookhaven National Laboratory, 02/2012 – 02/2013
Graduate Research Student, University of California, Davis, 09/2008 - 02/2012
Teaching Assistant, University of California, Davis, 09/2009 - 05/2011
Research Assistant, University of Redlands, 07/2005 - 05/2008
Research Assistant, University of California, Riverside, 06/2006 - 08/2006

Relevant Publications

Coupling in-situ TEM and ex-situ analysis to understand heterogeneous sodiation of antimony, Z. Li, X. Tan, P. Li, W. Kalisvaart, M. Janish, W. Mook, E. Luber, K. Jungjohann, C. B. Carter, and D. Mitlin, Nano Letters, In Press (2015).

TEM in situ lithiation of tin nanoneedles for battery applications, M. T. Janish, D. T. Mackay, Y. Liu, K. L. Jungjohann, C. B. Carter, M. G. Norton, *Journal of Materials Science*, In Press.

Lithium Electrodeposition Dynamics in Aprotic Electrolyte Observed In Situ via Transmission Electron Microscopy, A. J. Leenheer, K. L. Jungjohann, K. R. Zavadil, J. P. Sullivan, and C. T. Harris, *ACS Nano* **9**(4), 4379 (2015).

A Three-Dimensional Carbon Nano-Network for High Performance Lithium Ion Batteries, M. Tian, W. Wang, Y. Liu, K. L. Jungjohann, C. T. Harris, Y.-C. Lee, and R. Yang, *Nano Energy* **11**, 500 (2015).

In Situ Investigations of Li-MoS_2 with Planar Batteries, J. Wan, W. Bao, Y. Liu, J. Dai, F. Shen, L. Zhou, X. Cai, D. Urban, Y. Li, K. Jungjohann, M. S. Fuhrer, and L. Hu, *Advanced Energy Materials* **5**(5), 1401742 (2015).

In situ determination of the liquid/solid interface thickness and composition for the Li ion cathode LiMn1.5Ni0.5O4, J. F. Browning, L. Baggetto, K. L. Jungjohann, Y. Wang, W. E. Tenhaeff, J. K. Keum, D. L. Wood III, and G. M. Veith, *ACS Applied Materials & Interfaces* **6**(21), 18569 (2014).

Structural Evolution and Pulverization of Tin Nanoparticles during Lithiation-Delithiation Cycling, J. Wang, F. Fan, Y. Liu, K. L. Jungjohann, S. W. Lee, S. X. Mao, X. Liu, and T. Zhu, *Journal of Electrochemical Society* **161**(11), F3019 (2014).

Drying Effect Creates False Assemblies in DNA-Coated Gold Nanoparticles as Determined Through In Situ Liquid Cell STEM, A. R. Rudolph, K. L. Jungjohann, D. R. Wheeler, and S. M. Brozik, *Microscopy and Microanalysis* **20**(2), 437 (2014).

Template-free electrochemical synthesis of tin nanostructures, D. T. Macay, M. Y. Janish, U. Sahaym, P. G. Kotula, K. L. Jungjohann, C. B. Carter and M. G. Norton, *Journal of Material Science* **49**, 1476 (2014).

Awards and Synergistic Activities

Early Career Advisory Board Member for Nano Letters, 2015-2016
Organizing Committee of In Situ Electrochemical Electron Microscopy Workshop, 2014
Best Instrumentation/Software Development Paper in Microscopy and Microanalysis, 2012
Organizing Committee of the Frontiers of Electron Microscopy in Materials Science Meeting, 2011
Student Fellow of Frontiers of Electron Microscopy in Materials Science Meeting, 2011
Student Scholarship to the Winter School on High Resolution Electron Microscopy, 2011

Student Fellow of NSF Research Experience for Undergraduates SUNRISE Program, 2006

Collaborators (last 48 months)**:** P. Abellan (Pacific Northwest National Laboratory), J. Aguiar (National Renewable Energy Laboratory), I. Arslan (Pacific Northwest National Laboratory), S. Bliznakov (Brookhaven National Laboratory), J.F. Browning (Oak Ridge National Laboratory), C.B. Carter (University of Connecticut), P.-L. Chiu (Harvard Medical School), S.A. Dayeh (University of California San Diego), G. H. Dutrow (FEI Company), J. E. Evans (Pacific Northwest National Laboratory), Y. Liu (North Carolina State University), D. J. Masiel (Integrated Dynamic Electron Solutions), D. T. Mackay (Washington State University), S. Mao (University of Pittsburgh), D.J. Masiel (Integrated Dynamic Electron Solutions), J. McKeown (Lawrence Livermore National Laboratory), S. Mehraeen (University of California, Davis), D. Mitlin (Clarkson University), M.G. Norton (Washington State University), D. Nykypanchuk (Brookhaven National Laboratory), L. Parent (University of California, San Diego), B. Reed (Lawrence Livermore National Laboratory), W. D. Ristenpart (University of California, Davis), A.R. Rudolph (Washington State University), M. Santala (Lawrence Livermore National Laboratory), E. A. Stach (Brookhaven National Laboratory), E. A. Sutter (University of Nebraska), P. W. Sutter (University of Nebraska), G.M. Veith (Oak Ridge National Laboratory), C. Wang (University of Maryland), J. Wang (University of Pittsburgh), T. J. Woehl (National Institute of Standards and Technology), P. C. Wong (Molefarming Laboratory), H. Yang (Pacific Northwest National Laboratory), R.G. Yang (University of Colorado), T. Zhu (Georgia Institute of Technology)

Graduate Advisor: N. D. Browning, Pacific Northwest National Laboratory

Postdoctoral Advisor: Eli Sutter, Brookhaven National Laboratory

Postgraduate-Scholar Sponsor (Total: 1 postdoc): 2013-2014: Y. Liu, North Carolina State University

MICHAEL P. LILLY
Distinguished Member of Technical Staff
Center for Integrated Nanotechnologies, 01132
Sandia National Laboratories
Albuquerque, NM 87185-1303
Phone 505-844-4395
Fax 505-284-7778
E-mail mplilly@sandia.gov

Education

Undergraduate:	University of Illinois, Urbana-Champaign	Engineering Physics, B.S.	1991
Graduate:	University of Massachusetts, Amherst	Physics, PhD	1996

Professional Experience

Distinguished Member of Technical Staff, Sandia National Laboratories, 2012 – present
Principal Member of Technical Staff, Sandia National Laboratories, 2003 – 2011
Senior Member of Technical Staff, Sandia National Laboratories, 2000 – 2003
Postdoctoral Scholar, California Institute of Technology, Pasadena, CA, 1996 – 2000
Research Assistant, University of Massachusetts, Amherst, 1993 – 1996

Relevant Publications

Khoi. T. Nguyen, Michael. P. Lilly, Erik Nielsen, Nathan Bishop, Rajib Rahman, Ralph Young, Joel Wendt, Jason Dominguez, Tammy Pluym, Jeffery Stevens, Tzu-Ming Lu,Richard Muller, Malcolm. S. Carroll, *Charge sensed Pauli blockade in metal-oxide-semiconductor lateral double quantum dot*, Nanoletters 13, 5785 (2013).

Xujiao Gao, Erik Nielsen, Richard P. Muller, Ralph W. Young , Andrew G.Zalinger, Nathaniel Bishop, Michael Lilly and Malcolm S. Carroll, QCAD *Simulation and Optimization of Semiconductor Quantum Dots*, J. Appl. Phys. 114, 164302 (2013).

L. A. Tracy, T. M Lu, N. C. Bishop, G. A. Ten Eyck, T. Pluym, J. R. Wendt, M. P. Lilly, and M. S. Carroll, *Electron spin lifetime of a single antimony donor in silicon*, Appl. Phys. Lett. 103, 143115 (2013).

D. Laroche, G. Gervais, M. P. Lilly and J. L. Reno, *1D-1D Coulomb Drag Signature of a Luttinger Liquid*, Science 343, 631 (2014).

Gao, X, Mamaluy, D, Nielsen, E, Young, RW, Shirkhorshidian, A, Lilly, MP, Bishop, NC , Carroll, MS, and Muller, RP, *Efficient self-consistent quantum transport simulator for quantum devices*, J. Appl. Phys. Letters 115, 133707 (2014).

M. Rudolph, S. M. Carr, G. Subramania, G. Ten Eyck, J. Dominguez, T. Pluym, M. P. Lilly, M. S. Carroll, and E. Bussmann, *Probing limits of STM Field emission patterned Si:P -doped devices*, Applied Phys Lett. **105,** 163110 (2014).

Bussmann,Ezra ; Rudolph, Martin ; Subramania, Ganapathi Subramanian ; Misra, Shashank ; Carr, Stephen M; Langlois, Eric; Dominguez, Jason James; Ten Eyck, Gregory A.; Pluym, Tammy; Lilly, Michael; Carroll, Malcolm S., *Scanning capacitance microscopy registration of buried atomic-precision donor devices*, Nanotechnology **26**, 085701 (2014).

