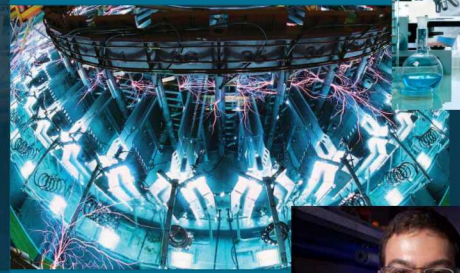
Sandia National Laboratories Information Session

SAND2020-0871PE



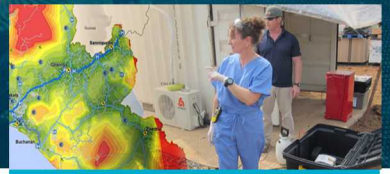
World-changing technologies.

Life-changing careers.

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC., a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA-0003525. SAND2019-9643 HR 08/2019

Sandia's Impact

Sandia is often called upon to respond to high-profile events, including 9/11 and the Ebola outbreak.



Ebola Outbreak

Sandia contributes to global response of Ebola outbreak by developing a sample delivery system cutting the wait time and potentially fatal exposure.

Cleanroom invented 1963

$50 billion worth of cleanrooms built worldwide. They're used in hospitals, laboratories and manufacturing plants today.

9/11

Sandia sets contingency plans for release of materials and aircraft attacks on critical facilities immediately after 9/11. Search dogs are equipped with cameras for search and rescue K-9 handlers. The capability allowed search efforts to be carried out in spaces inaccessible to humans.

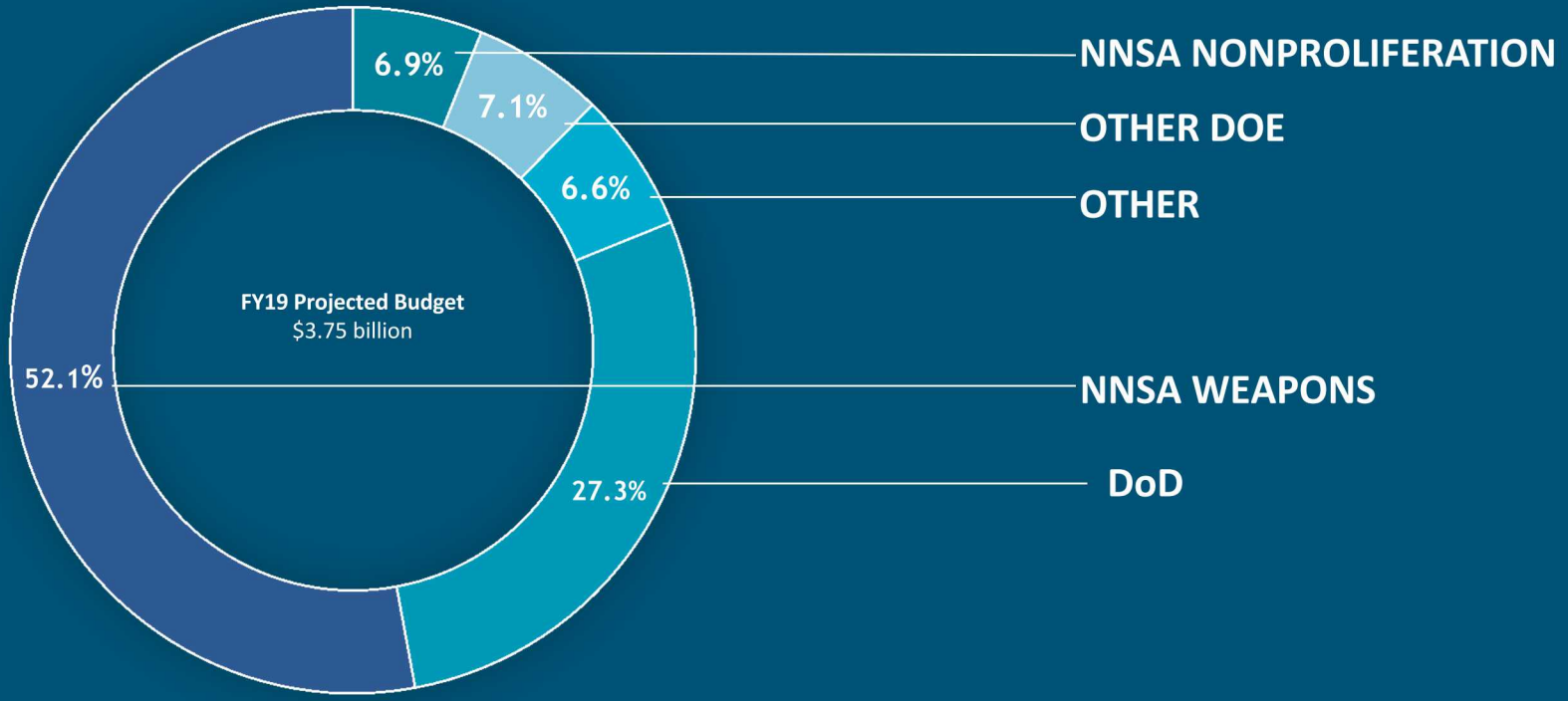
Detecting IEDs

Combat personnel now have a new tool for uncovering improvised explosive devices: Sandia's highly modified miniature synthetic aperture radar system, which is being transferred to the U.S. Army.

U.S. National Laboratories

Sandia Has Two Main Locations

Sandia's Funding ~ $3.75 Billion



FY19 Projected Funding

Fulfilling Our National Security Mission

Nuclear Deterrence

Defense Nuclear Nonproliferation

National Security Programs

Energy & Homeland Security

Advanced Science & Technology

We [illegible] of life.

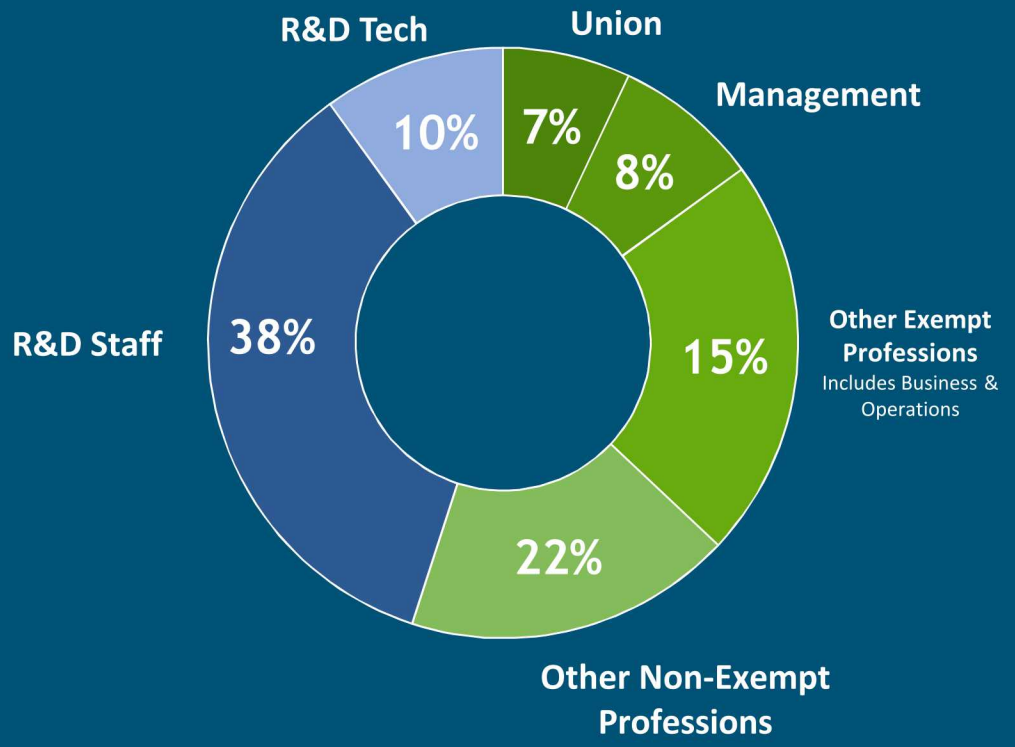
Our Workforce & Culture

Our Workforce ~14,100 employees

~12,300 Regular employees
~1,800 Temporary employees, students & postdoctoral appointees

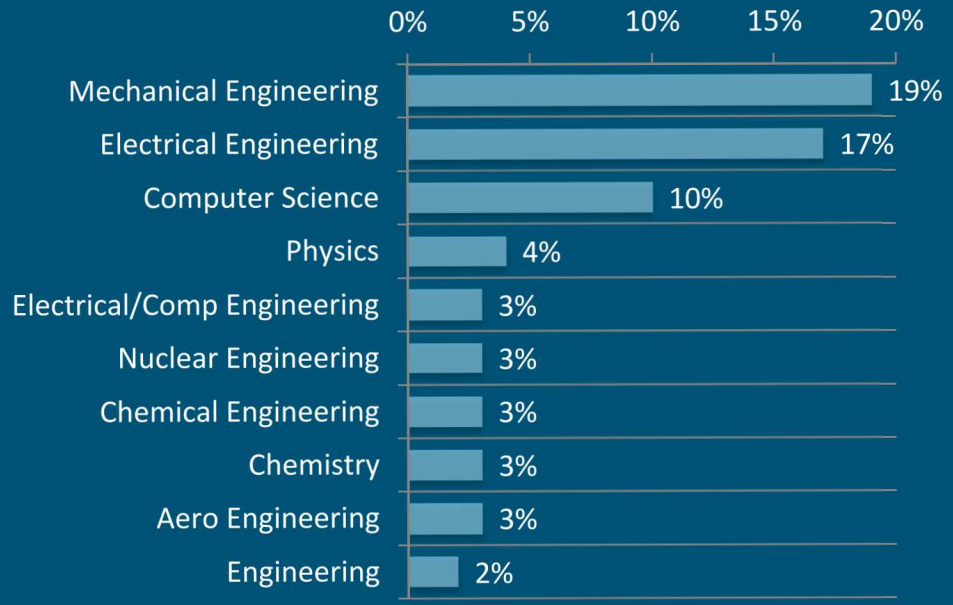
New Mexico Site: *(see breakout)*
Workforce: ~12,500
R&D employees: ~4,200
(R&D Staff & Technologists)

California Site: *(see breakout)*
Workforce : ~1,600
R&D employees: ~650
(R&D Staff & Technologists)

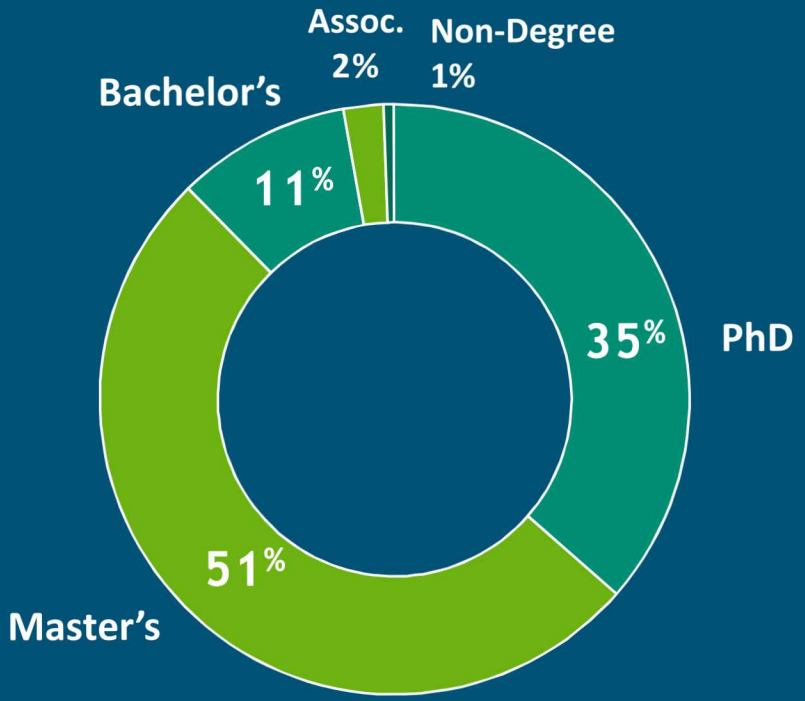


Data as of July 2019

R&D by Discipline & Degree

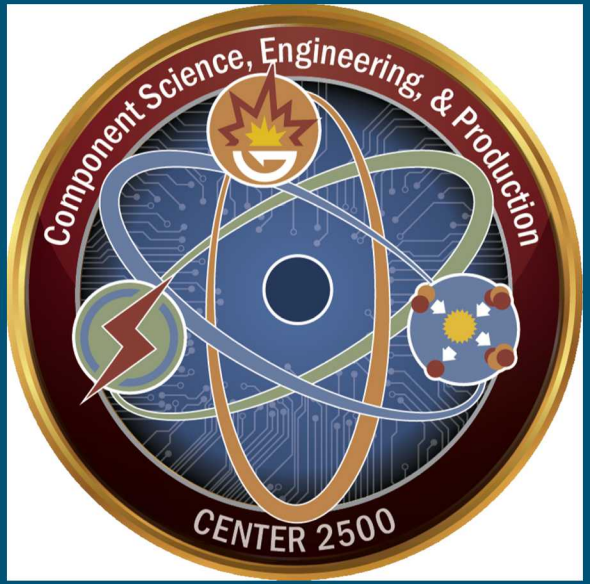


Top 10 job descriptions shown, Regular exempt non-management employees only



Data as of July 2019

Component Science, Engineering, and Production, Center 2500



Let's Talk About Center 2500 & the Neutron Generator Enterprise

How are we the same as the rest of Sandia?

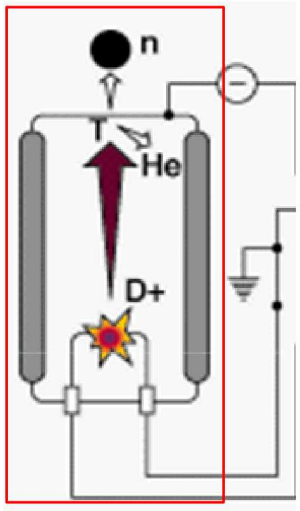
- We have an unwavering commitment to National Security ("Exceptional Service in the National Interest").

How are we different?

- We design and produce a limited life component.
- We have responsibility for over one hundred products across three product lines: power sources, explosives, and neutron generators.
- We have the most advanced Lean Culture in the laboratory (Continuous Improvement, Focus on the Customer, Eliminate Waste). Our lean culture ensures that we will be even more capable tomorrow than we are today.

Overview Neutron Generators

- Neutron generators are neutron source devices which contain compact linear accelerators and that produce neutrons by fusing isotopes of hydrogen together. The fusion reactions take place in these devices by accelerating either deuterium, tritium, or a mixture of these two isotopes into a metal hydride target which also contains deuterium, tritium or a mixture of these isotopes.



