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Materials & Multi-Scale Patterning Approaches to Inspire Printed Electronics Solutions

PRESENTED BY

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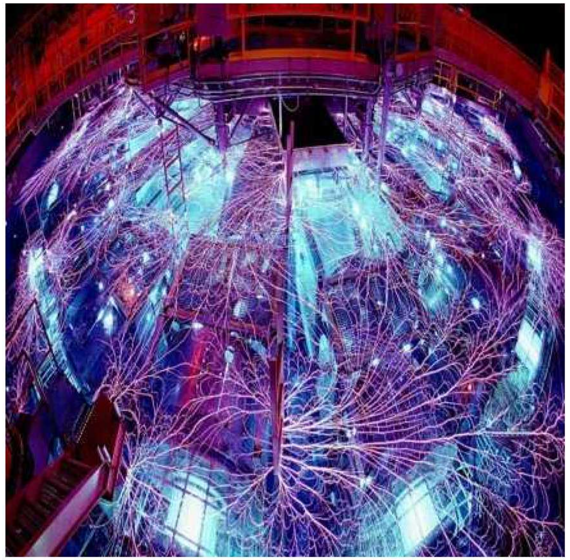
Sled Track Test

Albuquerque Labs

Z- Machine



- ~13,000 employees, ~$3.3B FY18 Budget
- Historical mission: Non-nuclear components of nuclear weapons & weapon system integration
- Today: Much broader mission in applied science & engineering for national security

> *"We work on technologies at a scientific lab, but we must emphasize that science is not an end. The end is solving problems for the nation. Science is perhaps the best tool to achieve that end."*
>
> C. Paul Robinson, SNL President 1995-2005

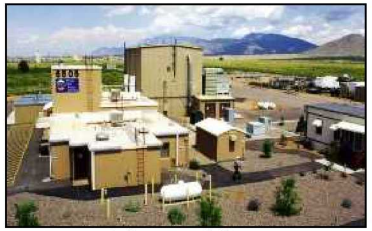
Sandia Materials & Process Science

- ***Fundamental Materials & Process Science***
  - Develop/integrate theoretical insights, computational simulation tools, and experiments to provide foundational, predictive understanding
  - Develop innovative new materials and process technologies
  - Create advanced materials analysis & process diagnostics tools
- ***Materials & Process Advanced Development***
  - Advanced & exploratory materials & process development
  - Production process development & technology transfer
- ***Materials Engineering/Production Support***
  - Materials & process selection/optimization
  - Problem solving, production support
  - Understanding & quantifying the margins