A. Shirkhorshidian, N. Bishop, J. Dominguez, J. Wendt, M. P. Lilly and M. S. Carroll, *"Transport spectroscopy of low disorder silicon tunnel barriers with and without Sb implants"*, accepted in Nanotechnology (2015).

J: Keyan Bennaceur, Benjamin A. Schmidt, Samuel Gaucher, Dominique Laroche, Michael P. Lilly, John L. Reno, Ken W. West, Loren N. Pfeiffer and Guillaume Gervais, "*Mechanical Flip-Chip for Ultra-High Electron Mobility Devices*", Scientific Reports 5, 13494 (2015).

M.J. Curry, T.D. England, N.C. Bishop, G. Ten-Eyck, J.R. Wendt, T. Pluym, M.P. Lilly, S.M. Carr, M.S. Carroll "*Cryogenic preamplification of a single-electron-transistor using a silicon-germanium heterojunction-bipolar-transistor*", Appl. Phys. Lett 106, 203505 (2015).

Awards and Synergistic Activities

2015 Co-chair of Joint APS/MRS/ACS Committee on Recycling Helium
2010 Panel reporting to NIST director on NIST nanoscience and fabrication capabilities
2009 National Academies Panel to review EEEL division at NIST
2008 Organizer of DMP Focus Session for the 2008 APS March meeting
2007 Program Committee Member, 17th International Conference on Electronic Properties of Two-Dimensional Systems (EP2DS-17) in Geneoa, Italy (July 2007)
2005 Co-Chair and Manuscript Editor for the 16th International Conference on Electronic Properties of Two-Dimensional Systems (EP2DS-16) in Albuquerque, NM (July 2005).
1993 – present, American Physical Society.
2015 - present, Materials Research society.

Collaborators: (last 48 months):
Malcolm Carroll (Sandia National Labs),
Ed Bielejec (Sandia National Labs),
Ezra Bussmann (Sandia National Labs),
Steve Lyon (Princeton),
Michel Pioro-Ladrarie (University of Sherbrooke),
Guillaume Gervais (McGill University),
Sankar Das Sarma (University of Maryland),
Joseph Orenstein (UC Berkeley / Lawrence Berkeley National Labs),

Graduate Advisor: Robert Hallock, University of Massachusetts
Postdoctoral Advisor: James Eisenstein, Caltech

Graduate Student and Postdoc Advisor:
Postdocs (7 total) in past 5 years:
Khoi Nguyen (2011-2014), Martin Rudolph (2013-2015), Meenakshi Singh (2013-present)
Graduate students (5 total) in past 5 years:
Dominique Laroche, McGill University (Ph. D., December 2014)

TAISUKE OHTA
Principal Member of Technical Staff
Nanosystems Synthesis/Analysis Department
Sandia National Laboratories
Albuquerque, NM 87185-1415

Phone 505-284-3167
Fax 505-844-5470
E-mail tohta@sandia.gov

Education

Undergraduate:	University of Tokyo, Japan	Mechanical Engineering, BE	1998
Graduate:	University of Washington,	Materials Science & Engineering, PhD	1992

Professional Experience

Principal Member of Technical Staff, Sandia National Laboratories, 2015 – present
Senior Member of Technical Staff, Sandia National Laboratories, 2012 –2015
Foreign national interim technical staff, Sandia National Laboratories, 2009 –2012
Limited term technical staff, Sandia National Laboratories, 2008 –2009
Max Planck Society postdoctoral fellow, Fritz Haber Institute (Germany) & Lawrence Berkeley National Laboratory, 2004-2007
Research Associate, University of Washington, 2001 – 2004
Research Associate, Swiss Federal Institute of Technology Lausanne (Switzerland), 1998 – 2001

Relevant Publications

Atomically Thin Heterostructures based on Single-Layer Tungsten Diselenide and Graphene, Y. C. Lin, C. Y. Chang, J. Li, R. Addou, R. K. Ghosh, B. Diaconescu, X. Peng, T. Ohta, N. Lu, M. J. Kim, J. T. Robinson, R. M, Wallace, T. S. Mayer, S. Datta, L. J. Li, J. A. Robinson, Nano Letters, 14, 6936 (2014).

Direct observation of grain boundary PN junction potentials in cigs using photoemission and low energy electron microscopy (PELEEM), C. K. Chan, T. Ohta, G.L. Kellogg, L. Mansfield, K. Ramanathan, R. Noufi, IEEE 40th Photovoltaic Specialist Conference (PVSC), 1908 (2014).

Facile Growth of Monolayer MoS2 Films on SiO2, J. Mann, D. Sun, Q. Ma, J.-R. Chen, E. Preciado, B. Diaconescu, T. Ohta, K. Yamaguchi, T. Tran, M. A. Wurch, K. Magnone, T. F. Heinz, G. L. Kellogg, R. Kawakami, L. Bartels, Eur. Phys. J. B, 86, 226 (2013).

Long-range atomic ordering and variable interlayer interactions in two overlapping graphene lattices with stacking misorientations, T. Ohta, T. E. Beechem, J. Robinson, G. L. Kellogg, Phys. Rev. B, 85, 075415 (2012).

Atmospheric pressure graphitization of SiC(0001) – A route towards wafer-size graphene layers, K. V. Emtsev, A. Bostwick, K. Horn, G. L. Kellogg, L. Ley, J. L. McChesney, T. Ohta, S. A. Reshanov, E. Rotenberg, A. K. Schmid, H. B. Weber, T. Seyller, Nature Materials, 8, 203 (2009).

Morphology of graphene thin film growth on SiC(0001), T. Ohta, F. El Gabaly, A. Bostwick, J. L. McChesney, K. V. Emtsev, A. Schmid, T. Seyller, K. Horn, E. Rotenberg, New J. Physics, 10, 023034 (2008).

Awards and synergistic Activities:

Program committee of the 10^{th} LEEM/PEEM Workshop, 2016
Program committee of the Novel 2D Materials Focus Topic, AVS, 2014 - 2015
WITec Paper Award, 2011

Collaborators: (last 48 months): Ludwig Bartels (UC Riverside), Thomas Beechem (Sandia National Laboratories), Aaron Bostwick (Advanced Light Source, Lawrence Berkeley National Laboratory), Calvin Chan (Sandia National Laboratories), Randall M. Feenstra (Carnegie Melon University), Chris Mann (Nanohmics, Inc), Aditya Mohite (Los Alamos National Laboratory), Rohit P. Prasankumar (Los Alamos National Laboratory), Jeremy T. Robinson (US Naval Research Laboratory), Joshua A. Robinson (Penn State University), Eli Rotenberg (Advanced Light Source, Lawrence Berkeley National Laboratory), Hisato Yamaguchi (Los Alamos National Laboratory)

Graduate Advisor: Prof. F. S. Ohuchi, University of Washington

Graduate Student and Postdoc Advisor: Past/current post-docs (current location): Morgann Berg (Sandia National Laboratories), C. Bogdan Diaconescu

JOHN L. RENO
Staff Scientist
Center for Integrated Nanotechnologies
Sandia National Laboratories
Albuquerque, NM 87185-1303

Phone: 505-844-9677
Fax: 505-284-7778
Email: jlreno@sandia.gov

Education
Ph.D. Physics, University of Illinois at Chicago, 1987
M.S. Physics, University of Illinois at Chicago, 1984
M.S. Applied Mathematics, Northern Illinois University, 1982
B.S. Physics & Mathematics, Wheaton College, 1978

Appointments
Principal Member of Technical Staff, Sandia National Laboratories, 2005 – Present
Senior Member of Technical Staff, Sandia National Laboratories, 1987 - 2005
Research Associate, University of Illinois at Chicago, January 1987 – July 1987

Selected Recent Publications

Fluegel. B., Mialitsin, A. V., Beaton, D. A., Reno, J. L., *Electronic Raman Scattering as an Ultra-Sensitive Probe of Strain Effects in Semiconductors*, Nature Communications, **6**, 7136, May 2015.

Kamaraju, N., Pan, W., Ekenberg, U., Gvozdic, D., Boubanga-Tombet, S., Upadhya, P. C., Reno, J. L., Taylor, A. J., Prasankumar, R. P., *Terahertz magneto-optical spectroscopy of two-dimensional hole and electron systems*, Applied Physics Letters, **106**, 3, 21 January 2015.

Zhang, Q., Arikawa, T., Kato, E., Reno. J. L., Pan. W., Watson, J. D., Manfra, M. J., Zudov, M. A., Tokman, M., Erukhimova, M., Belyanin, A., Kono, J., *Superradiant Decay of Cyclotron Resonance of Two-Dimensional Electron Gases*, Physical Review Letters **113**(4), July 21, 2014.