Tube

2576 – Analytical and Materials Sciences

Quality Control
-Incoming chemicals, gases materials
-Outgoing product: targets, sources, welds, films
-Product Spec Post Mortem

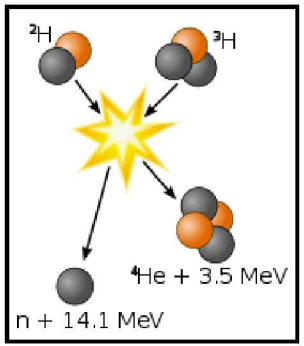
Failure Analysis
-ELNG failure modes
-FENG failure analyses
-Others

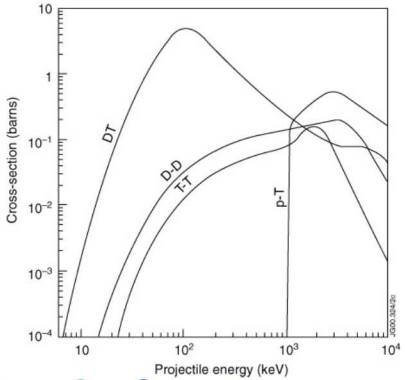
Infrastructure
-Radiochemistry
-Particle contamination
-TCS, Femtotechs, bubblers

Problem Solving/Discovery
-Cu tubulation cracks
-Sprytron laser marking
-Epoxy crystallization
-Source resistor staining
-Tube leak path

Characterization for KG's
-Active ceramics
-SEE/Quasi-metalize
-Active Braze
-Tritium in materials

Create Future
-Z-machine, GTS, Battery Support
-NLabs, U collaborations, LDRD space
Tritium-materials interaction
Materials/interface breakdown effects





Overview of Sandia's Analytical Tools for Measuring and Monitoring Tritium and Contaminated Materials

Sandia National Laboratories is a multi-mission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC., a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

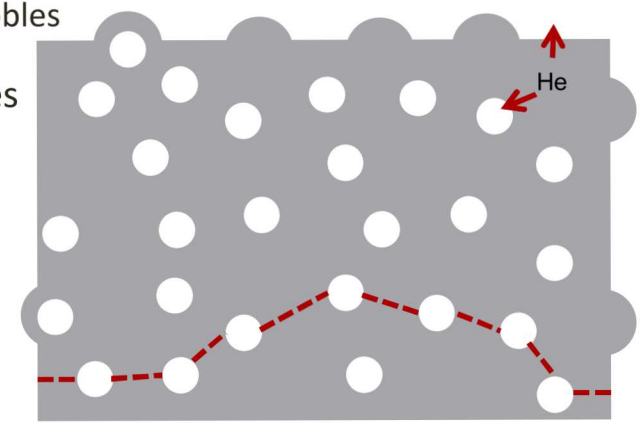
Outline

- Tritium materials interactions, and tube operations
- Tritium Safety
- Tritium Loading
- Tritium Forensics Tools and examples
- Other Facilities

Tritium-Material Interactions

- Tritium dissolves in material lattice causing metal embrittlement
- Tritium decays to ^{3}He
  - Insoluble in most materials
  - Forms high pressure nanometer sized bubbles
- Detrimental Impact on Material Properties
  - Embrittlement
  - Swelling

Helium bubbles cause materials to become prone to fracture and **catastrophic release** of helium



Schematic of Helium Bubbles Causing Cracks

Overview of Sandia/NM Tritium Capabilities

- All tritium operation is performed inside a “tritium envelope” with dedicated single-pass & monitored ventilation
- Equipment can be connected to both
  - Tritium Exhaust (smoke stack release).
  - Tritium Capture System
    - Only within the Tritium Envelope
    - Tritium Capture System (TCS)
    - Tritium Loaders (U-bed to Films)
    - Mass Spectrometers (analysis of produced parts, then to TCS)
    - Other Research Equipment

Tritium Capture System-Tritium Safety

80 ft^3 accumulation tank

- **Sub-atmospheric pressure**

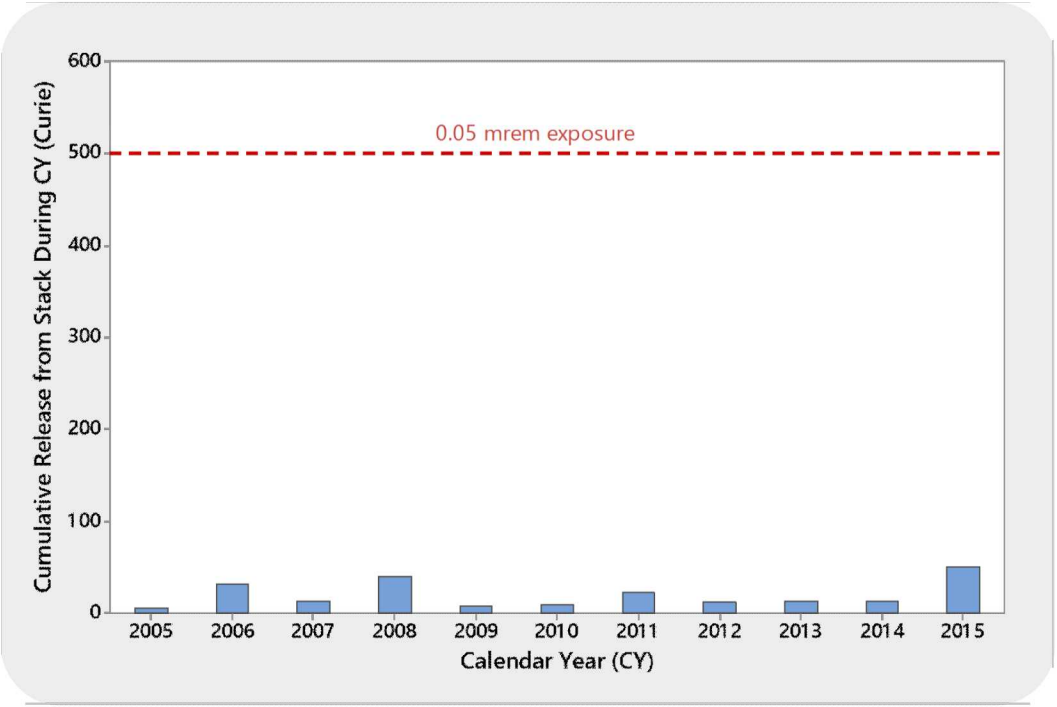
Valve control panel, sieve beds, catalytic burners

- **Effluent tritium verified, then sent to stack**

Calorimeter for sieve bed analysis

Ensures that effluent gasses have minimal tritium content-tritium safety

Overview of Sandia/NM Tritium Capabilities



Tritium Gas Loading

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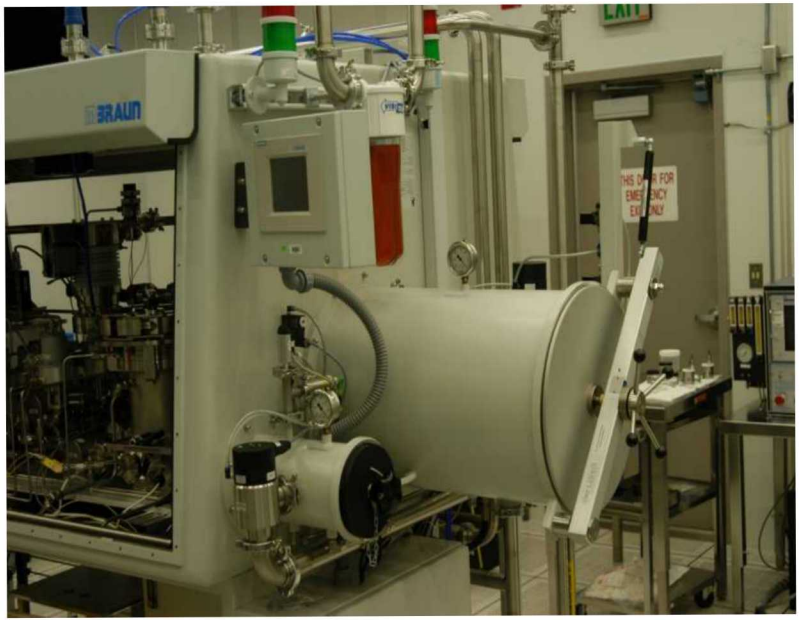
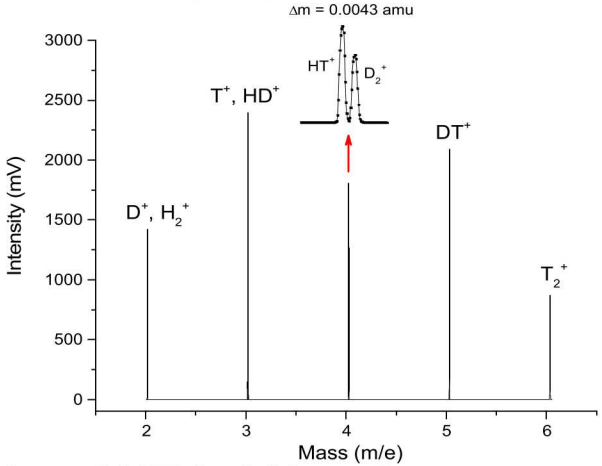
Tritium Loader – gas manifold built in a glove box, capable of 100% tritium or dilute loading of metal tritides



Gas Analysis Capabilities

Used for thin film analysis

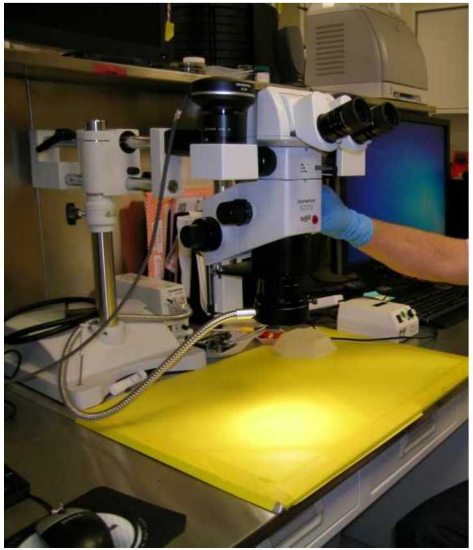
Mass Spectrometer: Optimized for analysis of the hydrogen isotopes



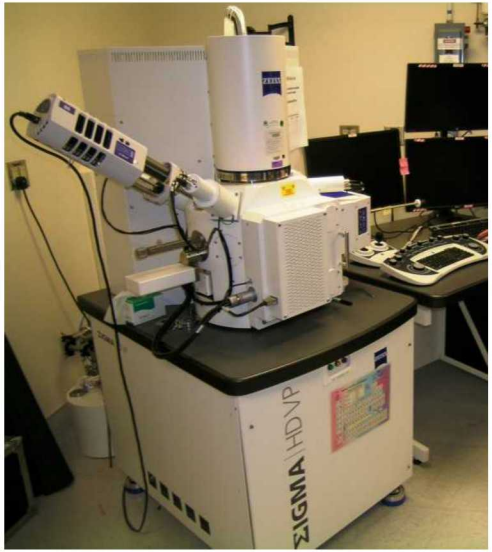
Finnigan MAT 271 Mass Spectrometers

- Measurement uncertainty < +/- 2% 1-150 mass range
- Capable of separating and independently measuring all hydrogen isotope combinations (Resolution > 1500)
- No other technology demonstrates as good a sensitivity/resolution in the low 1-6 mass range.
- Dynamic range of 10^9
- Very high adjacent mass rejection ratio
- Advanced ion source design which exhibits a low rate for hydrogen isotope exchange

Forensics and Materials Science



Optical Microscopy
- Magnifications of 3.5 to 1000x
- Ultraviolet light for Dye Penetrant

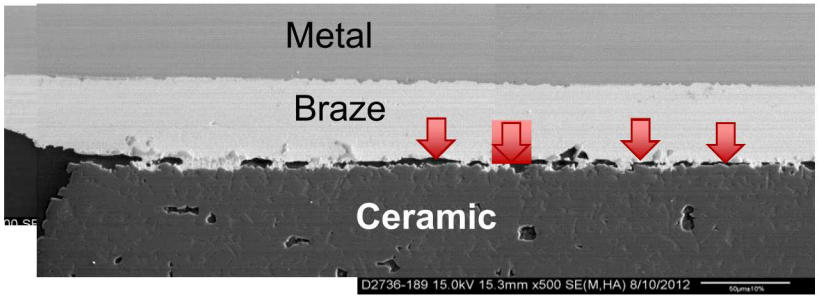


Scanning Electron Microscope (SEM)
- Variable pressure for insulating materials
- Magnifications up to 200,000x

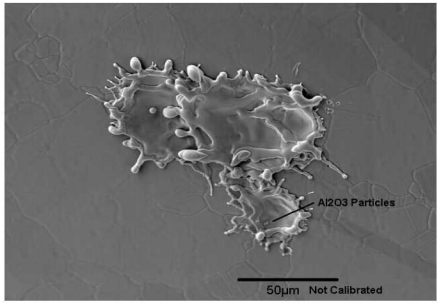
Rad-capable tools used for product inspections, problem solving and knowledge gap work

Examples: Troubleshooting

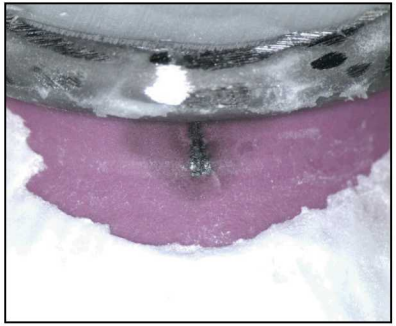
Leak path identified using dye penetrant



Potential leak path



I-High Voltage Breakdown

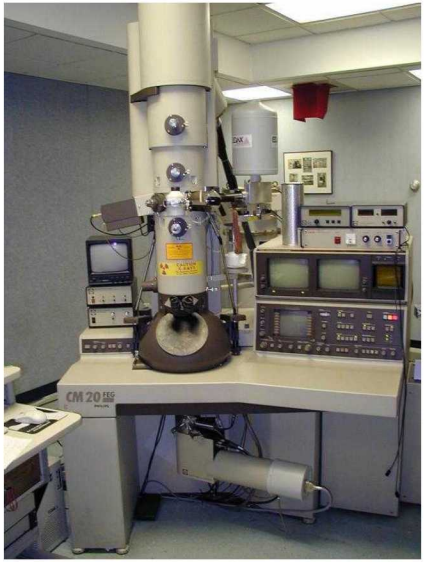


E-High Voltage Breakdown

Materials Science Tools

X-Ray Diffractometer (XRD)

- Phase identification
- Structure refinement
- Texture analysis



Transmission Electron Microscope (TEM)

- Resolution down to 0.3 nm
- Maximum magnification 750,000X
- Capable of chemical analysis on tritiated materials