<u>Multiple Large Materials R&D Facilities</u>

Processing & Environmental Technology Laboratory

Center for Integrated Nano Technologies



Thermal Spray Research Laboratory

Advanced Materials & Processes Laboratory

Ion Beam Laboratory

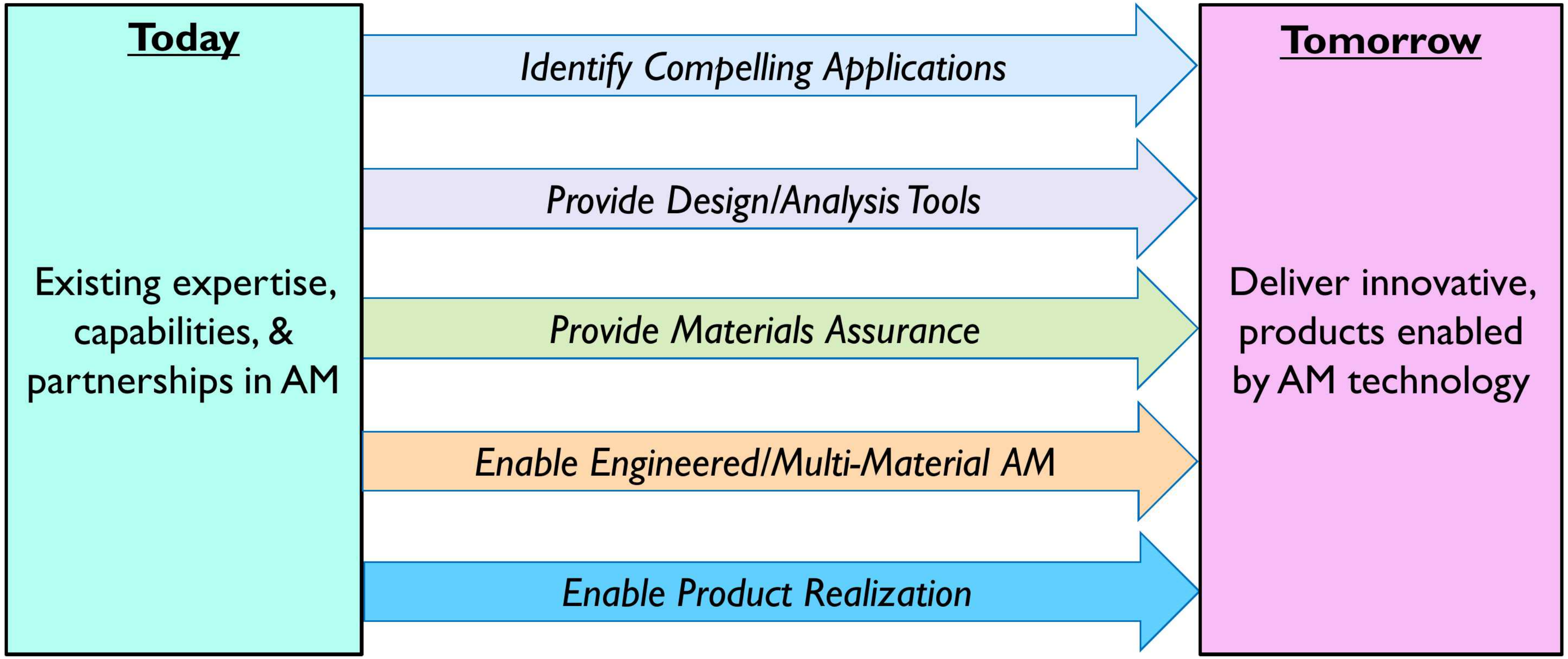
Integrated Materials Research Laboratory

Microsystems Science & Technology Center

Advanced Materials Laboratory

Sandia's Additive Strategy

Vision: *We will deliver innovative products – impossible to create with traditional technologies – by exploiting the revolutionary potential of Additive Manufacturing and Digital Printing*



5 Strategic Thrust Areas

Which tools are right for the job?

Powder Metal and Polymer

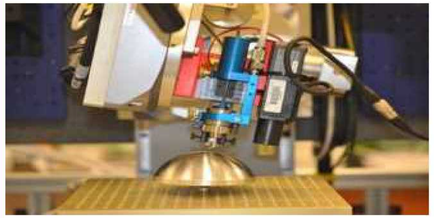

3D SYSTEMS

eos


stratasys

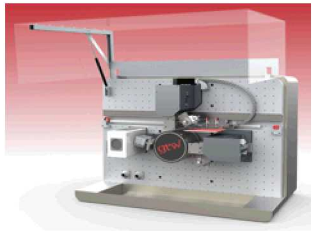
Direct Ink/Laser Write





OPTOMEC
Production Grade 3D Printers... with a Material Difference
nScrypt
nanoscribe
Nordson EFD
Sandia National Laboratories
FUJIFILM