Tracy, L. A., Reno, J. L., Hargett, T., *Few-Hole Double Quantum Dot in an Undoped GaAs/AlGaAs Heterostructure*, Applied Physics Letters, **104** (12) 123101, March 24, 2014.

Macfaden, A. J., Reno, J. L., Brener, I., Mitrofanov, O., *3μm aperture probes for near-field terahertz transmission microscopy*, Applied Physics Letters,**104** (1) 011110, Jan. 6, 2014.

Lee, J., Han, J. E., Xiao, S., Song, J., Reno, J. L., Bird, J. P., *Formation of a protected sub-band for conduction in quantum point contacts under extreme biasing*, Nature Nanotechnology **9**(2), 101-105, Feb. 2014.

Larouche, D., Gervais, G., Lilly, M. P., Reno, J. L., *1D-1D Coulomb Drag Signature of a Luttinger Liquid*, Science **343**(6171), 631-634, Feb. 7, 2014.

Karl, N., Reichel, K., Chen, H.-T., Taylor, A. J., Brener, I., Benz, A., Reno, J. L., Mendis, R., Mittleman, D. M., *An Electrically Driven Terahertz Modulator with over 20 dB of Dynamic Range*, Applied Physics Letters,**104** (9) 091115, March 3, 2014.

Fransson, J., King, M. G., Yoon, Y., Xiao, S., Ochiai, Y., Reno, J. L., Aoki, N., Bird, J. P., *Tuning the Fano Resonance with an Intruder Continuum*, Nano Letters **14**(2), 788-793, February 2014.

Burghoff, D., Kao, T.Y., Han, N. R., Chan, C. W. I., Cai, X. W., Yang, Y., Hayton, D. L., Gao, J. R., Reno J. L., Hu, Q., *Terahertz laser frequency combs*, Nature Photonics **8**(6), 462-467, June 2014.

Synergistic Activities

<u>**Awards**</u>

Employee Recognition Award for Meritorious Achievement as Part of the Terahertz Plasmon Detector Team, 2005
Employee Recognition Award for Meritorious Achievement as Part of the Center for Integrated Technology Team, 2003
Employee Recognition Award for Individual Technical Excellence, 2002

Primary Collaborators: Albert Betz (University of Colorado at Boulder), Jonathan Bird (University at Buffalo), Russ Bowers (University of Florida), Brian Fluegel (National Renewable Energy Laboratory), Jian-Rong Gao (Delft

University of Technology), Guillaume Gervais (McGill University), David J. Hilton (The University of Alabama at Birmingham), Qing Hu (Massachusetts Institute of Technology), Denis Karaiskaj (University of South Florida), Junichiro Kono (Rice University), Sushil Kumar (Lehigh University), Alan Wei Min Lee (Massachusetts Institute of Technology), Mike J. Manfra (Purdue), Angelo Mascarenhas (National Renewable Energy Laboratory), Oleg Mitrofanov (University College London), Dmitry Smirnov (National High Magnetic Field Laboratory), Benjamin Williams (University of California at Los Angeles), Luyi Yang (University of California-Berkely), Michael Zudov (University of Minnesota)

Graduate Advisor: Dr. Jean-Pierre Faurie, LUMILOG, Vallauris, France

Graduate Student Mentor Advisor: John Watson (graduate student at Purdue University)

JINKYOUNG YOO

Technical Staff Member
Materials Physics and Applications Division
Mail Stop K771
Los Alamos, NM 87545

Phone: (505) 664-0209
Fax: (505) 665-9030
E-mail: jyoo@lanl.gov

Education

Undergraduate:	POSTECH	Materials Science & Engineering, B.S.	2003
Graduate:	POSTECH	Materials Science & Engineering, Ph.D.	2010

Appointments

06/2013 – Present	Technical Staff Member , MPA-CINT, LANL
11/2010 – 05/2013	Postdoctoral Research Associate, MPA-CINT, LANL

Publications

"Engineering Heteromaterials to Control Lithium Ion Transport Pathways", Yang Liu, Siarhei Vishniakou, Jinkyoung Yoo, Shadi A. Dayeh, Scientific Reports 5, 18482 (2015).

"Emission color-tuned light-emitting diode microarrays of nonpolar $In_xGa_{1-x}N/GaN$ multishell nanotube heterostructures", Young Joon Hong, Chul-Ho Lee, Jinkyoung Yoo, Yong-Jin Kim, Junseok Jeong, Miyoung Kim, Gyu-Chul Yi, Scientific Reports 5, 18020 (2015).

"Young's modulus of [111] germanium nanowires", M. Maksud, J. Yoo, C. T. Harris, N. K. R. Palapati, A. Subramanian, APL Materials 3, 116101 (2015. 11. 02).

"Si radial p-i-n junction arrays for photovoltaics with built-in light concentrators", Jinkyoung Yoo, Binh-Minh Nguyen, Ian H. Campbell, Shadi A. Dayeh, Paul Schuele, David Evans, S. T. Picraux, ACS Nano 9(5), 5154-5163 (2015). *Selected as a DOE BES highlight

"Size-dependent silicon epiaxy at mesoscale dimensions", Jinkyoung Yoo, Shadi A. Dayeh, Norman C. Bartelt, Wei Tang, S. T. Picraux, Alp T. Findikoglu, Nano Letters 14(11), 6121 (2014).

"In-situ transmission electron microscopy (TEM) study on the lithium ion transport in Si/Ge heterostructured nanowires", Y. Liu, X. H. Liu, B. M. Nguyen, J. Yoo, J. P. Sullivan, S. T. Picraux, S. A. Dayeh, Microscopy and Microanalysis 20(S3), 1534 (2014).

"Mapping electrostatic profiles across axial p-n junctions in Si nanowires using off-axis electron holography", Zhaofeng Gan, Daniel E. Perea, Jinkyoung Yoo, S. Tom Picraux, David J. Smith, and Martha R. McCartney, Applied Physics Letters 103 (15), 153108 (2013).

"Tailoring lithiation behavior by interface and bandgap engineering at the nanoscale", Yang Liu, Xiao-Hua Liu, Binh-Minh Nguyen, Jinkyoung Yoo, John Sullivan, S. Tom Picraux, Jian Yu Huang, Shadi A. Dayeh, Nano Letters 13(10), 4876-4883 (2013).

"Catalyst composition and impurity-dependent kinetics of nanowire heteroepitaxy", Andrew D. Gamalski, Daniel E. Perea, Jinkyoung Yoo, Nan Li, Matthew J. Olszta, Robert Colby, Daniel K. Schreiber, Caterina Ducati, S. Tom Picraux, Stephan Hofmann, ACS Nano 7(9), 7689-7697 (2013).

"Metal-lined semiconductor nanotubes for surface plasmon-mediated luminescence enhancement", Jinkyoung Yoo, Xuedan Ma, Wei Tang, and Gyu-Chul Yi, Nano Letters 13(5), 2134-2140 (2013).

"Ultrafast optical wide field microscopy", M. Seo, S. Boubanga-Tombet, J. Yoo, Z. Ku, A. V. Gin, S. T. Picraux, S. R. J. Brueck, A. J. Taylor, and R. P. Prasankumar, Optics Express 21(7), 8763-8772 (2013).

"Epitaxial radial growth of Si p-i-n junction arrays for photovoltaic applications", Jinkyoung Yoo, Shadi A. Dayeh, Wei Tang, S. T. Picraux, Applied Physics Letters 102(9), 093113 (2013).

"Orientation-dependent local structural properties of Zn1-xMgxO nanorods studied by extended X-ray absorption fine structure", E. S. Jeong, C. Park, Z. Jin, J. Yoo, G.-C. Yi, S. W. Han, Journal of Nanoscience and Nanotechnology 13(3), 1880-1883 (2013).