Phase Identification

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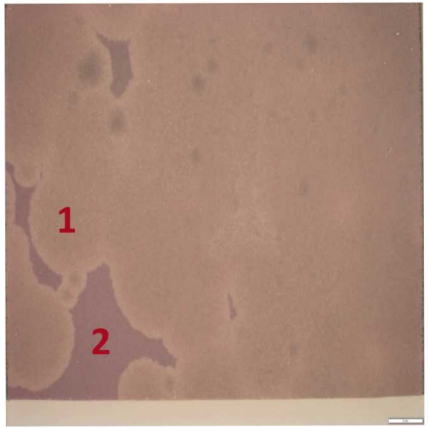
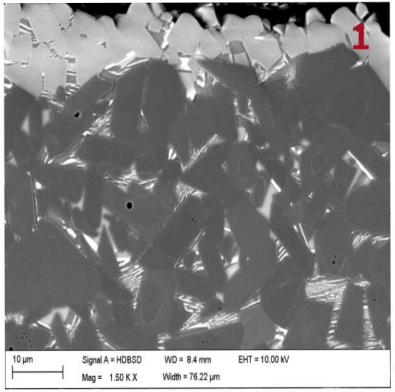
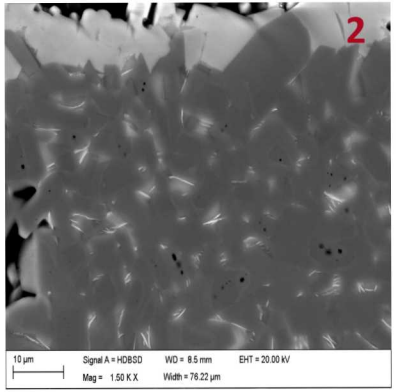
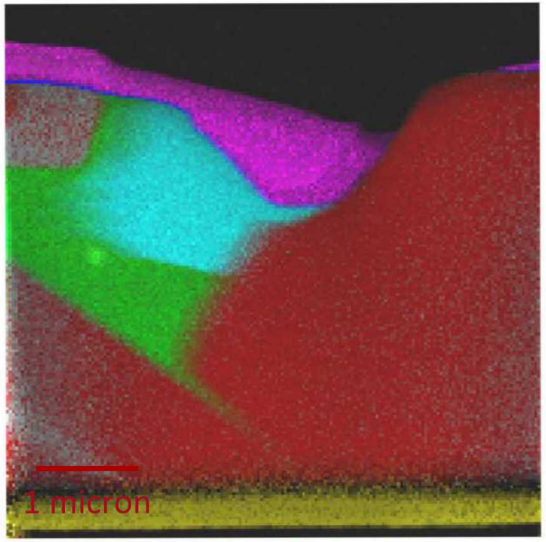
Optical View





SEM View





TEM View

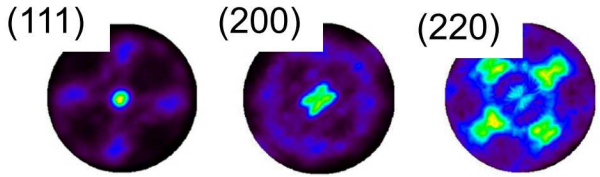
Multi-scale techniques used to identify relevant physical phenomenon

Concentration of Ti-rich Precipitates is different

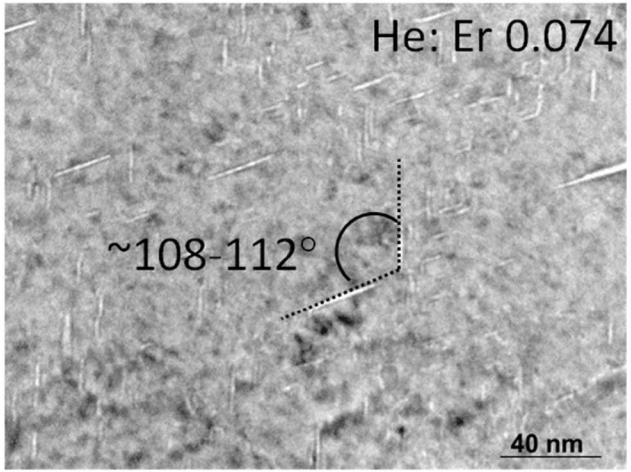
Aging of Metal tritides

ErT_2 loaded film

High resolution TEM imagining necessary to understand bubble evolution and lifetime of materials



Strong (111) texture with secondary (200) texture



Platelet helium bubbles which are aligned along the [111] crystallographic axis.

Quantitative and Trace Metal Analysis

Inductively Coupled Plasma –
Optical Emission Spectroscopy (ICP–OES)

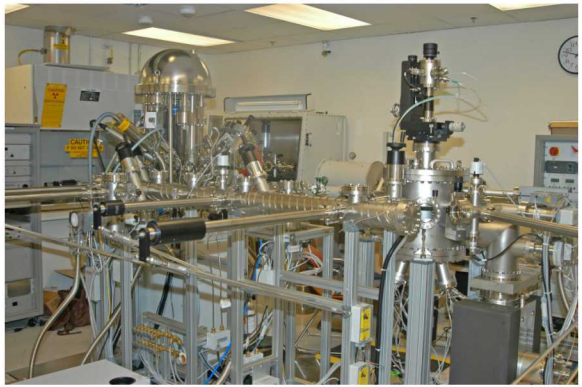
- Utilized to identify and quantify elemental constituents at the ppm level (parts per million, mg/L).

Erbium (targets) and scandium (source witnesses) metal analyses for T/D load ratio determination

Inductively Coupled Plasma –
Mass Spectroscopy (ICP – MS)

•Simultaneous multi-element analysis of most metals at ultra-trace ppb levels (**parts per billion, µg/L**) in aqueous solutions.

Film Deposition, Thermal desorption



- **Dual Chamber Thin Film Deposition**
  - 2 electron-beam evaporation cells
  - Can deposit 1-3 materials per run
  - Experimental films can be deposited

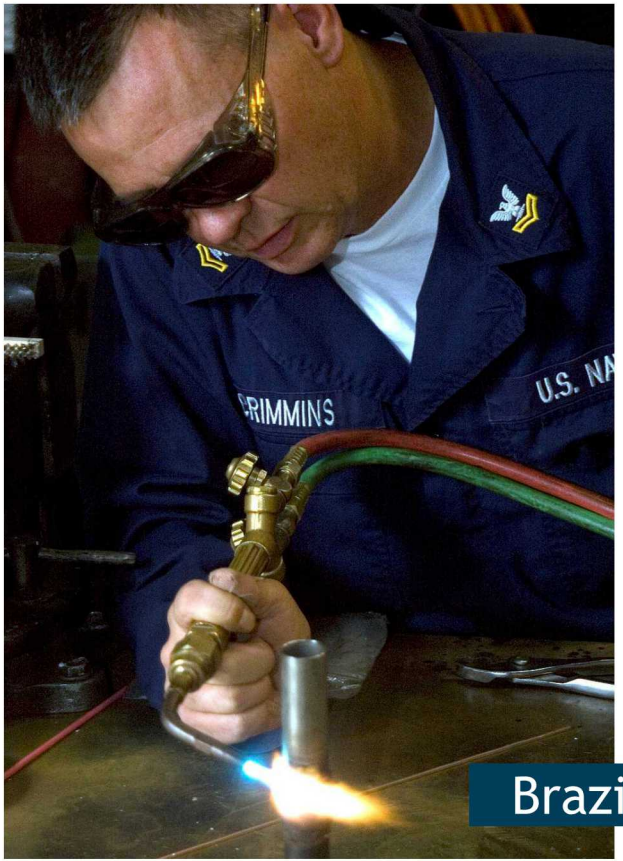
- **Thermal Desorption System**
  - Angular reflection time-of-flight mass spectrometer
  - Mass resolution ~ 212
  - ~750C upper temperature limit

Tools used to develop new materials, and study evolution of tritium from these materials