Scalable Printing

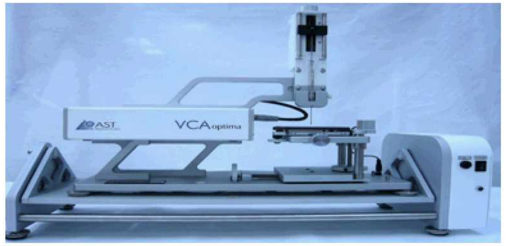



RK
gtw
HARPER
HarperScientific Division

Thermal/Photonic Processing


NOVACENTRIX
PLASMA ETCH
PROGRESS THROUGH INNOVATION

Characterization

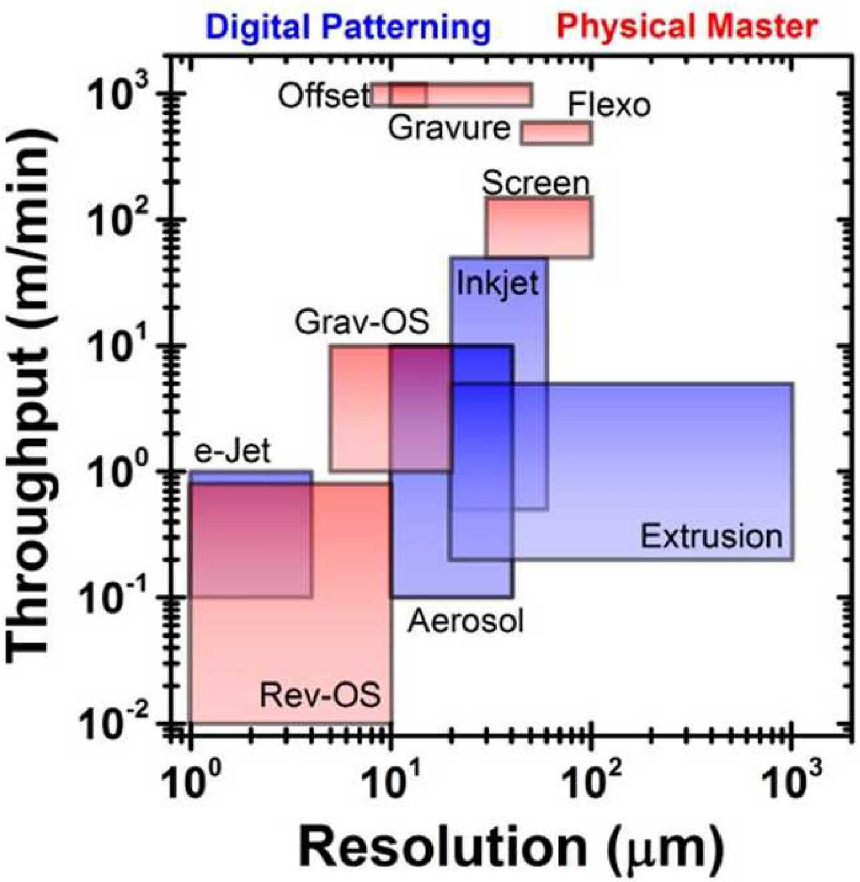



AST PRODUCTS, INC.
KEYENCE
BRUKER

Printing with Inks Carries Access to Functionality

The strong suit of printed systems is the integration of diverse materials, however process requirements and capability will influence material selections

- The research and development of inks, pastes, slurries, and resins are important for the successful implementation of *viable* printed electronics architectures
- Material properties, aging, compatibility, and lifetime performance *should* be known or well characterized prior to down-select
- Evaluate requirements and process scalability early in the design cycle
- Take calculated risks

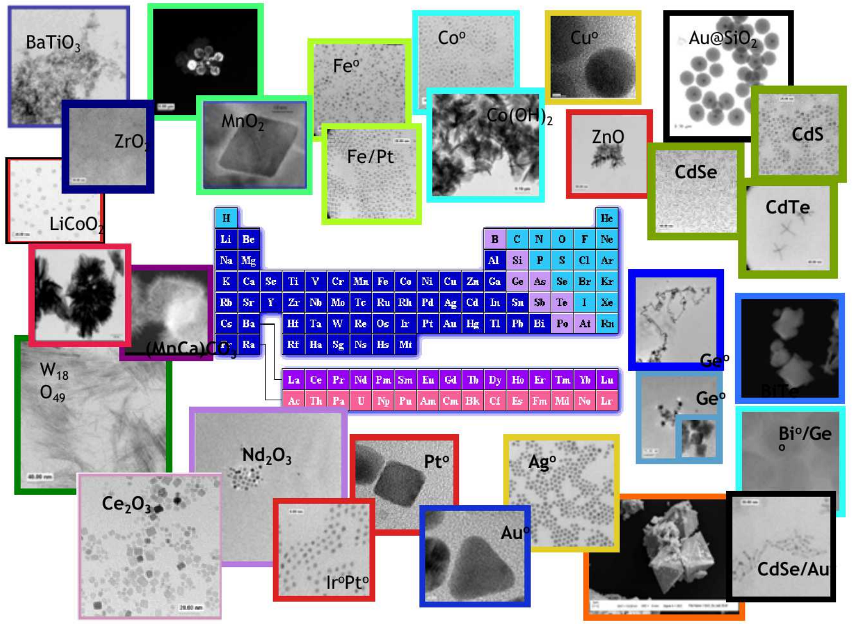


Secor, E. *Graphene Inks with Cellulosic Dispersants: Development and Applications for Printed Electronics* (2017)

AM with Particulate Inks at Sandia…Why ink-based processing?