Synergistic Activities

Awards:

Achievement Award, MPA-CINT, 2011

Outstanding Poster Honorable Mention, Los Alamos Postdoc Research Day, 2011

Best Poster Award, Korean Physical Society Fall Meeting, 2008

Outstanding Presentation Award, Joint Symposium on Materials Science and Engineering for the 21st Century, Republic of China, 2007

Outstanding Poster Award, Materials Research Society Spring Meeting, San Francisco, 2006
Best Poster Award, Korean Physical Society Fall Meeting, 2005
Professional Societies: 10+ year member of Materials Research Society, 5+ year member of SPIE

Collaborators (Last 48 months): Albert Davydov (National Institute for Standards and Technology), Stephen Goodnick (Arizona State University), J. Cummings (University of Maryland), S. A. Dayeh (University of California San Diego), Diana Huffaker (University of California Los Angeles), M. McCartney (Arizona State University), D. E. Perea (Pacific Northwest National Laboratory), G. Rubloff (University of Maryland), P. Schuele (Sharp Laboratories of America), D. Smith (Arizona State University), A. Zaslavsky (Brown University), S. X. Zhang (Indiana University),

Graduate and Postdoctoral Advisors: Prof. Gyu-Chul Yi (Seoul National University); Dr. S. T. Picraux (Los Alamos National Laboratory, Laboratory Fellow)

Graduate Student and Postdoc Advisor (2 postdocs):
2012-2015: Yung-Chen Lin
2015-present: Dongheun Kim

Section 9.0 – Other support of Investigators and Collaborators

Investigator: Brian S. Swartzentruber (El-Kady)	Other Agencies to which this proposal has been /will be submitted: None
Support (Current, Pending, Submission Planned in Future or Transfer of Support): C	
Project / Proposal Title and grant number, if appropriate: Seebeck enhancement via Quantum confinement in MOSFET's: Towards monolithic on-chip cooling	
Source of Support: Sandia LDRD Location of Project: Sandia National Laboratories	
Annual Award Amount: $607 k Total Award Period Covered: 10/2013 to 09/2016	
Annual Award Amount to PI's Research: $75 K	
Person-Months Per Year Committed to Project: 3.0 Per. Months; Specify Cal., Acad., or Smr: C	
Describe research including synergies and/or overlaps with this Proposal/Award: *Project Scope*: To develop MOSFET-based cooling elements for on-chip cooling, and to measure Seebeck enhancement in SiGe nanowires. *Swartzentruber's role*: Electrical and thermal transport measurements of nanowires and temperature dependent measurements of MOSFET devices. *Synergies/Overlaps:* Transport measurements of the nanowires are accomplished using the scanning-probe based nanomanipulator embedded in a scanning electron microscope. The custom electronics and software development for this instrument enable improvements in the CINT User program.	

Investigator: Nathan A. Mara	Other Agencies to which this proposal has been /will be submitted: None
Support (Current, Pending, Submission Planned in Future or Transfer of Support):C	
Project / Proposal Title and grant number, if appropriate: Size and Interface Effects on Deformation Physics of Ultrafine-Scale Materials	
Source of Support: DOE/BES Location of Project: LANL	
Annual Award Amount: $460k Total Award Period Covered: 10/1/15-09/30/16	
Annual Award Amount to PI's Research: $125 K	
Person-Months Per Year Committed to Project: 1.0 Per. Months; Specify Cal., Acad., or Smr: C	
Describe research including synergies and/or overlaps with this Proposal/Award: *Project Scope*: This BES project centers on determining the structures at bi-phase metallic boundaries that optimize the interface's ability to suppress dislocation gliding or transmission across when exposed to mechanical deformation. *Synergies/Overlaps:* The measurements of the strength of these composites is carried out at CINT via an approved user project.	
Investigator: Nathan A. Mara	Other Agencies to which this proposal has been /will be submitted: None
Support (Current, Pending, Submission Planned in Future or Transfer of Support): C	

Project / Proposal Title and grant number, if appropriate: Determining the stress-strain response of irradiated metallic materials via spherical nanoindentation
Source of Support: DOE-NE Location of Project: LANL
Annual Award Amount: $333k Total Award Period Covered: 10/1/13-09/30/16
Annual Award Amount to PI's Research: $200 K
Person-Months Per Year Committed to Project: 1.0 Per. Months; Specify Cal., Acad., or Smr: C
Describe research including synergies and/or overlaps with this Proposal/Award: *Project Scope*: Mara is PI for this work. This project aims to develop new nanomechanical test protocols for measuring mechanical response of ion-irradiated materials. *Synergies/Overlaps:* The measurements are carried out at CINT via an approved user project.

Investigator: Nathan A. Mara	Other Agencies to which this proposal has been /will be submitted: None
Support (Current, Pending, Submission Planned in Future or Transfer of Support):C	
Project / Proposal Title and grant number, if appropriate: LANL Institute for Materials Science	
Source of Support: LANL Location of Project: LANL	
Annual Award Amount: $1M Total Award Period Covered: 10/1/15-09/30/16	
Annual Award Amount to PI's Research: $200 K	
Person-Months Per Year Committed to Project: 3.0 Per. Months; Specify Cal., Acad., or Smr: C	
Describe research including synergies and/or overlaps with this Proposal/Award: *Project Scope*: Mara is Deputy Director of this Center, which aims to serve as an external outlet to the materials community at large, as well as a unifying organization for the internal LANL materials community. *Synergies/Overlaps:* There is no overlap with the proposed work	

Investigator: C. Thomas Harris (Shaner)	Other Agencies to which this proposal has been /will be submitted: None
Support (Current, Pending, Submission Planned in Future or Transfer of Support):C	
Project / Proposal Title and grant number, if appropriate: Electron Spin Qubits on Liquid Helium	
Source of Support: Sandia LDRD Location of Project: Sandia National Laboratories	
Annual Award Amount: $500K Total Award Period Covered: 10/2015 to 10/2018	
Annual Award Amount to PI's Research: $80 K	

Person-Months Per Year Committed to Project: 3.0 Per. Months; Specify Cal., Acad., or Smr: C
Describe research including synergies and/or overlaps with this Proposal/Award: *Project Scope*: Fabricate devices for electron shuttling demonstrations and develop and verify single electron turnstiles, use Pauli blockade in gate defined quantum dots to readout electron spin. *Harris's role*: Team lead for electron-beam lithography and microfabrication at CINT. *Synergies/Overlaps:* This program will enable new device fabrication capabilities, testing, and instrumentation that will be offered to the CINT user community.

Investigator: C. Thomas Harris (WFO)	Other Agencies to which this proposal has been /will be submitted: None
Support (Current, Pending, Submission Planned in Future or Transfer of Support): C	
Project / Proposal Title and grant number, if appropriate: WFO	
Source of Support: Undisclosed Location of Project: Sandia National Laboratories	
Annual Award Amount: Undisclosed Total Award Period Covered: 08/2009 to 08/2014	
Annual Award Amount to PI's Research: $80 K	
Person-Months Per Year Committed to Project: 3.0 Per. Months; Specify Cal., Acad., or Smr: C	
Describe research including synergies and/or overlaps with this Proposal/Award: *Project Scope*: Undisclosed *Harris's role*: Cryogenic electronic property measurements. *Synergies/Overlaps:* The cryogenic testing capabilities developed in this work will be directly portable to the CINT User program.	

Investigator: Katherine Jungjohann	Other Agencies to which this proposal has been /will be submitted: None
Support (Current, Pending, Submission Planned in Future or Transfer of Support): C	
Project / Proposal Title and grant number, if appropriate: Novel MEM Enabled Nanofracking of Subsurface Minerals	
Source of Support: LDRD Location of Project: Sandia National Laboratories	
Annual Award Amount: $680k Total Award Period Covered: 11/2015 to 09/2018	
Annual Award Amount to PI's Research: $180k	
Person-Months Per Year Committed to Project: 1 Per. Months; Specify Cal., Acad., or Smr: C	
Describe research including synergies and/or overlaps with this Proposal/Award: *Project Scope*: Jungjohann leads the project on developing new instrumentation to study stress-corrosion-cracking within a TEM to determine the liquid-mechanical properties of fracture in shale minerals. Postdoc preforms experiments. *Synergies/Overlaps:* Developed technology of the liquid-mechanical TEM platform will be incorporated into the CINT User program.	

Investigator: Katherine L. Jungjohann (G. Crabtree)	Other Agencies to which this proposal has been/will be submitted: None
Support (Current, Pending, Submission Planned in Future or Transfer of Support): C	
Project/Proposal Title and grant number, if appropriate: Joint Center for Energy Storage Research (FWP #12-015730)	
Source of Support: DOE-BES	Location of Project: SNL
Annual Award Amount**:** $1.214M	Total Award Period Covered: 2013-2018
Annual Award Amount to PI's Research: $130K	
Person-Months Per Year Committed to Project: 4 Pers. Months; Specify Cal., Acad., or Smr: C	
Describe the delineation between this research and the work you will perform for JCESR: Jungjohann will investigate Li-S battery processes for energy storage using high resolution imaging and analytical techniques. Jungjohann performs assembly, structural, and compositional characterization for in situ electrochemistry within the TEM. This project does not have a unique interest in the use of nanostructured electrode materials.	

Investigator: Katherine L. Jungjohann (G. Rubloff)	Other Agencies to which this proposal has been/will be submitted: None
Support (Current, Pending, Submission Planned in Future or Transfer of Support): C	
Project/Proposal Title and grant number, if appropriate: Science of Precision Multifunctional Nanostructures for Electrical Energy Storage (FWP #12-014516)	
Source of Support**:** DOE-BES	Location of Project: SNL
Annual Award Amount: $860K	Total Award Period Covered: 2013-2014
Annual Award Amount to PI's Research: $170K	
Person-Months Per Year Committed to Project: 1 Pers. Months; Specify Cal., Acad., or Smr: C	
Describe the delineation between this research and the work you will perform for JCESR: Jungjohann and postdoc will investigate nanostructured arrays for Li-ion intercalation to the key degradation mechanisms using electrochemical in situ TEM. There is no duplication of JCESR work as this project's focus is directed towards nanostructured materials for Li-ion cells. Jungjohann and postdoc performs assembly and imaging for electrochemical TEM measurements.	