Joining Options

Welding

Soldering

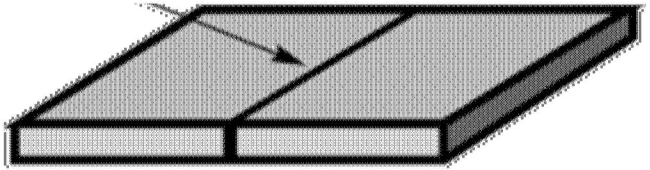


Brazing

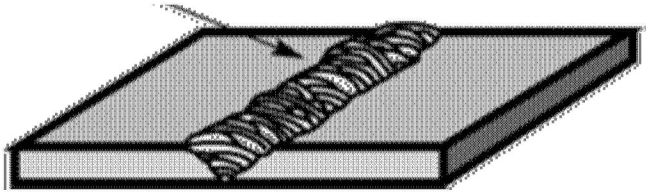
Brazing vs Welding

Cleaner Joint

Brazed Joint



Welded Joint

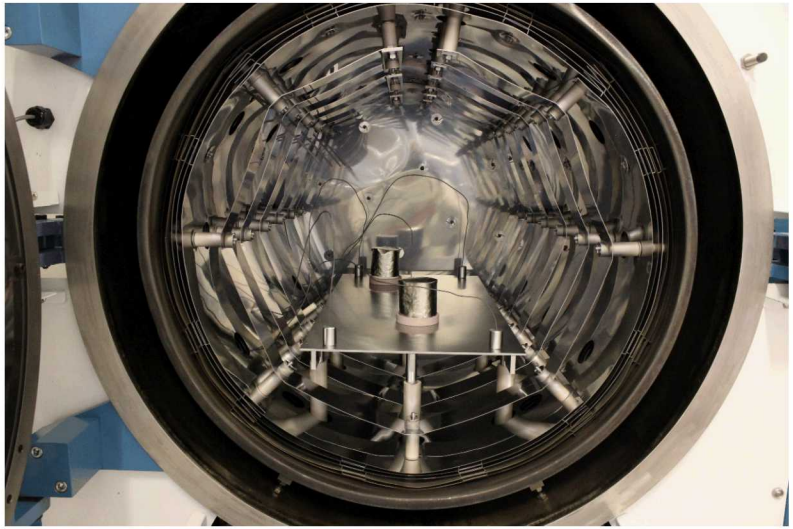


Joining Dissimilar Materials

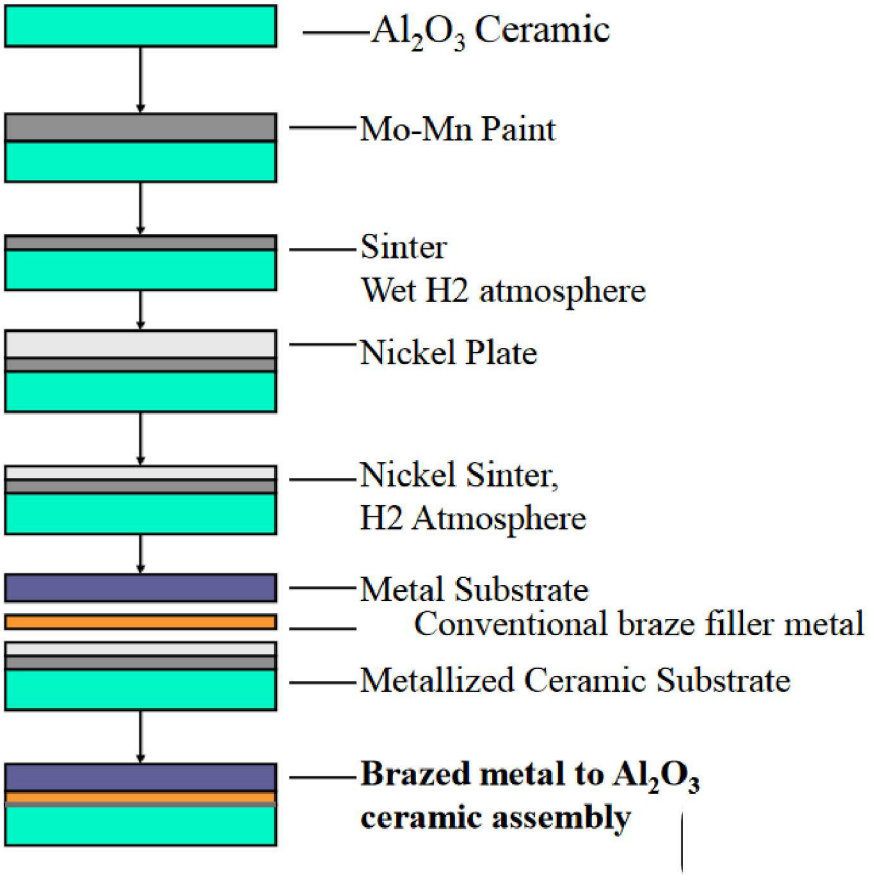
Weld

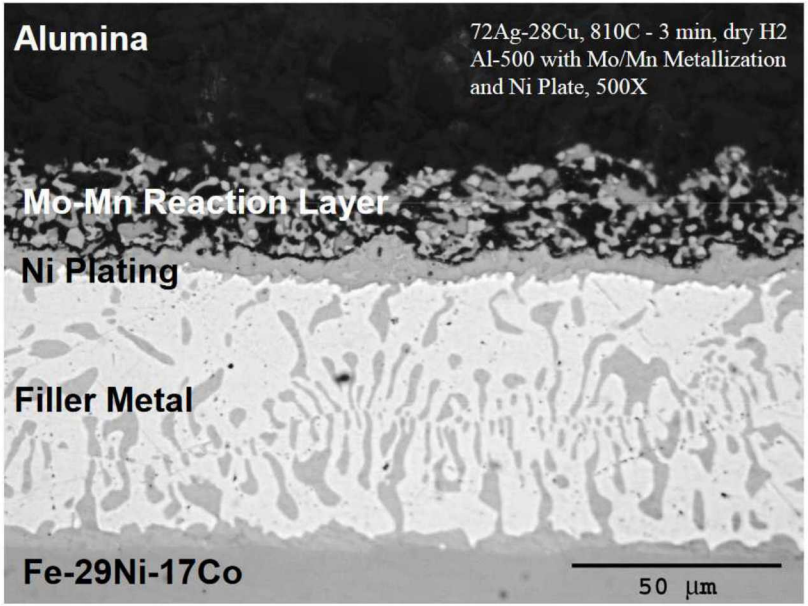
Active Braze

Furnace Brazing

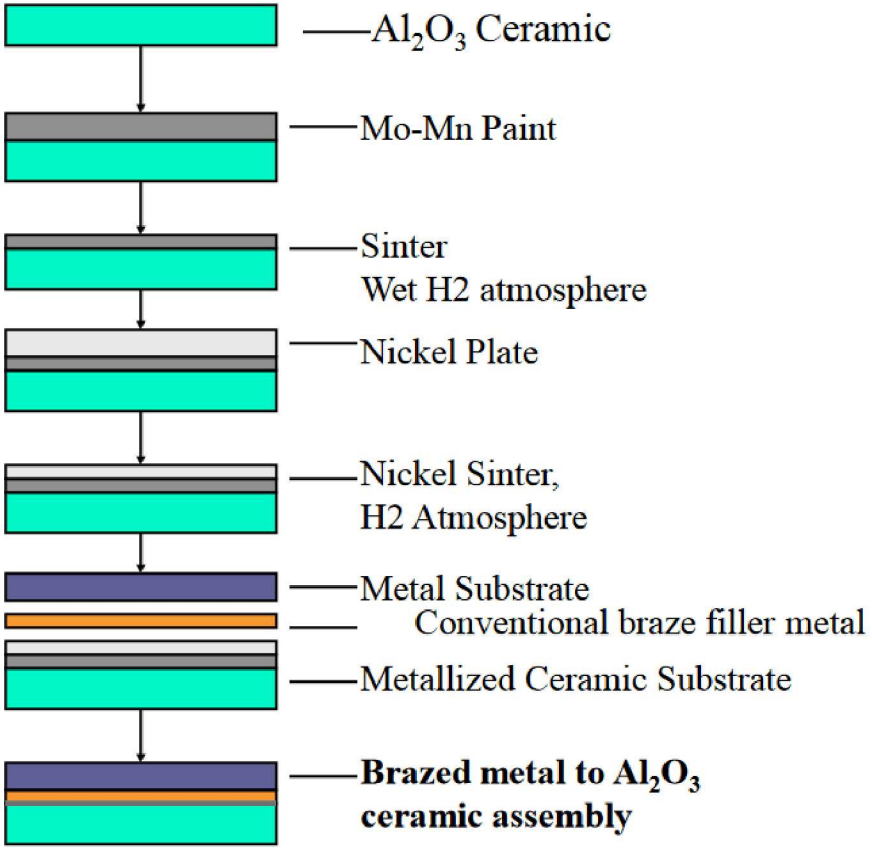


Conventional Braze

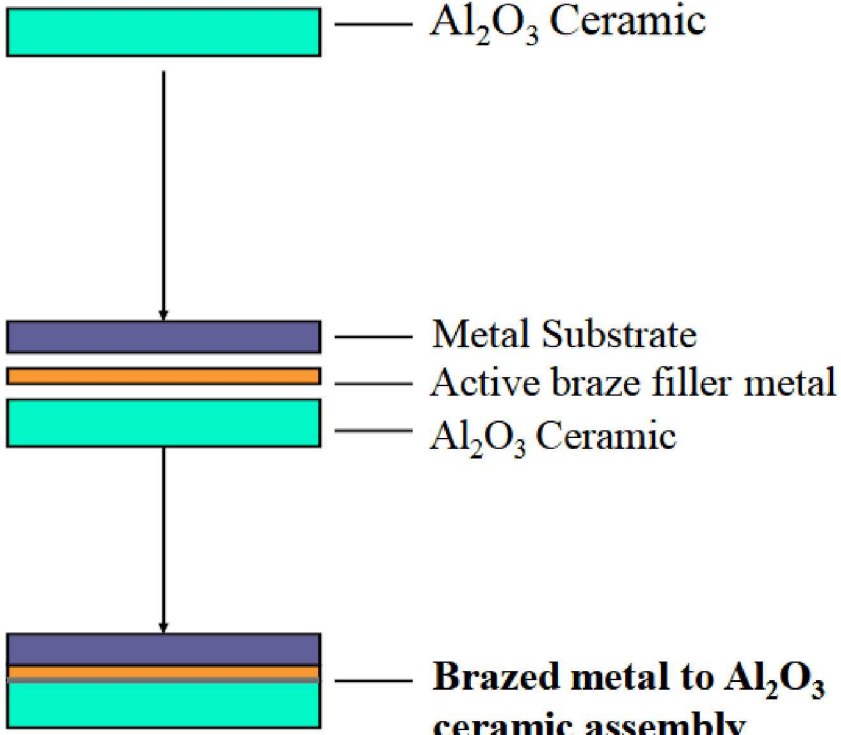




Conventional Braze

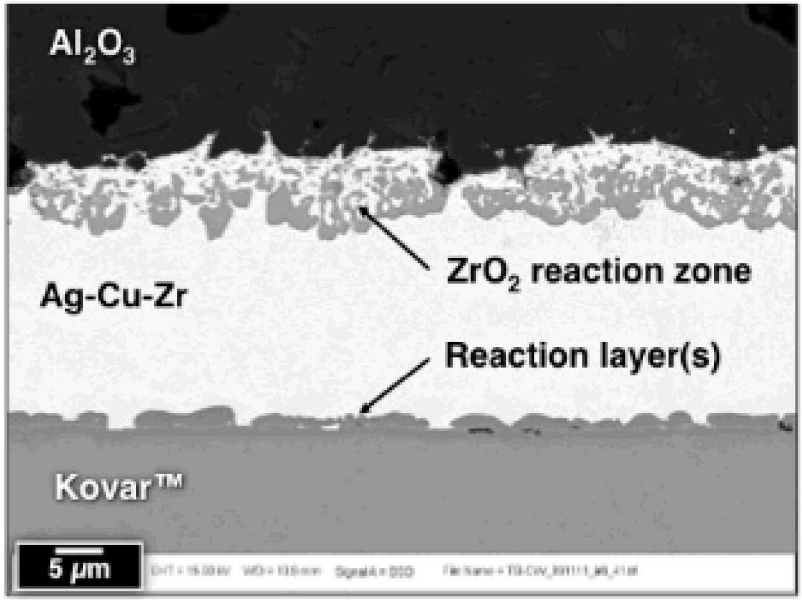


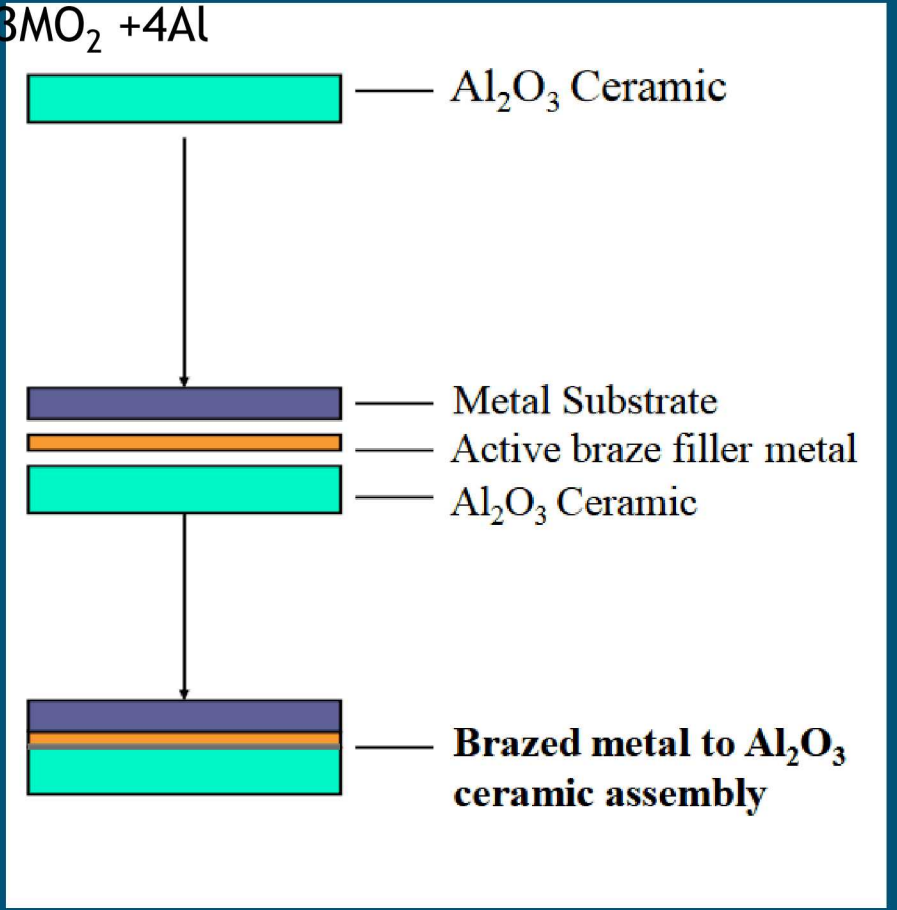
Active Braze



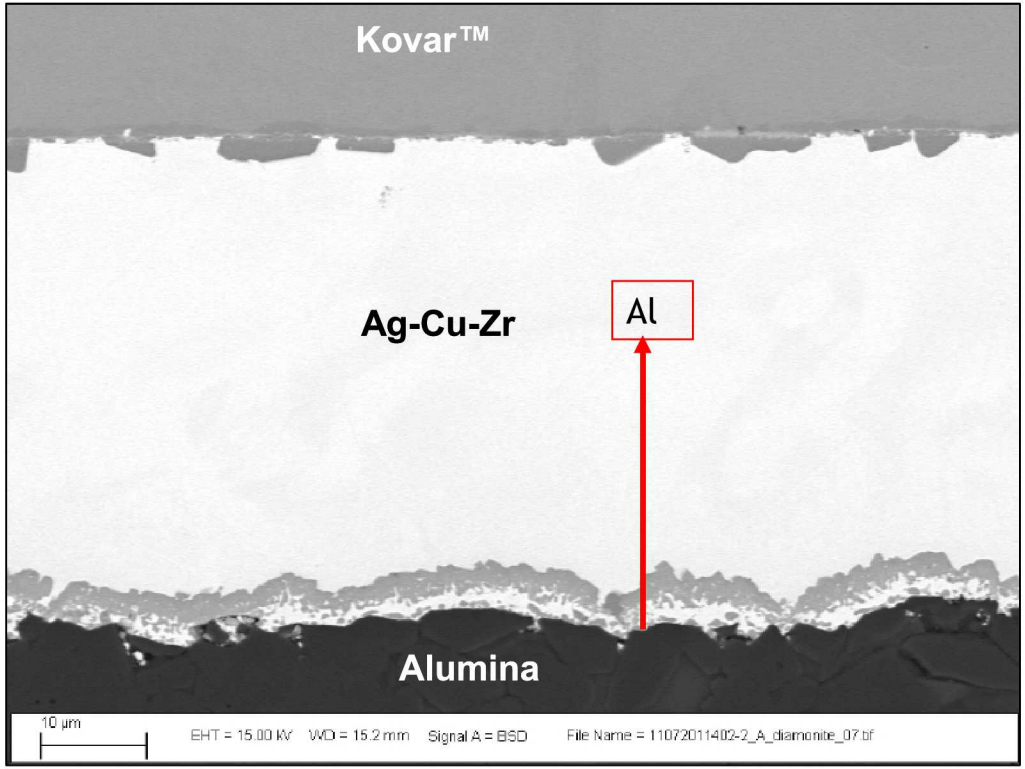
Active Braze

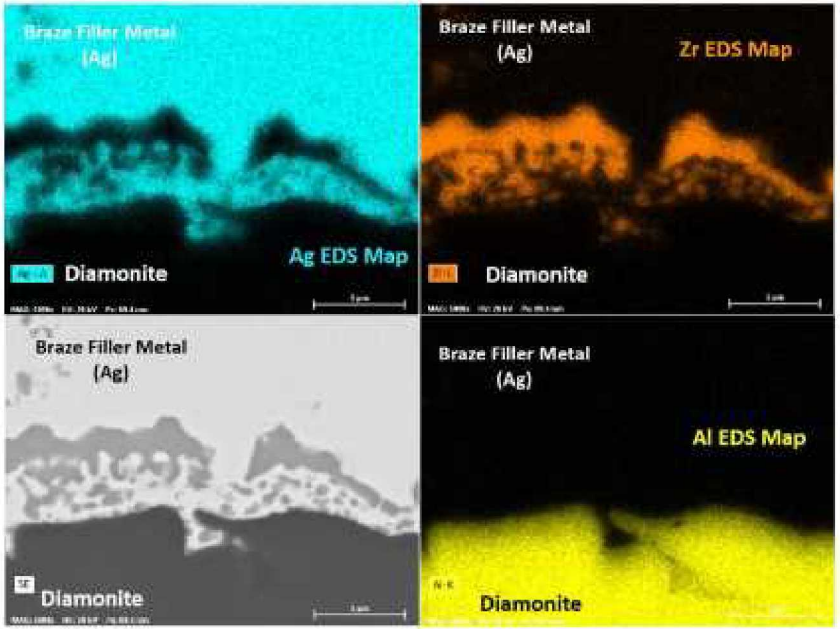
$3M + 2Al_2O_3 \rightarrow 3MO_2 + 4Al$



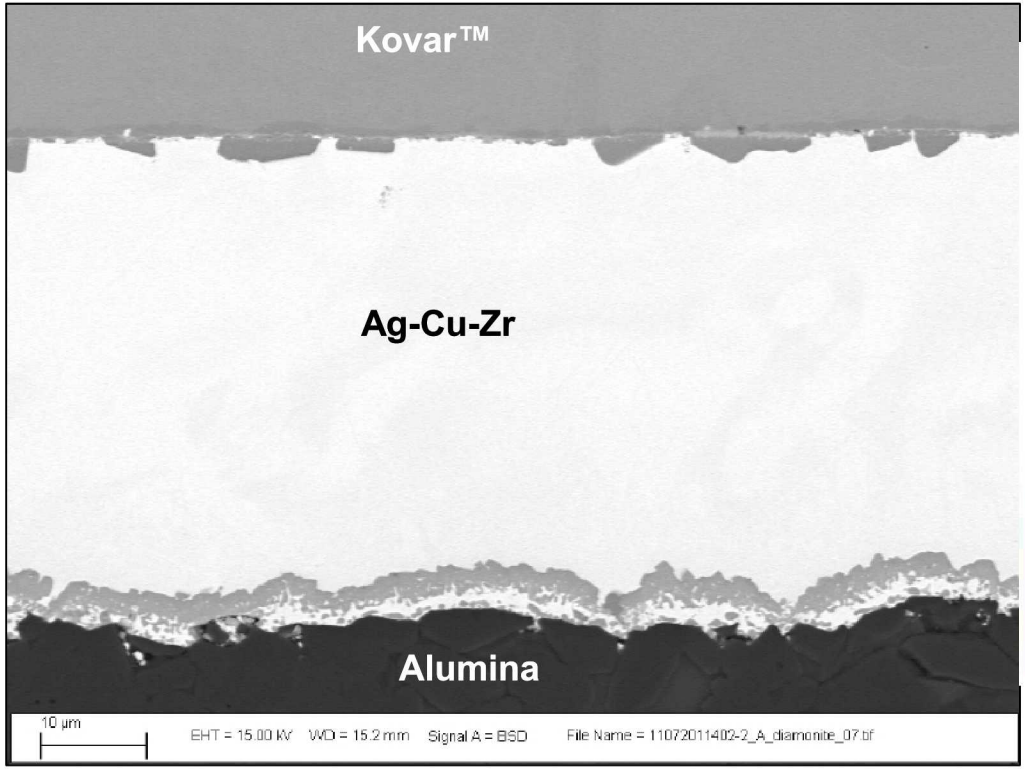


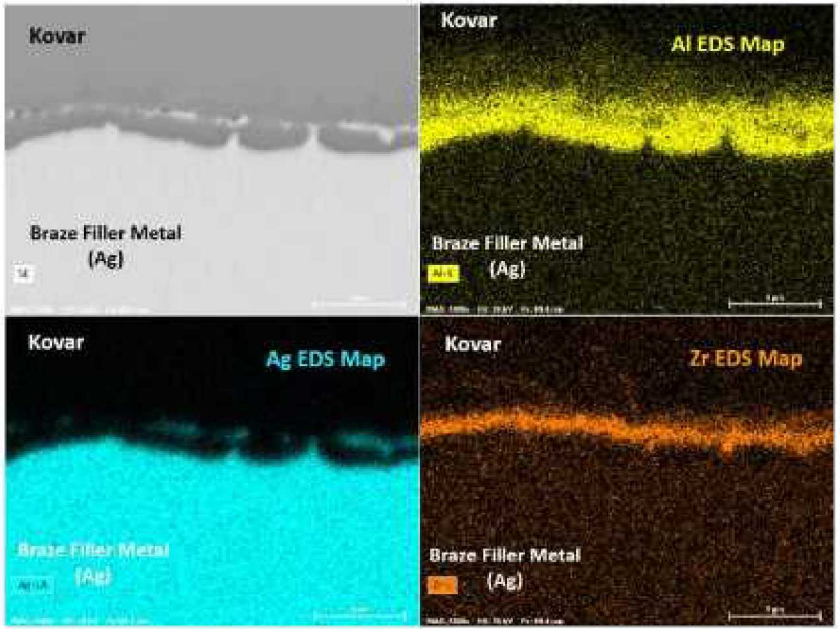