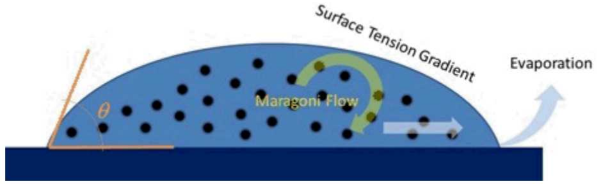
The electronic devices required for energy storage, power distribution, sensing, and RF needs require materials flexibility, low cost fabrication processes, and lean development cycles. Digital printing and templated deposition processes leverage the flexibility provided by ink based printing for advanced component research and development.

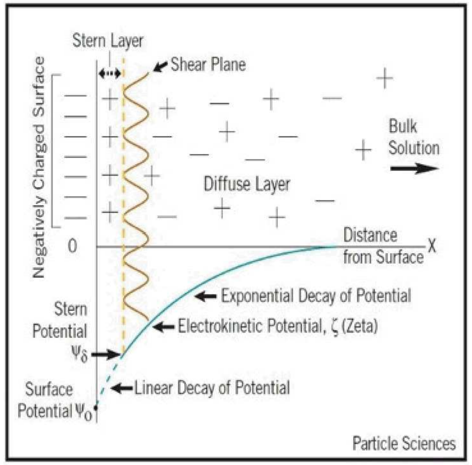
Numerous Material Possibilities



Specialty Inks

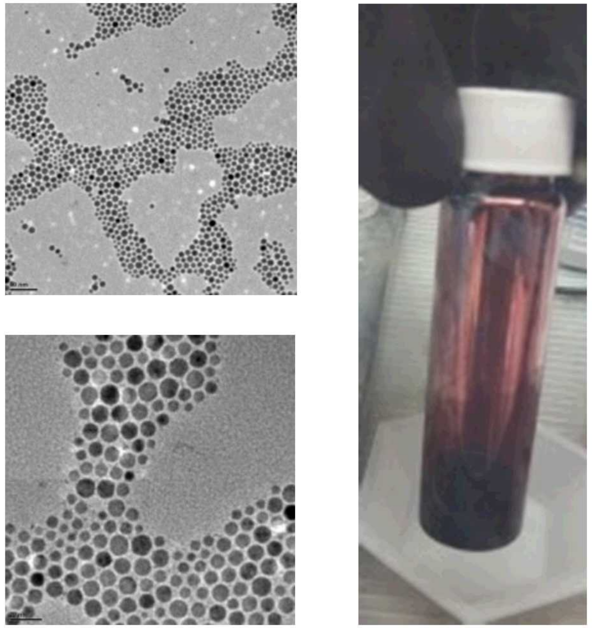
Formulation and Rheological Control





Ink Characterization

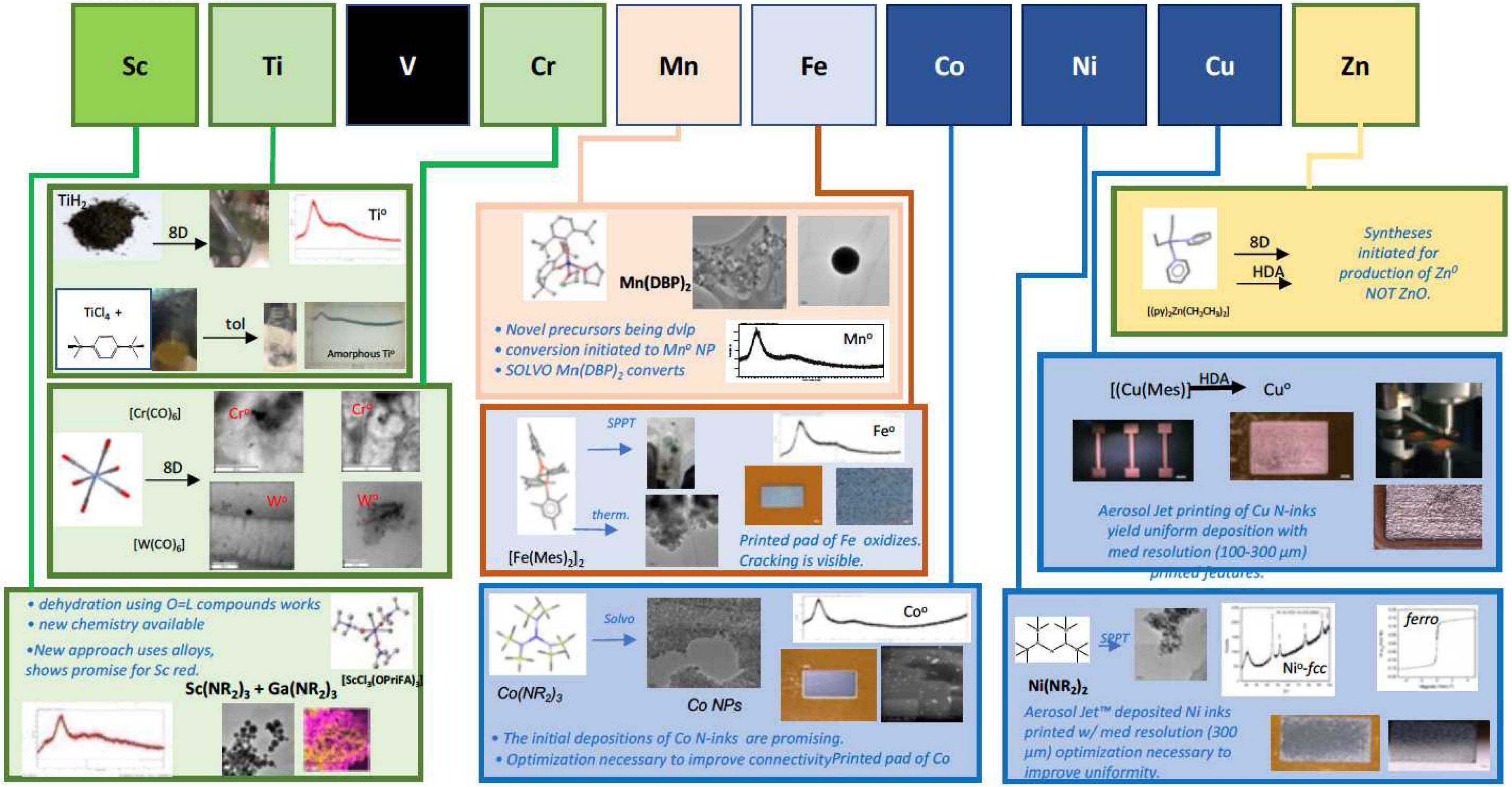
Quality Assurance



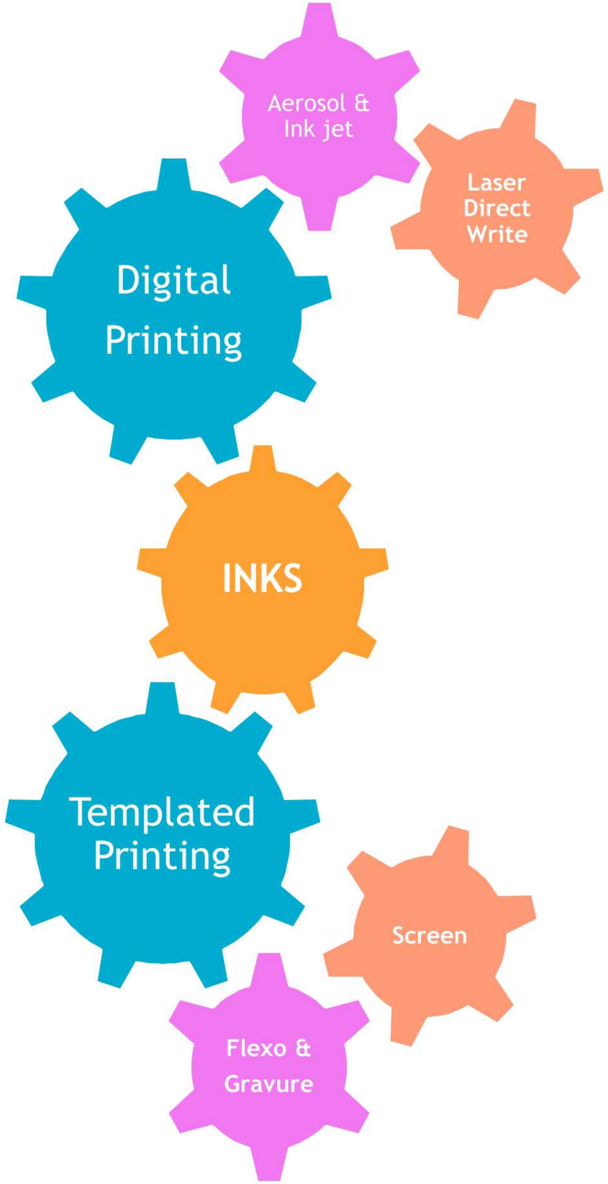
Cu Nanoparticles used to formulate an ink for aerosol jet printing