Investigator: Michael Lilly (Carroll)	Other Agencies to which this proposal has been /will be submitted: None
Support (Current, Pending, Submission Planned in Future or Transfer of Support):C	
Project / Proposal Title and grant number, if appropriate: Quantum Information Science and Technology	
Source of Support: work for others	Location of Project: Sandia National Laboratories

Annual Award Amount: Total Award Period Covered: 10/10 - present	
Annual Award Amount to PI's Research: $350 K	
Person-Months Per Year Committed to Project: 8 Per. Months; Specify Cal., Acad., or Smr: C	
Describe research including synergies and/or overlaps with this Proposal/Award: *Lilly's role*: Dr. Lilly is involved in the measurement and control single electron spin in silicon nanostructures. Dr. Lilly is involved in the measurement and control single electron spin in silicon nanostructures for single and two-qubit devices. *Synergies/Overlaps:* Low temperature measurement and some fabrication links to CINT through user projects.	
Investigator: Michael Lilly (Pan)	Other Agencies to which this proposal has been /will be submitted: None
Support (Current, Pending, Submission Planned in Future or Transfer of Support):C	
Project / Proposal Title and grant number, if appropriate: Quantum Electronic Phenomena and Structures, FWP Number 12-012951	
Source of Support: DOE/BES Location of Project: Sandia National Laboratories	
Annual Award Amount: $ 1,598K Total Award Period Covered: 4/2013 to present	
Annual Award Amount to PI's Research: $44 K	
Person-Months Per Year Committed to Project: 1.0 Per. Months; Specify Cal., Acad., or Smr: C	
Describe research including synergies and/or overlaps with this Proposal/Award: *Project Scope*: The focus of this project is to study the physics of novel quantum electronic phenomena, induced by strong electron-electron interactions and the interplay between electron and disorder interactions, in low dimensional quantum systems. *Lilly's role*: Investigate of 1D transport properties in double quantum wires, investigation of links between disorder and many-body effects in 1D and 2D systems. *Synergies/Overlaps:* This project uses high mobility GaAs heterostructures grown at CINT. Fabrication of GaAs and SiGe structures occurs at CINT. All related activities will link to CINT through user projects.	

Investigator: Taisuke Ohta (Peters)	Other Agencies to which this proposal has been /will be submitted: None
Support (Current, Pending, Submission Planned in Future or Transfer of Support):C	
Project / Proposal Title and grant number, if appropriate: Smart Sensor Technologies	
Source of Support: Sandia LDRD Location of Project: Sandia National Laboratories	
Annual Award Amount: $4.32 M Total Award Period Covered: 10/2015 to 09/2018	
Annual Award Amount to PI's Research: $86 K	
Person-Months Per Year Committed to Project: 2.1 Per. Months; Specify Cal., Acad., or Smr: C	
Describe research including synergies and/or overlaps with this Proposal/Award: *Project Scope*: Sandia OUO.	

Investigator: Taisuke Ohta (Allerman)	Other Agencies to which this proposal has been /will be submitted: None
Support (Current, Pending, Submission Planned in Future or Transfer of Support): C	
Project / Proposal Title and grant number, if appropriate: Beyond Graphene: BN-Based Semiconductor Alloys for Next-Generation Optoelectronics	
Source of Support: Sandia LDRD	Location of Project: Sandia National Laboratories
Annual Award Amount: $529 K	Total Award Period Covered: 10/2014 to 09/2017
Annual Award Amount to PI's Research: $57 K	
Person-Months Per Year Committed to Project: 1.7 Per. Months; Specify Cal., Acad., or Smr: C	
Describe research including synergies and/or overlaps with this Proposal/Award: *Project Scope*: Sandia OUO.	
Investigator: Taisuke Ohta (Beechem)	Other Agencies to which this proposal has been /will be submitted: None
Support (Current, Pending, Submission Planned in Future or Transfer of Support): C	
Project / Proposal Title and grant number, if appropriate: Harnessing Multiscale Periodicity of 2D-Crystals for Flexible Adaptable Broadband Optics	
Source of Support: Sandia LDRD	Location of Project: Sandia National Laboratories
Annual Award Amount: $500 K	Total Award Period Covered: 10/2013 to 09/2016
Annual Award Amount to PI's Research: $85 K	
Person-Months Per Year Committed to Project: 2.9 Per. Months; Specify Cal., Acad., or Smr: C	
Describe research including synergies and/or overlaps with this Proposal/Award: *Project Scope*: To develop hybrid 2D-crystals solid to realize improved and emerging optical responses by elucidating a framework under which the multiscale periodicity inherent in such solids can be leveraged systematically. *Ohta's role*: Microscopy studies of hybrid 2D-crystal solids using LEEM-PEEM. *Synergies/Overlaps:* Development of the measurement protocol for 2D crystals using LEEM-PEEM is directly portable to the application of the CINT User program.	

Investigator: John L. Reno (Pan)	Other Agencies to which this proposal has been /will be submitted: None
Support (Current, Pending, Submission Planned in Future or Transfer of Support):C	
Project / Proposal Title and grant number, if appropriate: Quantum Electronic Phenomena and Structures	
Source of Support: DOE/BES	Location of Project: Sandia National Laboratories

Annual Award Amount: $1.88M	Total Award Period Covered: 10/2010 to present
Annual Award Amount to PI's Research: $100 K	
Person-Months Per Year Committed to Project: 3.0 Per. Months; Specify Cal., Acad., or Smr: C	
Describe research including synergies and/or overlaps with this Proposal/Award: *Project Scope*: Explore the quantum electronic and optical properties in MBE/CVD grown and/or lithographically patterned nanoelectronic structures. The proposed research address the issues of what novel types of quantum collective behaviors can emerge from nanostructures and how well this behavior can be controlled and manipulated.. *Reno's role*: MBE growth of high mobility GaAs samples on which to perform the measurements. *Synergies/Overlaps:* High mobility GaAs samples are user in several proposals CINT User program.	
Investigator: John L. Reno (Hu)	Other Agencies to which this proposal has been /will be submitted: None
Support (Current, Pending, Submission Planned in Future or Transfer of Support): C	
Project / Proposal Title and grant number, if appropriate: Monolithic THz and LWIR QCL frequency combs for threat detection and identification	
Source of Support: DARPA	Location of Project: Sandia National Laboratories, MIT, Princeton, John Hopkins
Annual Award Amount: $1.27M	Total Award Period Covered: 6/2015 to 12/2018
Annual Award Amount to PI's Research: $175 K	
Person-Months Per Year Committed to Project: 3.0 Per. Months; Specify Cal., Acad., or Smr: C	
Describe research including synergies and/or overlaps with this Proposal/Award: *Project Scope*: This project is to develop monolithic, powerful and broadband frequency combs targeting two spectral ranges: the terahertz (THz) and long-wave infrared (LWIR) using quantum cascade lasers (QCL). *Reno's role*: MBE growth of samples on which QCLs are fabricated. *Synergies/Overlaps:* THz QCL samples are user in several proposals CINT User program. The growth of InAlAs/InGaAs structures provides a new capability for CINT users.	

Investigator: Jinkyoung Yoo	Other Agencies to which this proposal has been /will be submitted: None
Support (Current, Pending, Submission Planned in Future or Transfer of Support): C	
Project / Proposal Title and grant number, if appropriate: Controlling the Electronic Structure of Emerging Atomically Thin Materials Through Heterostructuring	
Source of Support: LDRD	Location of Project: Los Alamos National Laboratory
Annual Award Amount: $225K	Total Award Period Covered: 1/2015 – 1/2017
Annual Award Amount to PI's Research: $225 K	
Person-Months Per Year Committed to Project: 3.6 Per. Months; Specify Cal., Acad., or Smr: C	
Describe research including synergies and/or overlaps with this Proposal/Award: (This program) *Project Scope*: Prepare and characterize semiconductor (Si, Ge, InAs) thin films and nanostructures on atomically thin two-dimensional materials.	

Yoo's role: Serve as PI and conduct materials synthesis and device fabrications. *Synergies/Overlaps:* Conventional semiconductor nanostructures are prepared on another form of nanomaterials (2D materials such as graphene, h-BN, monolayer TMDCs). The knowledge about the hybrid materials preparation and characteristics of the heterostructures learned from this project will help to develop new CINT User programs.