Ag-1Cu-2Zr Microstructure



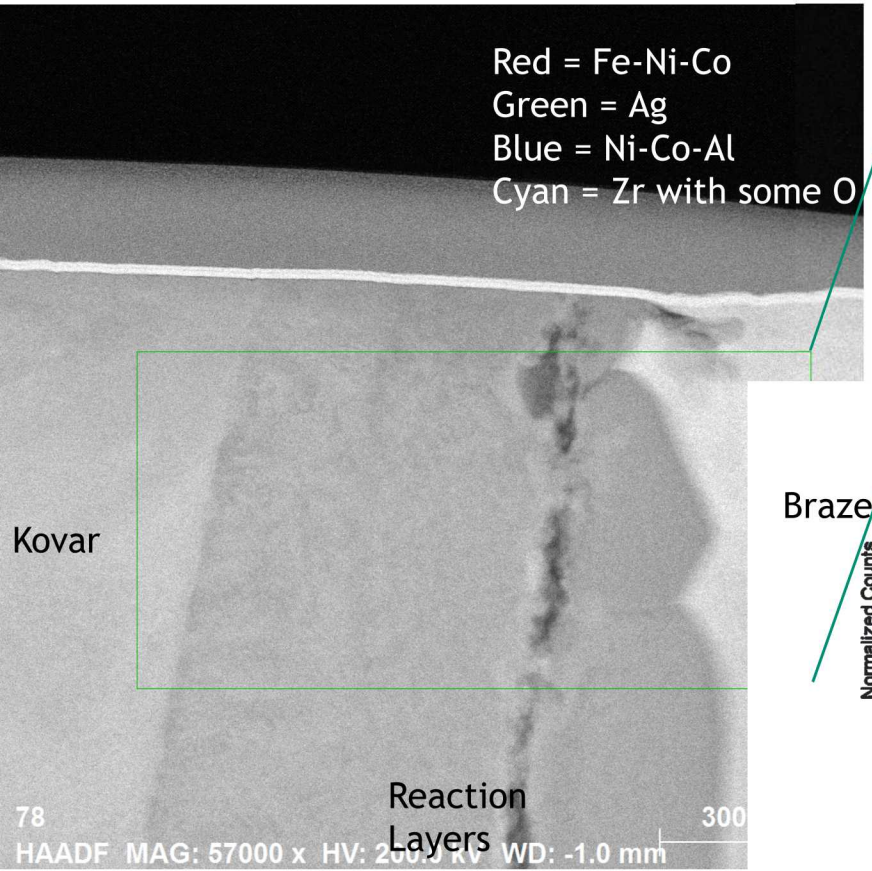


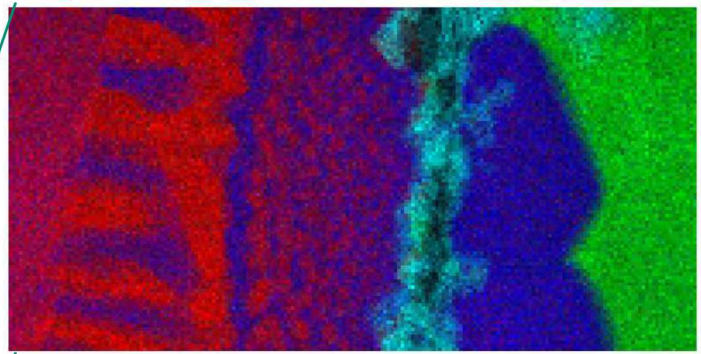
Ag-1Cu-2Zr Microstructure

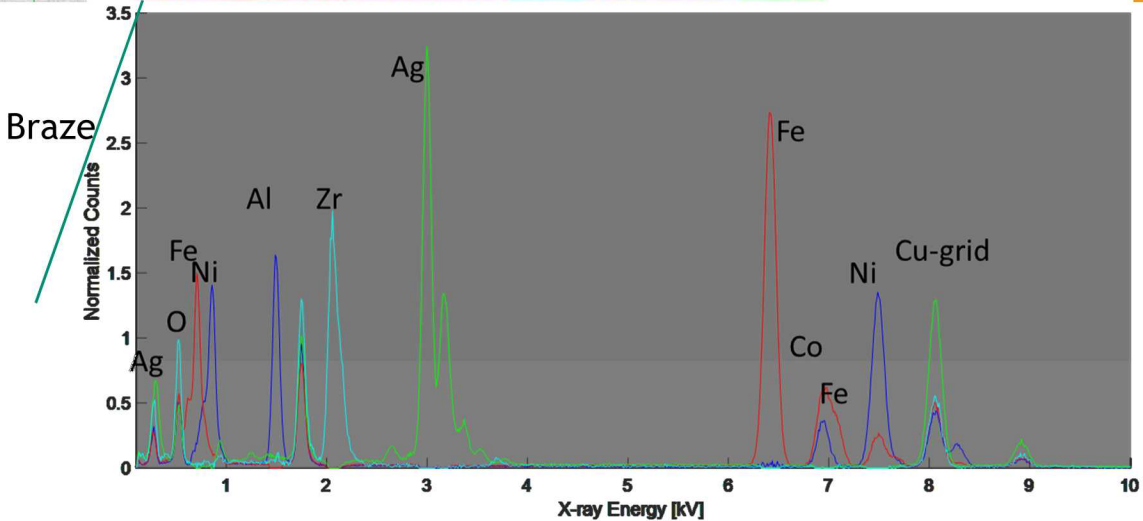




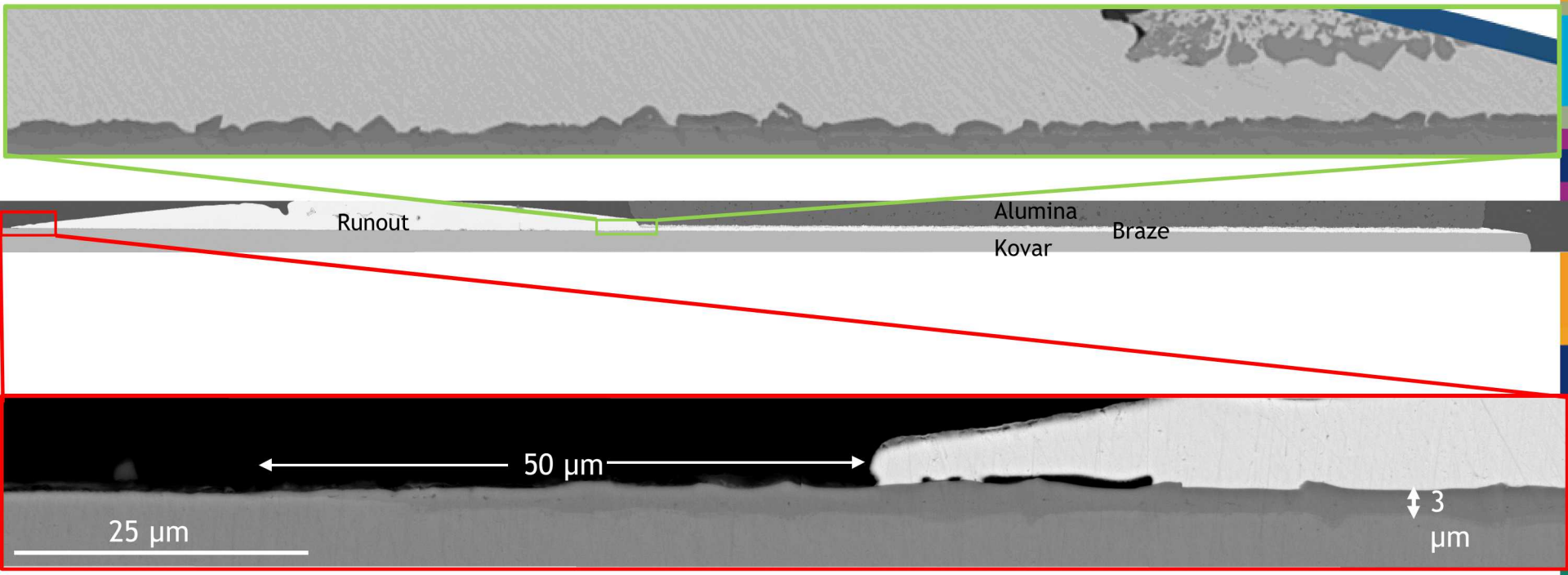
FIB cross section of braze



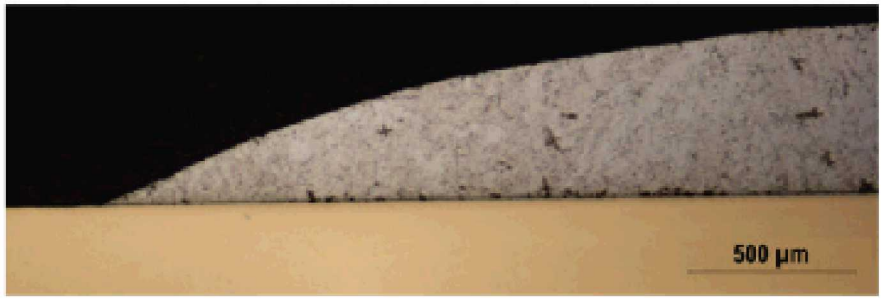




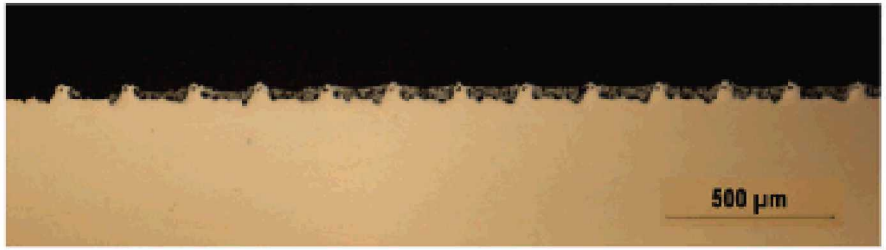
Cross section of Braze with **Significant Runout**



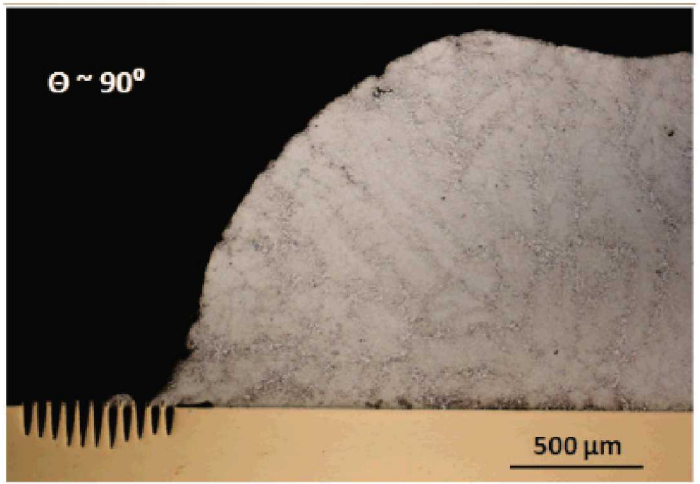
Laser Surface Modification



θ ~ 23°

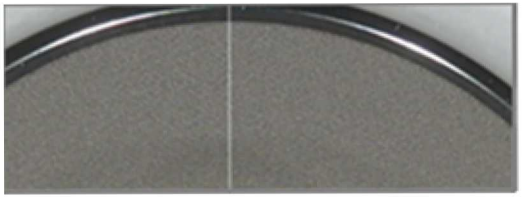


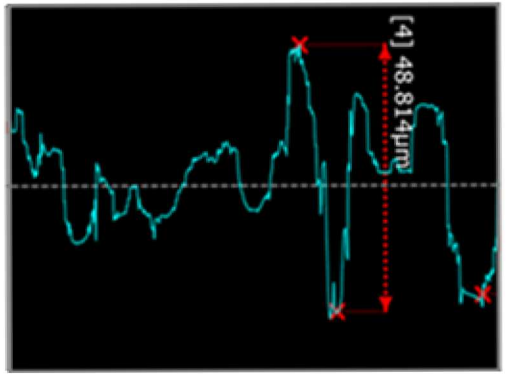
θ ~ 0°

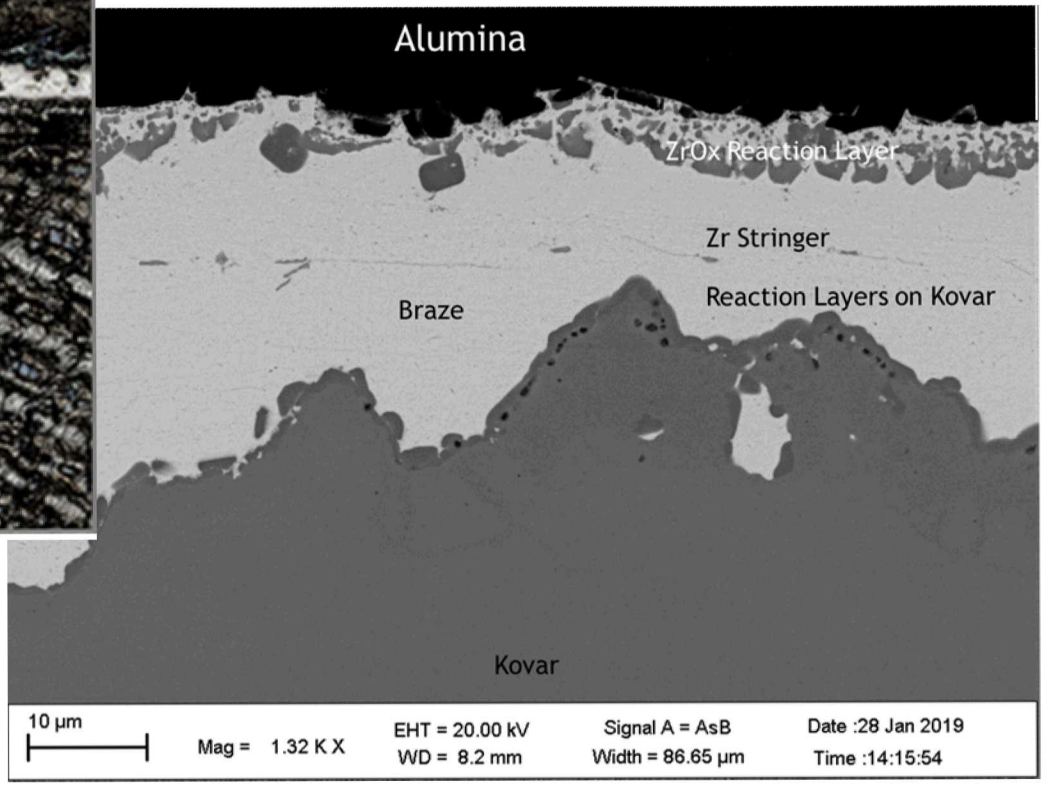


Laser Surface Modification to Enhance Brazing Joints. Nerea OTERO, Pablo ROMERO, José Carlos SOTELO and Alejandro GONZÁLEZ. JLMN-Journal of Laser Micro/Nanoengineering Vol. 8, No. 2, 2013137