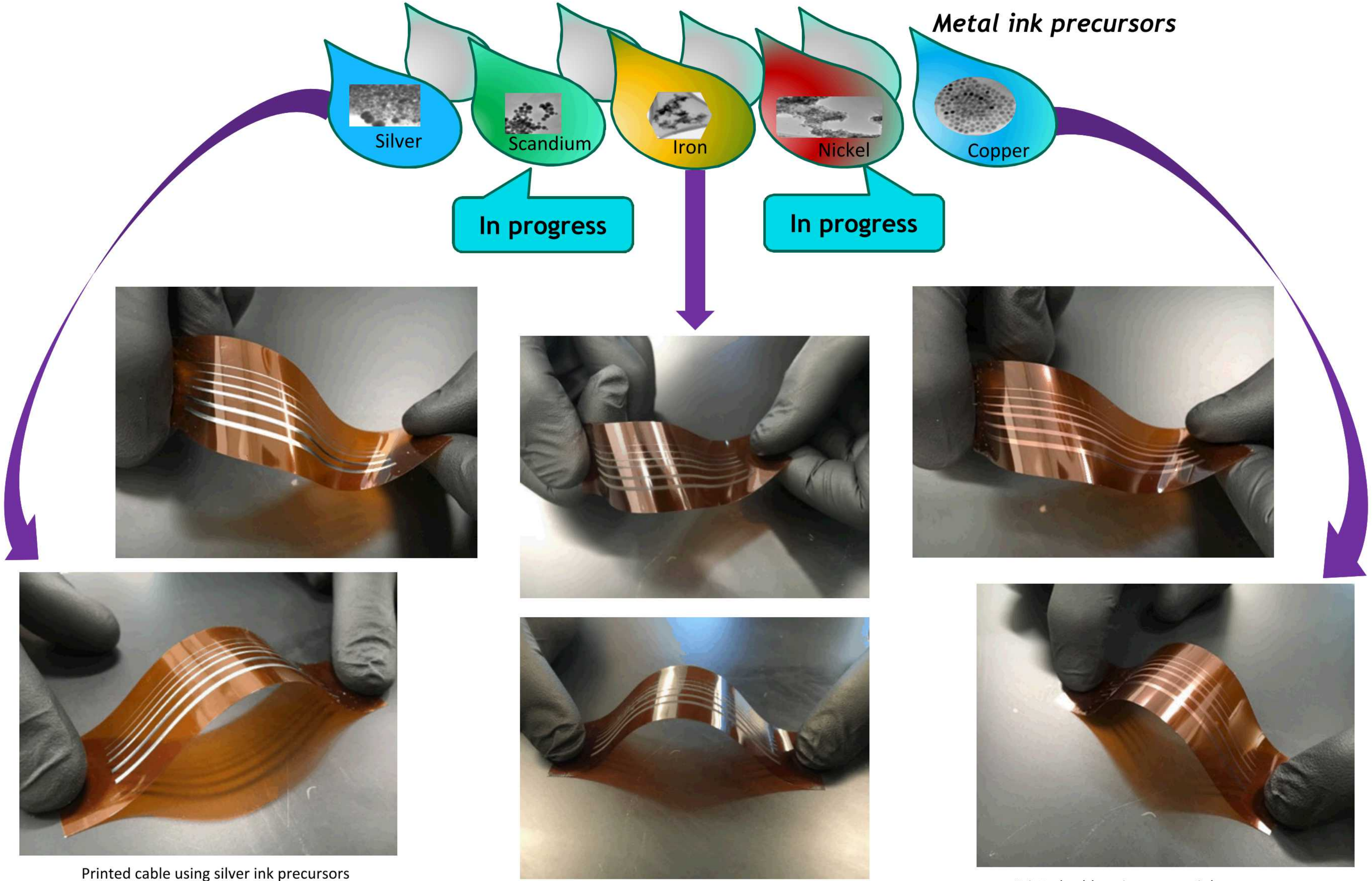
Printed Electronic Materials Development Program