10.0 Budget and Budget Explanation

DOE F 4620.1 (04-93) *All Other Editions Are Obsolete*	**U.S. Department of Energy** **Budget Page** (See reverse for Instructions)	OMB Control No. 1910-1400 OMB Burden Disclosure Statement on Reverse

ORGANIZATION Sandia National Laboratories	**Budget Page No:**	1
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR Swartzentruber, Brian (NEM Thrust Leader)	Requested Duration:	12 (FY16) (Months)

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title; A.6. show number in brackets)	DOE Funded Person-mos. CAL	ACAD	SUMR	Funds Requested by Applpicant	Funds Granted by DOE
1. Swartzentruber, Brian (.75 FTE)	9.00			124,547.00	
2. Harris, Charles Thomas (.5 FTE)	6.00			61,491.00	
3. Jungjohann, Katherine (.5 FTE)	6.00			61,491.00	
4. Lilly, Michael (.5 FTE)	6.00			91,767.00	
5. Ohta, Taisuke (.5 FTE)	6.00			67,966.00	
6. (2) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)	18.00			211,051.00	
7. (7) TOTAL SENIOR PERSONNEL (1-6)	51.00			618,313.00	0.00
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (1) POST DOCTORAL ASSOCIATES	12.00			91,083.00	
2. (7) OTHER PROFESSIONAL (TECHNICIAN, PROGRAMMER, ETC.)	84.00			668,297.00	
3. ( ) GRADUATE STUDENTS					
4. ( ) UNDERGRADUATE STUDENTS					
5. ( ) SECRETARIAL - CLERICAL					
6. ( ) OTHER					
TOTAL SALARIES AND WAGES (A+B)				1,377,693.00	0.00
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				502,858.00	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)				1,880,551.00	0.00
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM.)					
TOTAL PERMANENT EQUIPMENT					
E. TRAVEL 1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)					
2. FOREIGN					
TOTAL TRAVEL				0.00	0.00
F. TRAINEE/PARTICIPANT COSTS					
1. STIPENDS (Itemize levels, types + totals on budget justification page)					
2. TUITION & FEES					
3. TRAINEE TRAVEL					
4. OTHER (fully explain on justification page)					
TOTAL PARTICIPANTS ( ) TOTAL COST				0.00	0.00
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				655,309.00	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION					
3. CONSULTANT SERVICES					
4. COMPUTER (ADPE) SERVICES					
5. SUBCONTRACTS					
6. OTHER				666,868.00	
TOTAL OTHER DIRECT COSTS				1,322,177.00	0.00
H. TOTAL DIRECT COSTS (A THROUGH G)				3,202,728.00	0.00
I. INDIRECT COSTS (SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS				2,133,430.00	
J. TOTAL DIRECT AND INDIRECT COSTS (H+I)				5,336,158.00	0.00
K. AMOUNT OF ANY REQUIRED COST SHARING FROM NON-FEDERAL SOURCES					
L. TOTAL COST OF PROJECT (J+K)				5,336,158.00	0.00

DOE F 4620.1
(04-93)
All Other Editions Are Obsolete

U.S. Department of Energy

Budget Page

(See reverse for Instructions)

OMB Control No.
1910-1400
OMB Burden Disclosure
Statement on Reverse

ORGANIZATION Sandia National Laboratories				**Budget Page No:** 2	
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR Swartzentruber, Brian (NEM Thrust Leader)				Requested Duration: 12 (FY17) (Months)	
A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title; A.6. show number in brackets)	DOE Funded Person-mos. CAL	ACAD	SUMR	Funds Requested by Applpicant	Funds Granted by DOE
1. Swartzentruber, Brian (.75 FTE)	9.00			127,774.00	
2. Harris, Charles Thomas (.5 FTE)	6.00			63,088.00	
3. Jungjohann, Katherine (.5 FTE)	6.00			63,088.00	
4. Lilly, Michael (.5 FTE)	6.00			94,149.00	
5. Ohta, Taisuke (.5 FTE)	6.00			69,729.00	
6. (2) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)	18.00			216,527.00	
7. (7) TOTAL SENIOR PERSONNEL (1-6)	51.00			634,355.00	0.00
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (1) POST DOCTORAL ASSOCIATES	12.00			93,448.00	
2. (7) OTHER PROFESSIONAL (TECHNICIAN, PROGRAMMER, ETC.)	84.00			675,404.00	
3. ( ) GRADUATE STUDENTS					
4. ( ) UNDERGRADUATE STUDENTS					
5. ( ) SECRETARIAL - CLERICAL					
6. ( ) OTHER					
TOTAL SALARIES AND WAGES (A+B)				1,403,207.00	0.00
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				512,170.00	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)				1,915,377.00	0.00
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM.)					
TOTAL PERMANENT EQUIPMENT					
E. TRAVEL 1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)					
2. FOREIGN					
TOTAL TRAVEL				0.00	0.00
F. TRAINEE/PARTICIPANT COSTS					
1. STIPENDS (Itemize levels, types + totals on budget justification page)					
2. TUITION & FEES					
3. TRAINEE TRAVEL					
4. OTHER (fully explain on justification page)					
TOTAL PARTICIPANTS ( ) TOTAL COST				0.00	0.00
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				666,585.00	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION					
3. CONSULTANT SERVICES					
4. COMPUTER (ADPE) SERVICES					
5. SUBCONTRACTS					
6. OTHER				678,343.00	
TOTAL OTHER DIRECT COSTS				1,344,928.00	0.00
H. TOTAL DIRECT COSTS (A THROUGH G)				3,260,305.00	0.00
I. INDIRECT COSTS (SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS				2,199,430.00	
J. TOTAL DIRECT AND INDIRECT COSTS (H+I)				5,459,735.00	0.00
K. AMOUNT OF ANY REQUIRED COST SHARING FROM NON-FEDERAL SOURCES					
L. TOTAL COST OF PROJECT (J+K)				5,459,735.00	0.00

DOE F 4620.1	U.S. Department of Energy	OMB Control No.
(04-93)	**Budget Page**	1910-1400
All Other Editions Are Obsolete	(See reverse for Instructions)	OMB Burden Disclosure Statement on Reverse

ORGANIZATION Sandia National Laboratories	Budget Page No: 3
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR Swartzentruber, Brian (NEM Thrust Leader)	Requested Duration: 12 (FY18) (Months)

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title; A.6. show number in brackets)	DOE Funded Person-mos. CAL	ACAD	SUMR	Funds Requested by Applpicant	Funds Granted by DOE
1. Swartzentruber, Brian (.75 FTE)	9.00			132,020.00	
2. Harris, Charles Thomas (.5 FTE)	6.00			65,185.00	
3. Jungjohann, Katherine (.5 FTE)	6.00			65,185.00	
4. Lilly, Michael (.5 FTE)	6.00			97,278.00	
5. Ohta, Taisuke (.5 FTE)	6.00			72,046.00	
6. (2) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)	18.00			223,723.00	
7. (7) TOTAL SENIOR PERSONNEL (1-6)	51.00			655,437.00	0.00
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (1) POST DOCTORAL ASSOCIATES	12.00			96,553.00	
2. (7) OTHER PROFESSIONAL (TECHNICIAN, PROGRAMMER, ETC.)	84.00			690,398.00	
3. ( ) GRADUATE STUDENTS					
4. ( ) UNDERGRADUATE STUDENTS					
5. ( ) SECRETARIAL - CLERICAL					
6. ( ) OTHER					
TOTAL SALARIES AND WAGES (A+B)				1,442,388.00	0.00
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				526,472.00	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)				1,968,860.00	0.00
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM.)					
TOTAL PERMANENT EQUIPMENT					
E. TRAVEL 1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)					
2. FOREIGN					
TOTAL TRAVEL				0.00	0.00
F. TRAINEE/PARTICIPANT COSTS					
1. STIPENDS (Itemize levels, types + totals on budget justification page)					
2. TUITION & FEES					
3. TRAINEE TRAVEL					
4. OTHER (fully explain on justification page)					
TOTAL PARTICIPANTS ( ) TOTAL COST				0.00	0.00
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				679,338.00	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION					
3. CONSULTANT SERVICES					
4. COMPUTER (ADPE) SERVICES					
5. SUBCONTRACTS					
6. OTHER				691,321.00	
TOTAL OTHER DIRECT COSTS				1,370,659.00	0.00
H. TOTAL DIRECT COSTS (A THROUGH G)				3,339,519.00	0.00
I. INDIRECT COSTS (SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS				2,274,391.00	
J. TOTAL DIRECT AND INDIRECT COSTS (H+I)				5,613,910.00	0.00
K. AMOUNT OF ANY REQUIRED COST SHARING FROM NON-FEDERAL SOURCES					
L. TOTAL COST OF PROJECT (J+K)				5,613,910.00	0.00

DOE F 4620.1 (04-93) All Other Editions Are Obsolete	**U.S. Department of Energy** **Budget Page** (See reverse for Instructions)	OMB Control No. 1910-1400 OMB Burden Disclosure Statement on Reverse