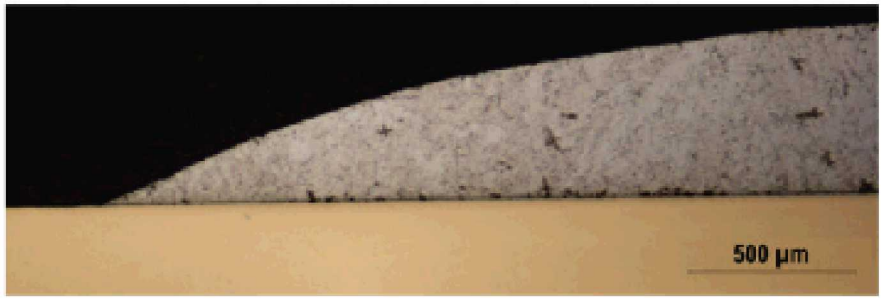
Laser Surface Modification



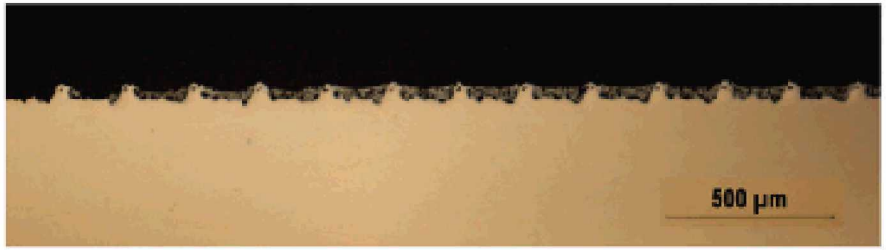




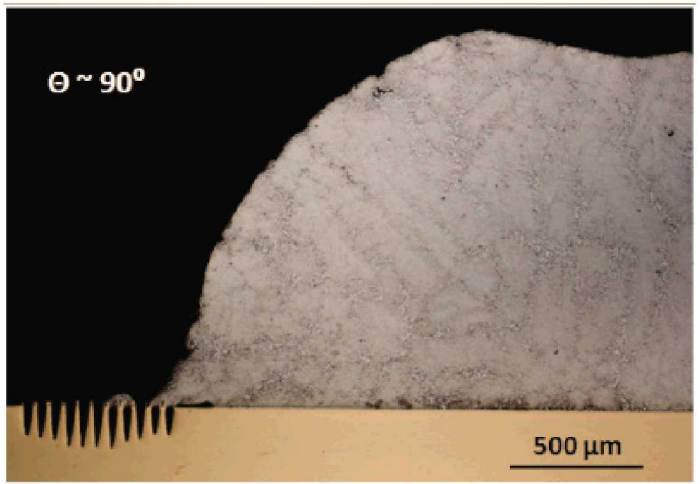
Laser Surface Modification



θ ~ 23º

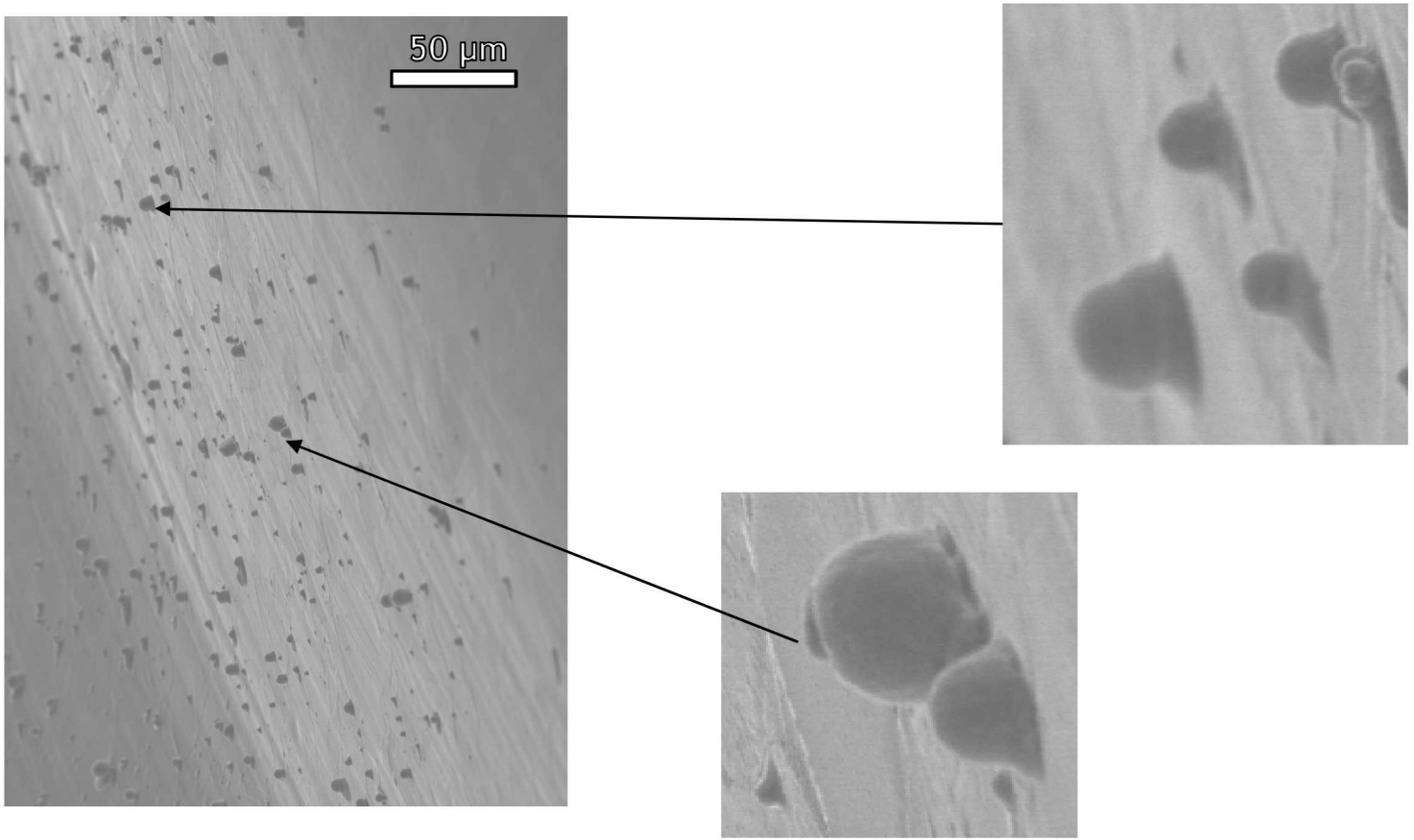


θ ~ 0º

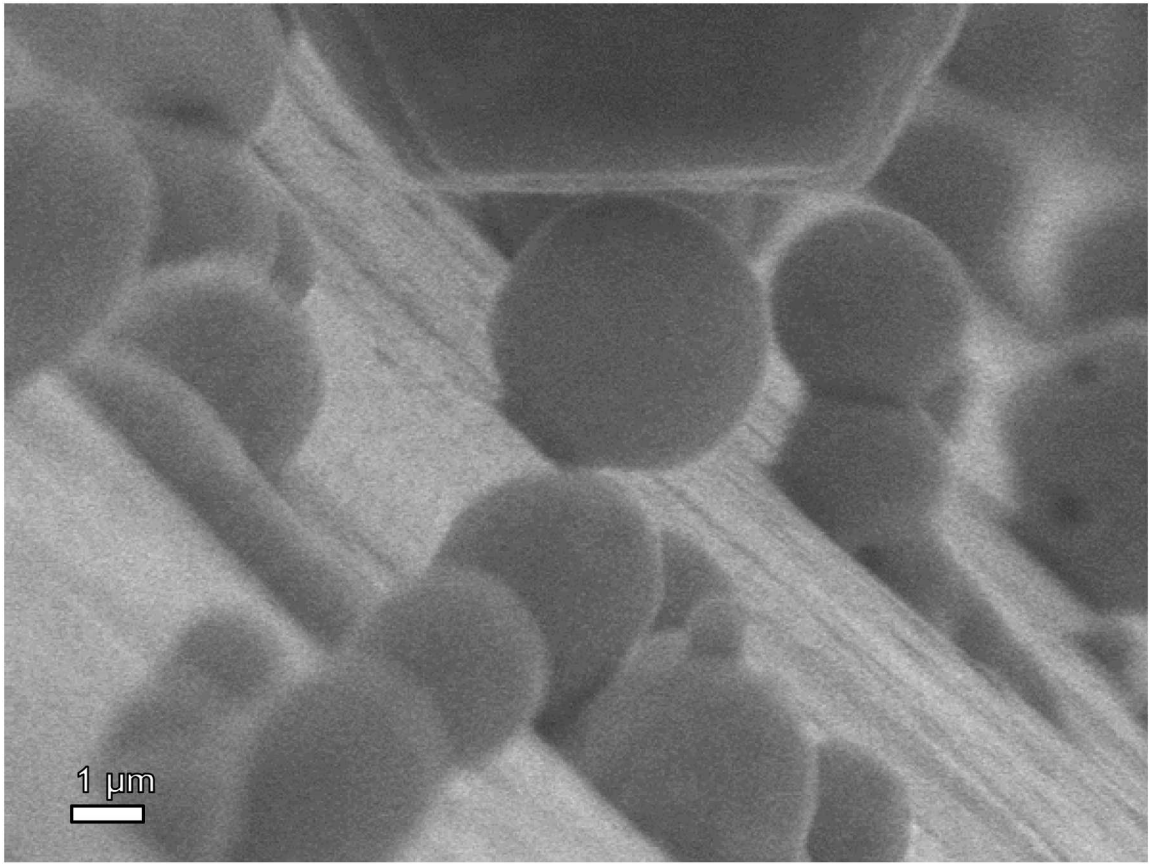


Laser Surface Modification to Enhance Brazing Joints. Nerea OTERO, Pablo ROMERO, José Carlos SOTELO and Alejandro GONZÁLEZ. JLMN-Journal of Laser Micro/Nanoengineering Vol. 8, No. 2, 2013137

Laser Surface Modification



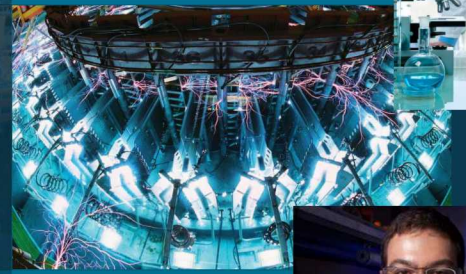
SEM Video of Kovar Splatter



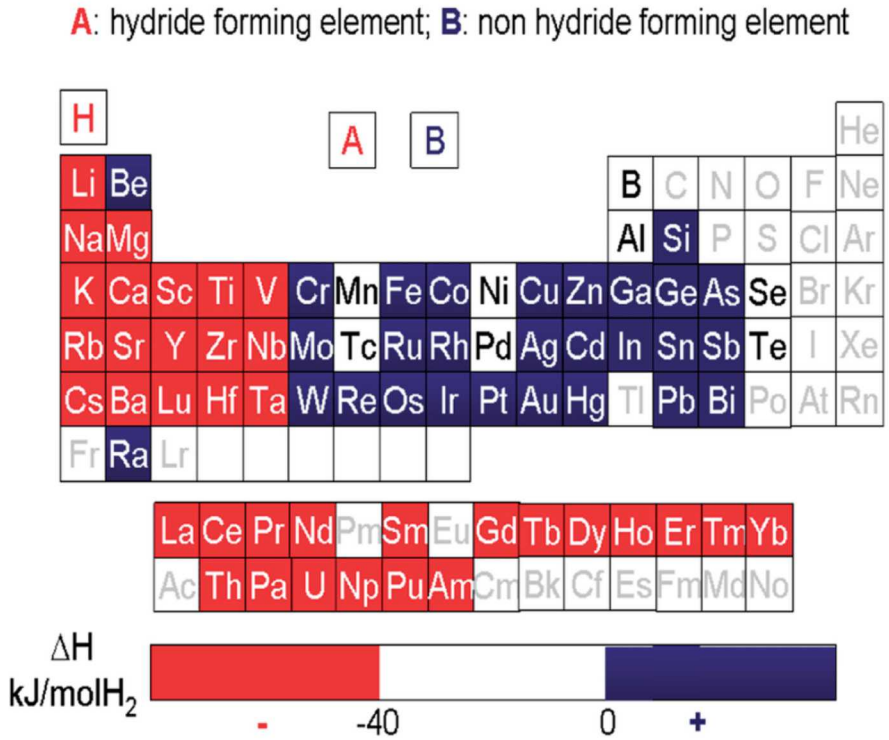
Titanium Hydride Films Processing and Characterization

Ron Goeke

January 24th, 2020



Hydride Forming Elements

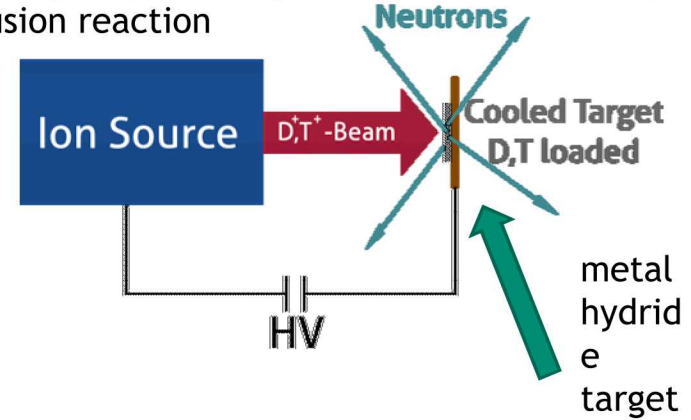


Reversible Reaction: $M + H_2 \leftrightarrow MH_x$

Zhang, et. al. (2019). RSC Advances. 9. 408-428.