Materials development initiatives are underway to address system-level incompatibilities, materials reliability (e.g. corrosion resistance), and an initial qualification framework to support acceptance and use of printed electronic materials.



Towards Printing Flexible Cables With Enabling Nano Inks





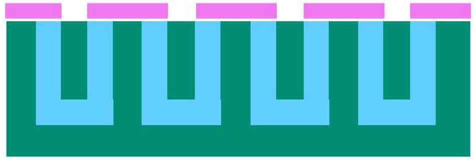
Printed cable using silver ink precursors
1.5-2 X's Bulk Resistivity

Printed cable using iron ink precursors
Permeability TBD, alloys to be developed

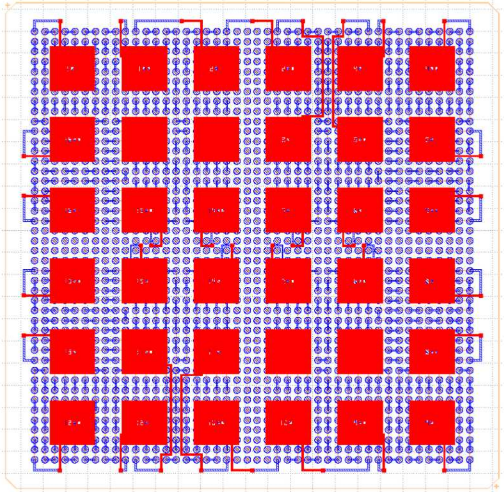
Printed cable using copper ink precursors
3.5-5 X's Bulk Resistivity