ORGANIZATION Sandia National Laboratories				Budget Page No: 4	
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR Swartzentruber, Brian (NEM Thrust Leader)				Requested Duration: 36 (FY16-18) (Months)	
A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title; A.6. show number in brackets)	DOE Funded Person-mos. CAL	ACAD	SUMR	Funds Requested by Applpicant	Funds Granted by DOE
1. Swartzentruber, Brian (.75 FTE)	27.00			384,343.00	
2. Harris, Charles Thomas (.5 FTE)	18.00			189,763.00	
3. Jungjohann, Katherine (.5 FTE)	18.00			189,763.00	
4. Lilly, Michael (.5 FTE)	18.00			283,195.00	
5. Ohta, Taisuke (.5 FTE)	18.00			209,741.00	
6. (2) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)	54.00			651,302.00	
7. (7) TOTAL SENIOR PERSONNEL (1-6)	153.00			1,908,107.00	0.00
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (1) POST DOCTORAL ASSOCIATES	36.00			281,084.00	
2. (7) OTHER PROFESSIONAL (TECHNICIAN, PROGRAMMER, ETC.)	252.00			2,034,097.00	
3. ( ) GRADUATE STUDENTS					
4. ( ) UNDERGRADUATE STUDENTS					
5. ( ) SECRETARIAL - CLERICAL					
6. ( ) OTHER					
TOTAL SALARIES AND WAGES (A+B)				4,223,288.00	0.00
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				1,541,500.00	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)				5,764,788.00	0.00
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM.)					
TOTAL PERMANENT EQUIPMENT					
E. TRAVEL 1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)					
2. FOREIGN					
TOTAL TRAVEL				0.00	0.00
F. TRAINEE/PARTICIPANT COSTS					
1. STIPENDS (Itemize levels, types + totals on budget justification page)					
2. TUITION & FEES					
3. TRAINEE TRAVEL					
4. OTHER (fully explain on justification page)					
TOTAL PARTICIPANTS ( ) TOTAL COST				0.00	0.00
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				2,001,232.00	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION					
3. CONSULTANT SERVICES					
4. COMPUTER (ADPE) SERVICES					
5. SUBCONTRACTS					
6. OTHER				2,036,532.00	
TOTAL OTHER DIRECT COSTS				4,037,764.00	0.00
H. TOTAL DIRECT COSTS (A THROUGH G)				9,802,552.00	0.00
I. INDIRECT COSTS (SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS				6,607,251.00	
J. TOTAL DIRECT AND INDIRECT COSTS (H+I)				16,409,803.00	0.00
K. AMOUNT OF ANY REQUIRED COST SHARING FROM NON-FEDERAL SOURCES					
L. TOTAL COST OF PROJECT (J+K)				16,409,803.00	0.00

DOE F 4620.1
(04-93)
All Other Editions Are Obsolete

U.S. Department of Energy

Budget Page

(See reverse for Instructions)

OMB Control No.
1910-1400
OMB Burden Disclosure
Statement on Reverse

ORGANIZATION: Los Alamos National Laboratory				Budget Page No: 1	
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR: Brian Swartzentruber (NEM Thrust Leader)				Requested Duration: 12 (FY16) (Months)	
A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title; A.6. show number in brackets)	DOE Funded Person-mos. CAL	ACAD	SUMR	Funds Requested by Applicant	Funds Granted by DOE
1. Mara, Nathan (0.60FTE)	7.20			$90,545	
2. Yoo, Jinkyoung (0.50FTE)	6.00			$59,979	
3. TBD (0.50FTE)	6.00			$59,979	
4. TBD (0.50FTE)	6.00			$82,784	
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)					
7. (4) TOTAL SENIOR PERSONNEL (1-6)	25.20			$293,288	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (1) POST DOCTORAL ASSOCIATES	12.00			$76,911	
2. (3) OTHER PROFESSIONAL (TECHNICIAN, PROGRAMMER, ETC.)	36.00				
3. ( ) GRADUATE STUDENTS					
4. ( ) UNDERGRADUATE STUDENTS					
5. ( ) SECRETARIAL - CLERICAL					
6. ( ) OTHER					
TOTAL SALARIES AND WAGES (A+B)				$370,199	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				$635,101	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)				$1,005,300	
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM.)					
TOTAL PERMANENT EQUIPMENT					
E. TRAVEL 1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)					
2. FOREIGN					
TOTAL TRAVEL					
F. TRAINEE/PARTICIPANT COSTS					
1. STIPENDS (Itemize levels, types + totals on budget justification page)					
2. TUITION & FEES					
3. TRAINEE TRAVEL					
4. OTHER (fully explain on justification page)					
TOTAL PARTICIPANTS ( ) TOTAL COST					
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				$225,000	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION					
3. CONSULTANT SERVICES					
4. COMPUTER (ADPE) SERVICES					
5. SUBCONTRACTS- University contract					
6. OTHER					
TOTAL OTHER DIRECT COSTS				$225,000	
H. TOTAL DIRECT COSTS (A THROUGH G)				$1,230,300	
I. INDIRECT COSTS (SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS				$1,272,737	
J. TOTAL DIRECT AND INDIRECT COSTS (H+I)				$2,503,037	
K. AMOUNT OF ANY REQUIRED COST SHARING FROM NON-FEDERAL SOURCES					
L. TOTAL COST OF PROJECT (J+K)				$2,503,037	

DOE F 4620.1
(04-93)
All Other Editions Are Obsolete

U.S. Department of Energy
Budget Page
(See reverse for Instructions)

OMB Control No.
1910-1400
OMB Burden Disclosure
Statement on Reverse

ORGANIZATION Los Alamos National Laboratory				Budget Page No: 2	
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR Brian Swartzentruber (NEM Thrust Leader)				Requested Duration: 12 (FY17) (Months)	
A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title; A.6. show number in brackets)	DOE Funded Person-mos.			Funds Requested by Applicant	Funds Granted by DOE
	CAL	ACAD	SUMR		
1. Mara, Nathan (0.60FTE)	7.20			$93,261	
2. Yoo, Jinkyoung (0.50FTE)	6.00			$61,779	
3. TBD (0.50FTE)	6.00			$61,779	
4. TBD (0.50FTE)	6.00			$85,268	
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)					
7. (4) TOTAL SENIOR PERSONNEL (1-6)	25.20			$302,087	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (1) POST DOCTORAL ASSOCIATES	12.00			$79,219	
2. (3) OTHER PROFESSIONAL (TECHNICIAN, PROGRAMMER, ETC.)	36.00			$339,197	
3. ( ) GRADUATE STUDENTS					
4. ( ) UNDERGRADUATE STUDENTS					
5. ( ) SECRETARIAL - CLERICAL					
6. ( ) OTHER					
TOTAL SALARIES AND WAGES (A+B)				$720,502	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				$314,956	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)				$1,035,458	
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM.)					
TOTAL PERMANENT EQUIPMENT					
E. TRAVEL 1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)					
2. FOREIGN					
TOTAL TRAVEL					
F. TRAINEE/PARTICIPANT COSTS					
1. STIPENDS (Itemize levels, types + totals on budget justification page)					
2. TUITION & FEES					
3. TRAINEE TRAVEL					
4. OTHER (fully explain on justification page)					
TOTAL PARTICIPANTS ( ) TOTAL COST					
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				$250,000	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION					
3. CONSULTANT SERVICES					
4. COMPUTER (ADPE) SERVICES					
5. SUBCONTRACTS- University Contract					
6. OTHER					
TOTAL OTHER DIRECT COSTS				$250,000	
H. TOTAL DIRECT COSTS (A THROUGH G)				$1,285,458	
I. INDIRECT COSTS (SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS				$1,315,401	
J. TOTAL DIRECT AND INDIRECT COSTS (H+I)				$2,600,859	
K. AMOUNT OF ANY REQUIRED COST SHARING FROM NON-FEDERAL SOURCES					
L. TOTAL COST OF PROJECT (J+K)				$2,600,859	

DOE F 4620.1 (04-93) *All Other Editions Are Obsolete*	**U.S. Department of Energy** **Budget Page** (See reverse for Instructions)	OMB Control No. 1910-1400 OMB Burden Disclosure Statement on Reverse