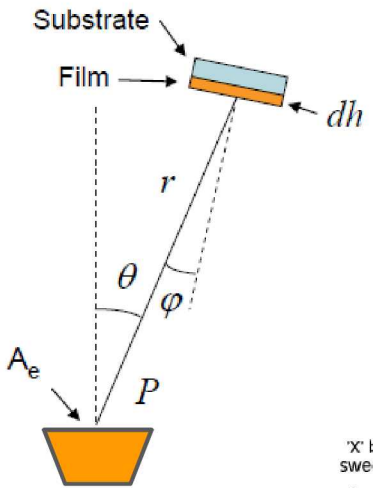
Uses for Metal Hydrides

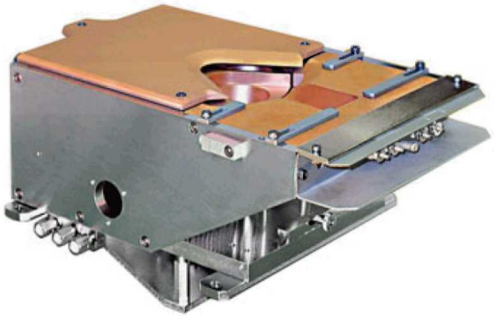
- Catalysts
- Batteries (Nickel Metal Hydride – example of weakly bound hydrogen)
- Hydrogen Storage (higher densities and safer than compressed gas)
- Neutron tube uses hydrogen isotopes stored in a metal hydride target for D-T Fusion reaction

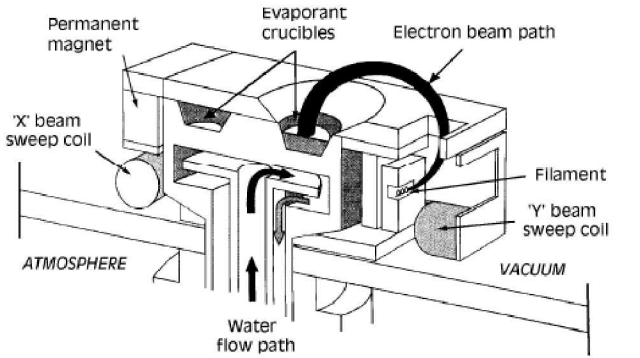


Fabrication of titanium metal hydride thin film for applications as neutron tube target

Thin Film Deposition by Electron Beam Evaporation



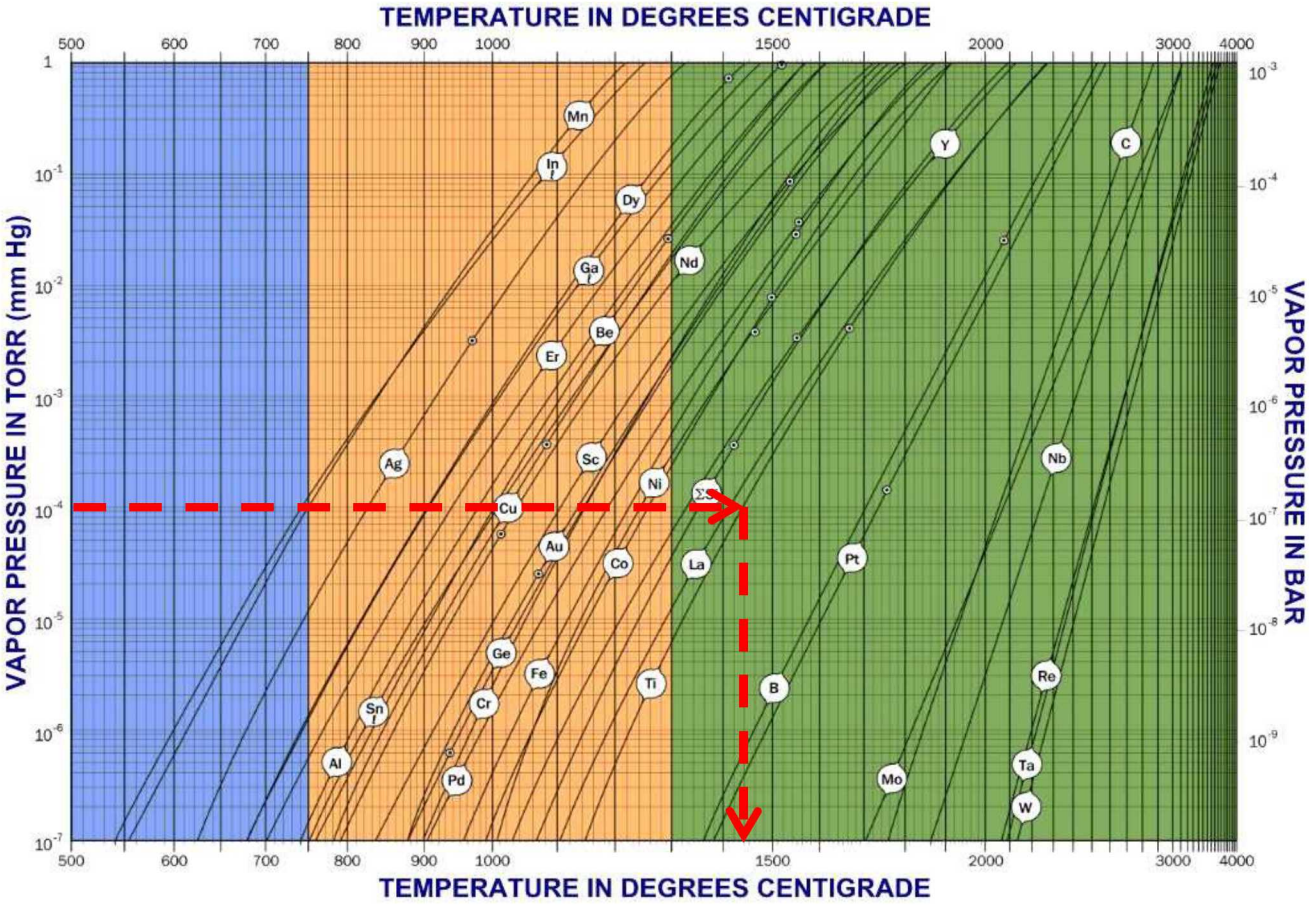




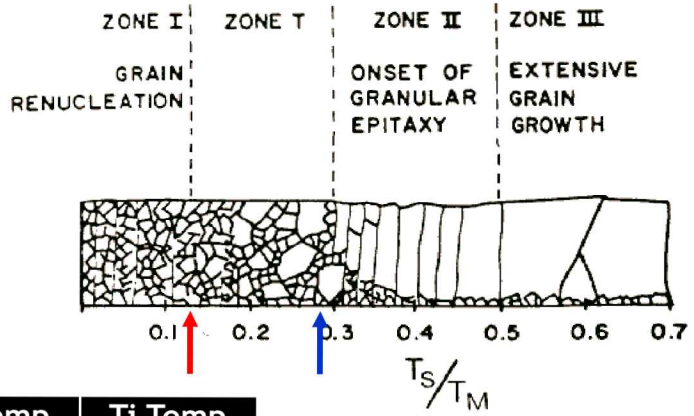
• *Courtesy of AP&T/Ferrofluidics*

To minimize the amount of impurities in the thin film, we used a high purity starting material with 99.995% purity, a very low base pressure < 7 x 10-7 torr at deposition temperature and a deposition rate of 20 Å/sec.

Vapor Pressure



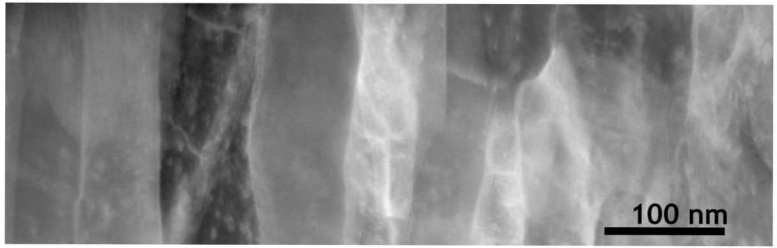
Zone Model for Evaporated Films



Hentzell, JVST-A 1984

Homologous Temperature T_S/T_M

Fraction of T_m	Ti Temp (˚C)	Ti Temp (K)
T_m	1668	1941
0.5 T_m	697	970
0.4 T_m	503	776
0.3 T_m	309	582
0.15 T_m	25	298

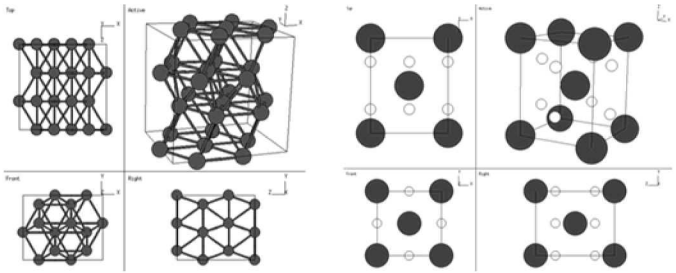


Zone II: Surface diffusion is becoming dominant. Grain boundaries are mobile. Growth of columns with tight grain boundaries. Voids are filled by surface diffusion. Fewer defects.

Crystal Structure for Ti and TiH2

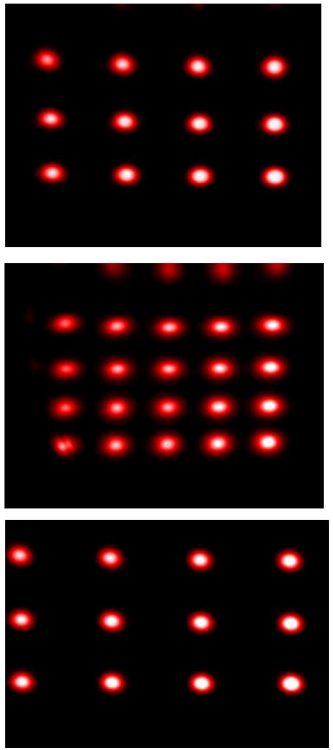
Ti – Hexagonal
Space Group $P6_3/mmc$
a=0.29486 nm
b=0.29786 nm
c=0.467 nm
volume
17.76 Å³ / Ti atom

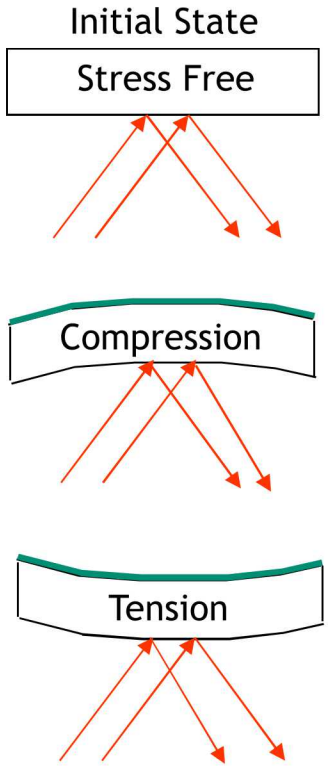
TiH_2 – Tetragonal
Space Group I4/mmm
a=0.3177 nm
b=0.3177 nm
c=0.4363 nm
volume
22.02 Å³ / Ti atom



- The titanium film when transformed into the hydride phase will the increase in volume.
- As the film is constrained by the substrate the volume expansion will be entirely in the z-direction or film thickness.
- Hydride film thickness increases 24% larger than that of the metal film.

Reflected laser spot spacings are monitored to determine $\Delta\kappa$



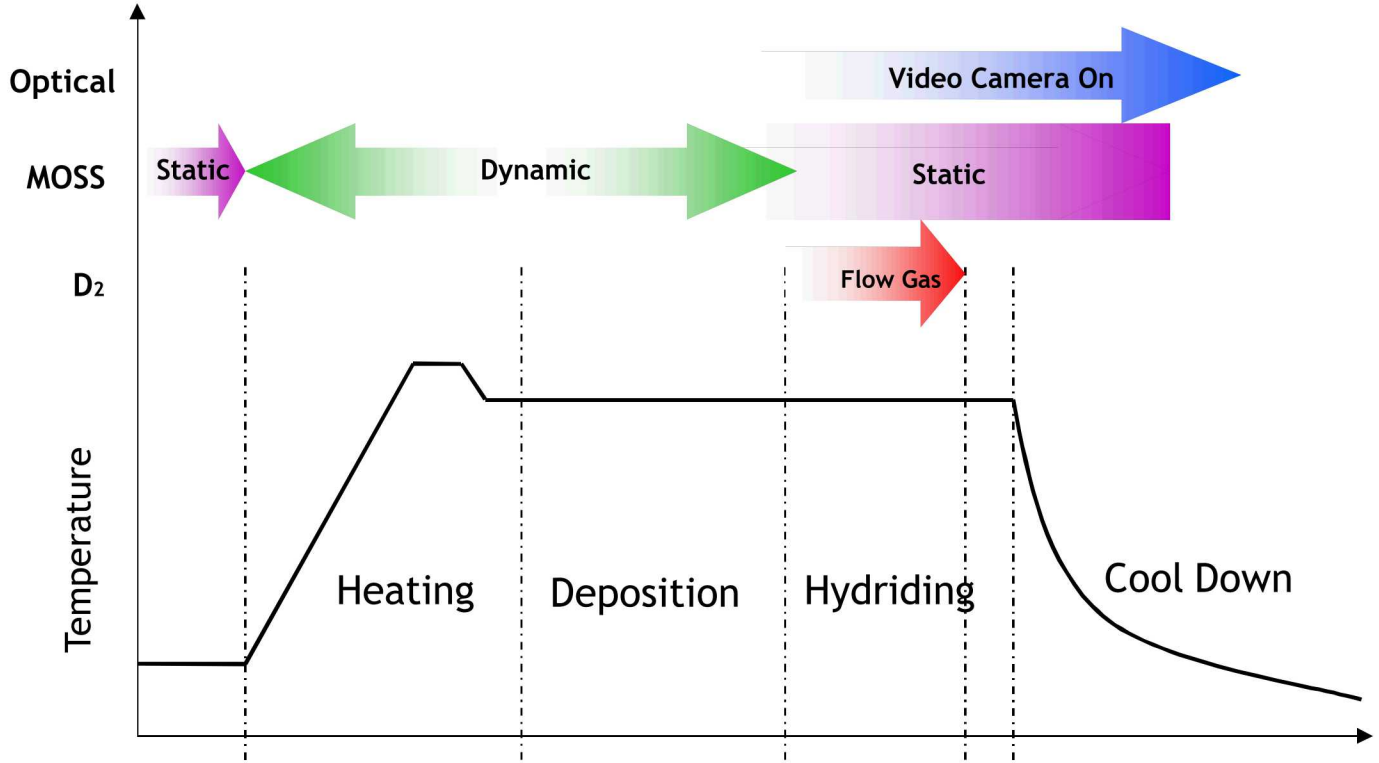


Stoney's Equation for 'Growth Stress':

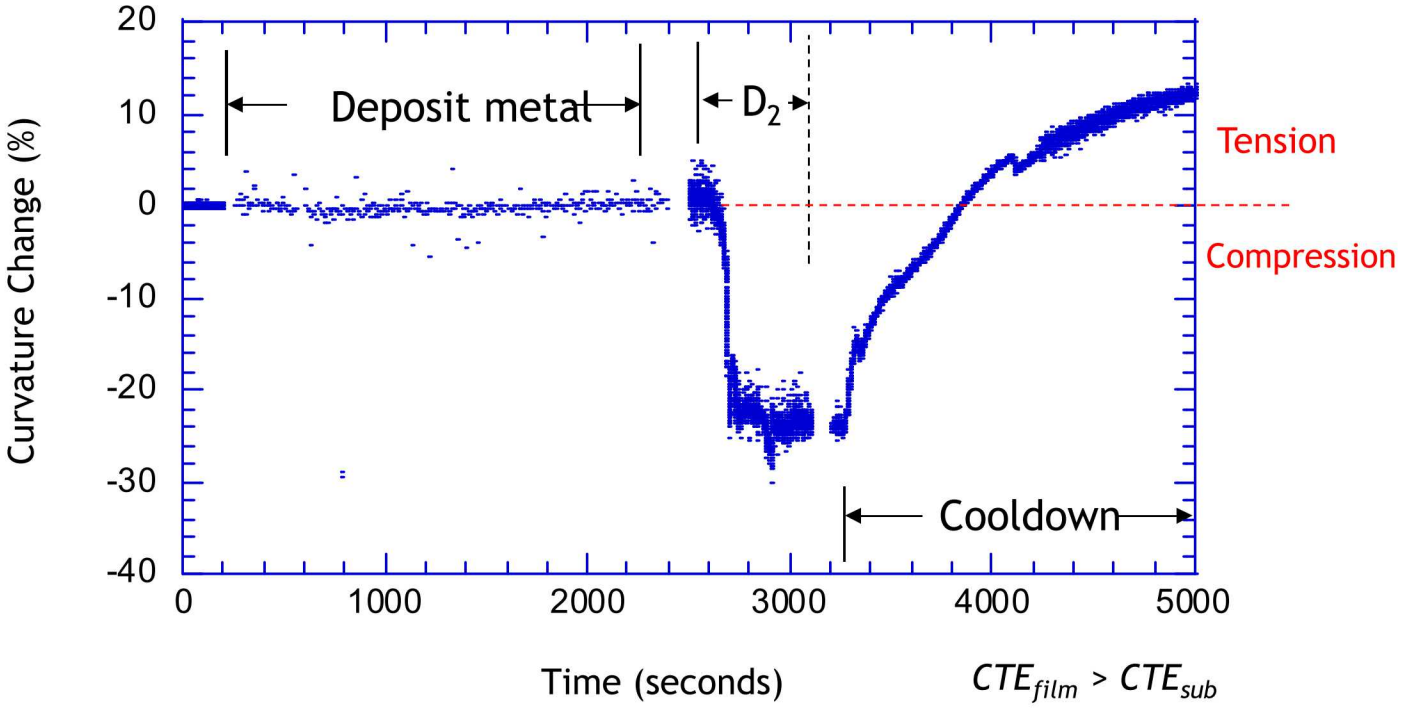
$$\kappa - \kappa_o = \frac{-6\sigma h_f}{M_s h_s^2}$$