Printing High Density Interconnects while Demonstrating Scalability

An interconnect strategy for CMOS device test and evaluation

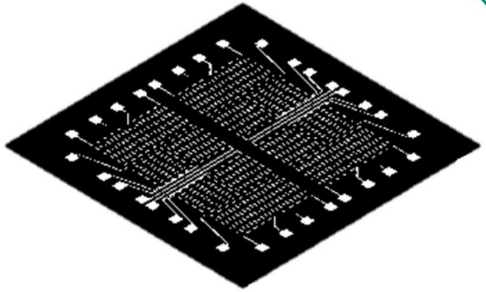


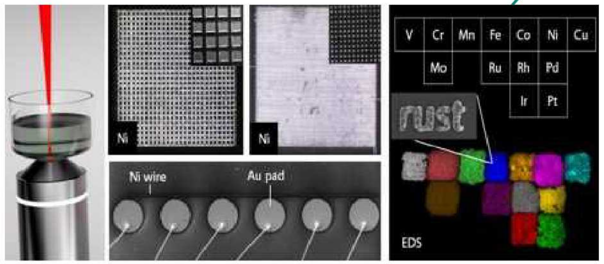
CMOS
STACK
REQUIRED METALIZATION



16 daisy chain sub-nets consisting of 100 contact points per sub-nets

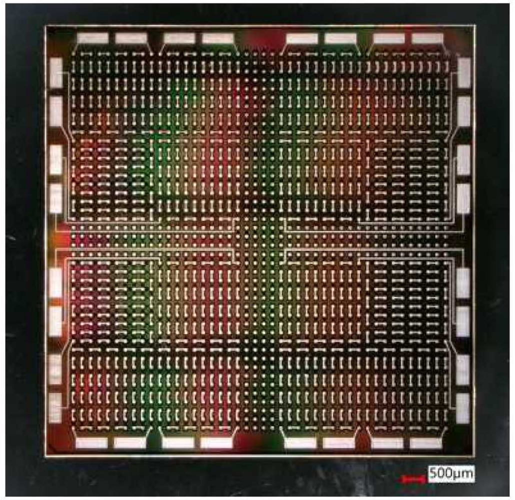
Aerosol Deposition



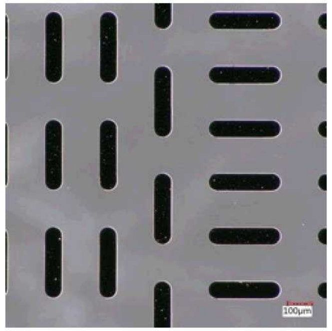


Multiphoton Lithography/

Aerosol Jet printed interconnects

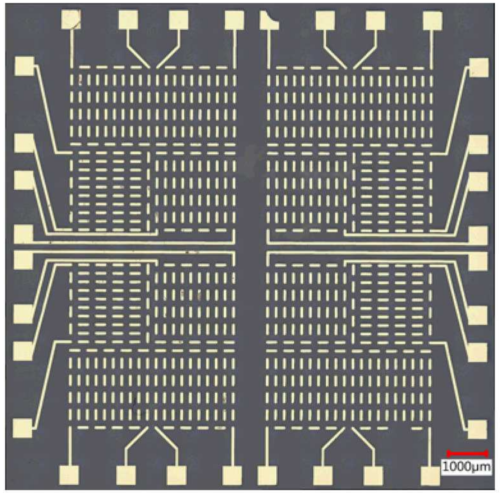


Direct digital Ag on bare die



Fully printed shadow mask

Metal Evaporation



Digital enabled Au on Si

The Need for Printed Electronics is Growing

Issue

- New functionalities, more robust packaging and SWAP-agile integration methods not achievable with current commercial alternatives are needed
- Material synthesis, rheology, and process science gaps inhibit timely development & adoption of printed electronic technologies for low volume, high-rigor applications
- As an example, cables and connectors constrain system design options and can drive significant costs during development cycles

Solution

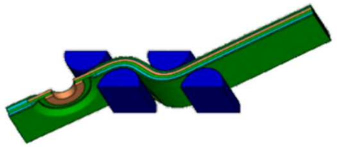
- Establish the materials and process science basis for technology development and maturation so that qualification and component insertion opportunities can adapt to evolving and fluid requirements
- Develop a fuller material selection palette to provide specific tailored functionality through engineered nanomaterials (semiconductors, conductors, dielectrics) with differentiating attributes

Impact

- Reduced design cycles & development costs for electronic subsystems
- Advance a low-volume product realization capability supportive of the lab-to-fab philosophy
- Predictive capability for creating and introducing new materials and electronic components with an ability to quantify performance margins and resilience.

Current State

Aging uncertainties, limited resilience to insult, and qualification & acceptance challenges hinder adoption of new products that utilize novel materials.

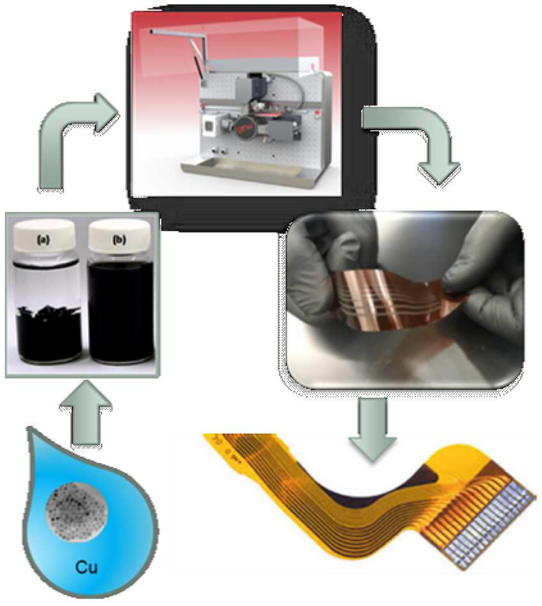


FEA model of deformed flex circuit

Flex Circuit Failure

Future State

Science guided materials synthesis & manufacturing routes to support acceptance of printed electronics piece parts and assemblies



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Thank you!
Question?