ORGANIZATION Los Alamos National Laboratory				Budget Page No: 3	
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR Brian Swartzentruber (NEM Thrust Leader)				Requested Duration: 12 (FY18) (Months)	
A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title; A.6. show number in brackets)	DOE Funded Person-mos. CAL	ACAD	SUMR	Funds Requested by Applicant	Funds Granted by DOE
1. Mara, Nathan (0.60FTE)	7.20			$96,059	
2. Yoo, Jinkyoung (0.50FTE)	6.00			$63,632	
3. TBD (0.50FTE)	6.00			$63,632	
4. TBD (0.50FTE)	6.00			$87,826	
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)					
7. (4) TOTAL SENIOR PERSONNEL (1-6)	25.20			$311,150	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (1) POST DOCTORAL ASSOCIATES	12.00			$81,595	
2. (3) OTHER PROFESSIONAL (TECHNICIAN, PROGRAMMER, ETC.)	36.00			$349,374	
3. ( ) GRADUATE STUDENTS					
4. ( ) UNDERGRADUATE STUDENTS					
5. ( ) SECRETARIAL - CLERICAL					
6. ( ) OTHER					
TOTAL SALARIES AND WAGES (A+B)				$742,119	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				$324,405	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)				$1,066,524	
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM.)					
TOTAL PERMANENT EQUIPMENT					
E. TRAVEL 1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)					
2. FOREIGN					
TOTAL TRAVEL					
F. TRAINEE/PARTICIPANT COSTS					
1. STIPENDS (Itemize levels, types + totals on budget justification page)					
2. TUITION & FEES					
3. TRAINEE TRAVEL					
4. OTHER (fully explain on justification page)					
TOTAL PARTICIPANTS ( ) TOTAL COST					
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				$275,000	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION					
3. CONSULTANT SERVICES					
4. COMPUTER (ADPE) SERVICES					
5. SUBCONTRACTS- University Contract					
6. OTHER					
TOTAL OTHER DIRECT COSTS				$275,000	
H. TOTAL DIRECT COSTS (A THROUGH G)				$1,341,524	
I. INDIRECT COSTS (SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS				$1,359,158	
J. TOTAL DIRECT AND INDIRECT COSTS (H+I)				$2,700,682	
K. AMOUNT OF ANY REQUIRED COST SHARING FROM NON-FEDERAL SOURCES					
L. TOTAL COST OF PROJECT (J+K)				$2,700,682	

DOE F 4620.1
(04-93)
All Other Editions Are Obsolete

U.S. Department of Energy

Budget Page

(See reverse for Instructions)

OMB Control No.
1910-1400
OMB Burden Disclosure
Statement on Reverse

ORGANIZATION				Budget Page No:	4
Los Alamos National Laboratory					
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR				Requested Duration:	36 (FY16-18) (Months)
Brian Swartzentruber (NEM Thrust Leader)					

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title; A.6. show number in brackets)	DOE Funded Person-mos. CAL	ACAD	SUMR	Funds Requested by Applicant	Funds Granted by DOE
1. Mara, Nathan (0.60FTE)	21.60			$279,865	
2. Yoo, Jinkyoung (0.50FTE)	18.00			$185,390	
3. TBD (0.50FTE)	18.00			$185,390	
4. TBD (0.50FTE)	18.00			$255,878	
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)					
7. (4) TOTAL SENIOR PERSONNEL (1-6)	75.60			$906,524	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (1) POST DOCTORAL ASSOCIATES	36.00			$237,725	
2. (3) OTHER PROFESSIONAL (TECHNICIAN, PROGRAMMER, ETC.)	108.00			$688,571	
3. ( ) GRADUATE STUDENTS					
4. ( ) UNDERGRADUATE STUDENTS					
5. ( ) SECRETARIAL - CLERICAL					
6. ( ) OTHER					
TOTAL SALARIES AND WAGES (A+B)				$1,832,821	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				$1,274,461	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)				$3,107,282	
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM)					
TOTAL PERMANENT EQUIPMENT					
E. TRAVEL 1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)					
2. FOREIGN					
TOTAL TRAVEL					
F. TRAINEE/PARTICIPANT COSTS					
1. STIPENDS (Itemize levels, types + totals on budget justification page)					
2. TUITION & FEES					
3. TRAINEE TRAVEL					
4. OTHER (fully explain on justification page)					
TOTAL PARTICIPANTS ( ) TOTAL COST					
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				$750,000	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION					
3. CONSULTANT SERVICES					
4. COMPUTER (ADPE) SERVICES					
5. SUBCONTRACTS					
6. OTHER					
TOTAL OTHER DIRECT COSTS				$750,000	
H. TOTAL DIRECT COSTS (A THROUGH G)				$3,857,282	
I. INDIRECT COSTS (SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS				$3,947,296	
J. TOTAL DIRECT AND INDIRECT COSTS (H+I)				$7,804,578	
K. AMOUNT OF ANY REQUIRED COST SHARING FROM NON-FEDERAL SOURCES					
L. TOTAL COST OF PROJECT (J+K)				$7,804,578	

A. Budget Explanation

A. Senior Personnel

Tom Harris – (CINT Scientist) Provides support for approved CINT user projects and conducts independent research in support of CINT internal science program.

Katherine Jungjohann - (CINT Scientist) Provides support for approved CINT user projects and conducts independent research in support of CINT internal science program.

Mike Lilly - (CINT Scientist) Provides support for approved CINT user projects and conducts independent research in support of CINT internal science program.

Nathan Mara – (NEM Partner Science Leader) Provides scientific leadership for Thrust, provides support for approved CINT user projects and conducts independent research in support of CINT internal science program.

John Nogan – (Integration Lab Lead) Provides oversight and direction for Integration Lab activities in support of CINT user program.

Taisuke Ohta - (CINT Scientist) Provides support for approved CINT user projects and conducts independent research in support of CINT internal science program.

John Reno - (CINT Scientist) Provides support for approved CINT user projects and conducts independent research in support of CINT internal science program.

Brian Swartzentruber – (NEM Thrust Leader) Provides scientific leadership for Thrust, provides support for approved CINT user projects and conducts independent research in support of CINT internal science program.

Jinkyoung Yoo – (CINT Scientist) Provides support for approved CINT user projects and conducts independent research in support of CINT internal science program.

TBD – (CINT Scientist) Provides support for approved CINT user projects and conducts independent research in support of CINT internal science program.

TBD – (CINT Scientist) Provides support for approved CINT user projects and conducts independent research in support of CINT internal science program.

B. Other Personnel

1. Postdoctoral Associates – Conduct research in support of CINT internal science program and work with users as appropriate to support user projects.

2. Other Professional – Research technologists supporting laboratory operations, instrumentation usage, and Integration Lab support

C. Other Direct Costs

1. Materials and Supplies – Laboratory supplies to support CINT Thrust user projects and internal science efforts; Thrust staff travel costs; publication costs.

6. Other (Service Contracts) – Direct costs to provide service and maintenance for the TEM, MBE Lab, Integration Lab, and LEEM

11.0 Description of Facilities and Resources

Key components of the NEM Thrust's scientific strengths are facilities and capabilities. Unique tools in this thrust include: molecular beam epitaxy (MBE) to grow semiconductor heterostructures for producing ultra-clean low-dimensional electron and hole systems; laser MBE to synthesize complex metal oxide films for multifunctionalities; a high current state-of-the-art ion implanter; new tools for nanomanipulation and for *in situ* STM/TEM experiments; and specialized growth techniques for films, nanowires, and other nanostructures.

Additional techniques and tools that are part of this thrust that enable CINT to integrate science and user projects include: pulsed laser deposition systems; magnetron sputtering chambers; an E-beam evaporator; a chemical vapor deposition (CVD) nanowire growth reactor; a transmission electron microscope (TEM); nano-indenters; a sub-nm point-to-point resolution scanning electron microscope (SEM); an environmental field-emission SEM; a focused ion beam (FIB) system; a top loading dilution refrigerator and superconducting magnet; an atomic force microscope (AFM); a high cycle fatigue tester; and a laser strain measurement tool.

In addition, the CINT Integration Lab is a fabrication resource with 9000 ft^2 of class 1000 cleanroom space containing the following equipment: an electron beam writer; two field-emission SEMs for e-beam writing (one with FIB capability), a photolithography mask aligner; a reactive ion etch tool; an electron beam evaporator tool; an inductively coupled plasma chemical vapor deposition (ICP-CVD) system; a rapid thermal annealer; a profilometer; wafer processing tools; cleanroom benches (Solvent, Acid, Base); and an inductively coupled plasma reactive ion etch (ICP-RIE) tool.

The fabrication capabilities at CINT are complemented by a significant fabrication infrastructure at SNL. The Microsystems and Engineering Sciences Applications (MESA) facility is a cleanroom complex at Sandia that houses both a traditional silicon facility and a compound semiconductor processing facility. The silicon fab can produce a wide range of complementary metal-oxide semiconductor (CMOS) devices, micro-electro-mechanical (MEMs) structures with multiple independently moving layers and photonic devices. The compound semiconductor facility has a wide range of tools for semiconductor growth, oxide deposition, photo and electron beam lithography, etching, and metals deposition. In addition to the processing tools, there is a full suite of characterization and back-end-of-the-line tools. These capabilities have been critical to our Discovery Platform development.