κ = **Curvature**
M_s = Substrate modulus
h_s = Substrate thickness
h_f = Film thickness
σ = Stress

TiH_2 Thin Film Process Flow

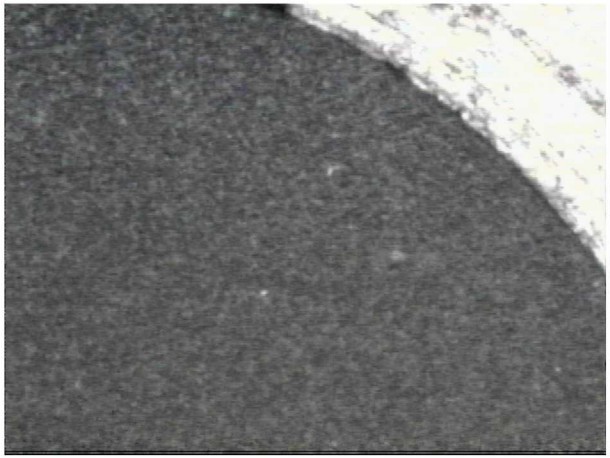


Metal thin film deposition on Al_2O_3, hydriding and cooldown



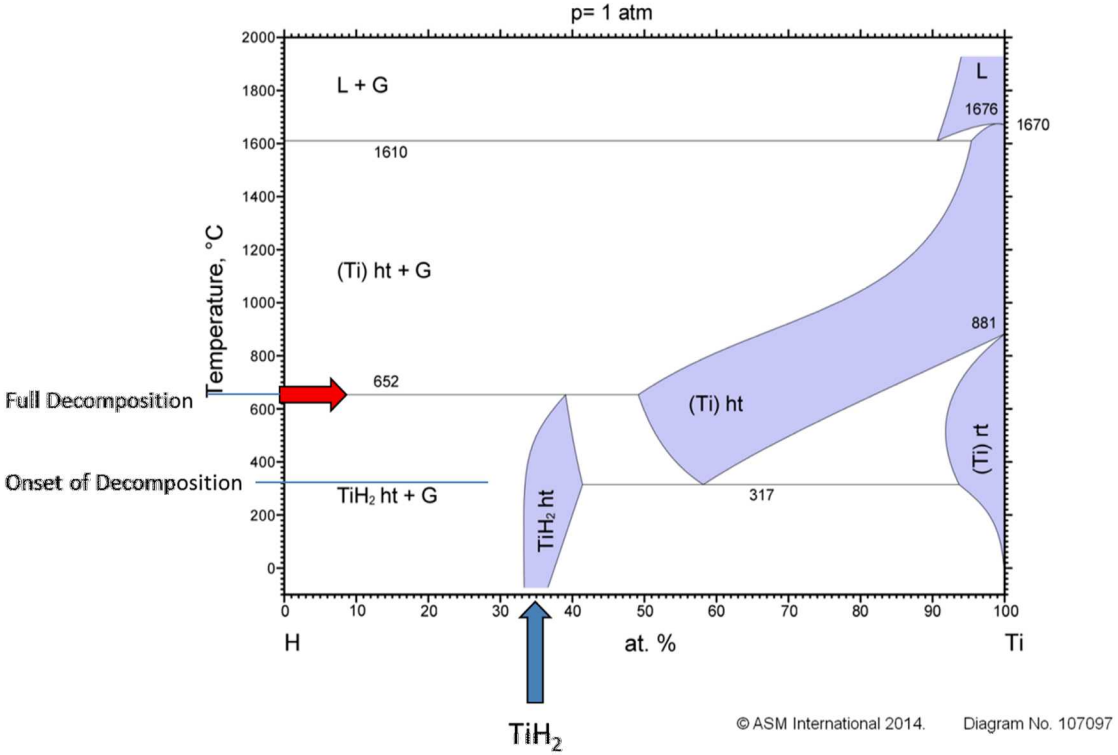
Optical Changes with Hydrogen Introduction

Evaporated Titanium Film
on Quartz Witness (metallic appearance)

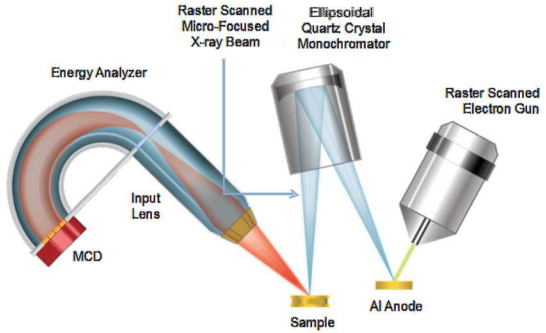


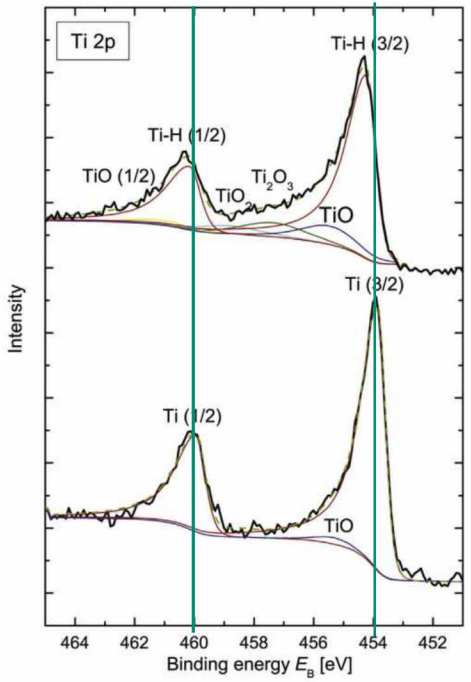
Just After
Hydrogen Introduction
(film appears dark and rough)

Hydrogen-Titanium Binary Phase Diagram



X-ray Photoelectron Spectroscopy (XPS/ESCA)

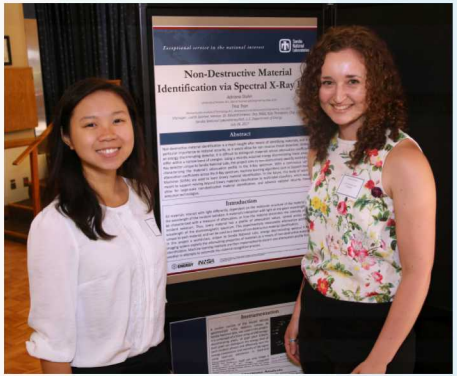


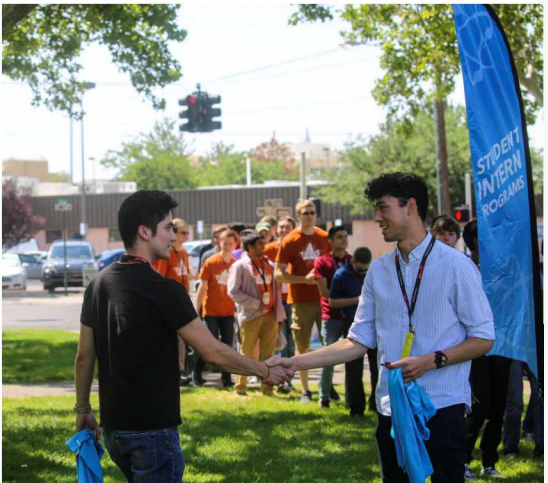


Small binding energy shifts allows hydride compositional analysis, Ti, TiHx, TiOy

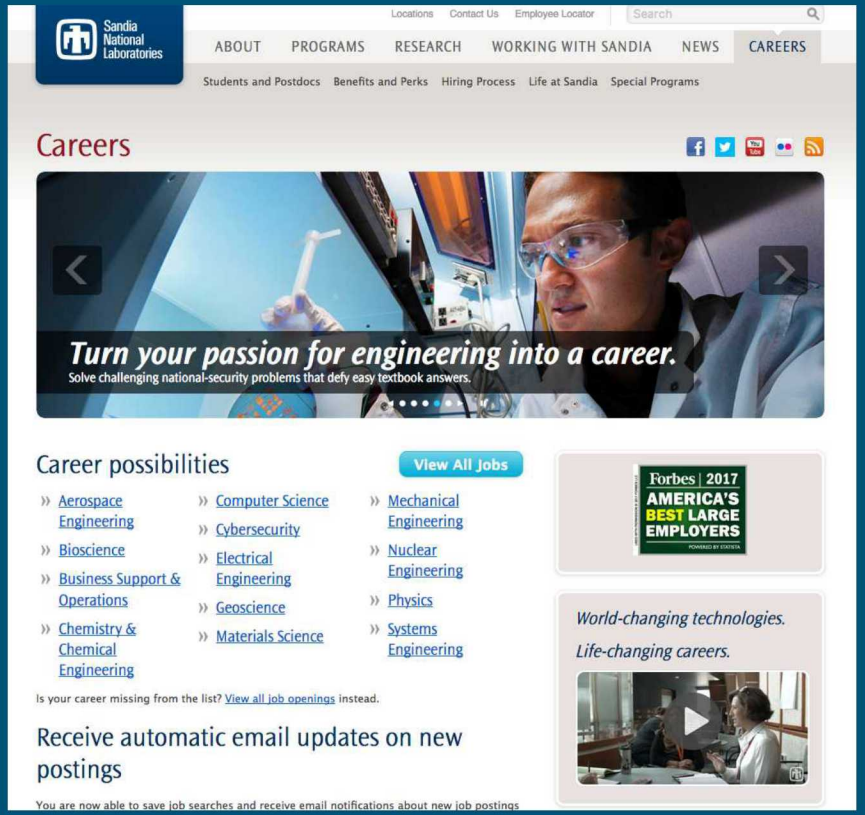
Internships – Outreach and Networking Events

- Summer Welcome Event
- Intern Career Fair
- Intern Symposium
- Facility Tours
- Speaker Forums
- Professional Development Classes



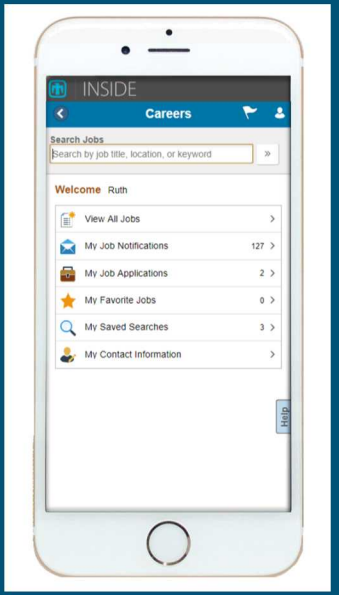


Apply Online! sandia.gov/careers



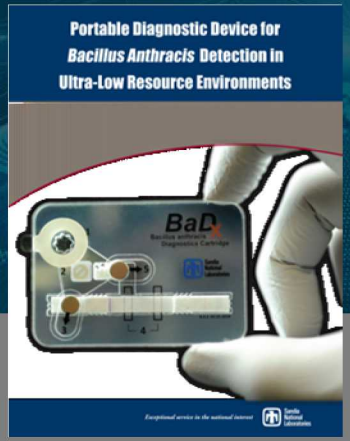
Sign up for Automated Job Notifications!

Mobile Job Applications



Backup Slides

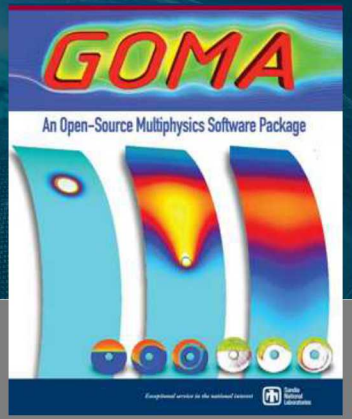
Work with real-world impact



Portable Diagnostic Device for Bacillus Anthracis Detection

Sandia developed a pocket-sized cartridge to sense concentrations of virulent B. anthracis, the bacteria that causes anthrax infection.

>> WATCH VIDEO



GOMA 6.0

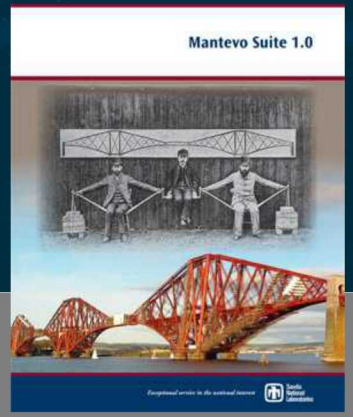
Sandia develops a software package for modeling and simulation, which solves problems in all branches of mechanics, including fluids, solids, and thermal analysis.

>> WATCH VIDEO

Triple Harvesting Plastic Scintillators

A new class of plastic scintillator enables efficient detection of illicit special nuclear materials that may be used to construct a nuclear weapon.

>> WATCH VIDEO



Montevo Suite 1.0

An integrated collection of small software programs (miniapps) models the performance of full-scale applications, yet requires a fraction of the code.

>> WATCH VIDEO

Sandia's Brand Promise - *Sandia's Employee Value Proposition*

- ***National Security Mission:***
  Your work contributes to the security, peace and freedom of our nation and the world
- ***Uniquely Challenging and Important Work:***
  The work you do will be challenging, and amazing with real-world impact
- ***Work with Great People:***
  You will work with extraordinary people, the top minds in their field
- ***Research Facilities Like None Other:***
  You will have access to some of the best tools, equipment, and research facilities in the world
- ***Healthy Lifestyle, Work-Life Balance:***
  You will experience a balance between your work life and personal life through flexible schedules, competitive benefits, and convenient amenities
- ***Career Mobility:***
  You can have a full-life career at Sandia by working across multiple projects and areas of your interest

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Videos require wifi in order to play

Sandia Mission Video (4:36)
Sandia Our Roots(3:05)

Location Videos
Sandia New Mexico Location (3:23)
Sandia California Location (3:41)

Diversity & Inclusion Videos
Black Leadership Outreach
Asian Leadership Outreach
American Indian Outreach
Hispanic Leadership Outreach

*For more Sandia Videos refer to Sandia's YouTube Channel