A Scalable Additive Manufacturing Technology for Large Area Printed Circuit Boards

Contract # DE-SC0017233

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Outline

- Overview of UHV Technologies/nanoRANCH
  - History and Core Competencies
- DOE NP Phase II SBIR Project for LARGE AREA PCBS
  - Confined Electro-Deposition (CED)
  - Preliminary Data and Results

- Parallel Programs:
  - DOE Office of Science SBIR Project for small SIZE 3D Chips
  - NASA SBIR Project for Alloy Deposition

UHV Technologies, Inc. (aka nanoRANCH)

- **25 year old high tech company with facilities in Lexington, KY and Fort Worth, TX**
  1. **New headquarters in Lexington, KY opened in 2016**
  2. **Over 30,000 sq. ft. combined Manu. & R&D Space**
  3. **Active collaboration with 10+ Universities**
- **3-Prong business strategy**
  1. **R&D in Advanced Thin Films, Diamond, Nano-Materials & Devices, X-Rays, Artificial Intelligence and Deep Learning, & Optical Fiber Coatings**
  2. **In-House Small Scale Manufacturing**
  3. **Commercialization through Subsidiaries and Alliances**
  4. **Various spin-offs including 1 IPO (NASDAQ) and > 22 million in Venture Capital**
- **Current Status**
  1. **20+ employees**
  2. **$2.5M revenue in 2018, $3.0M expected in 2019**
  3. **Multiple R&D contracts and products**

R&D Facilities

Core Competencies

1. **Advanced Materials R&D including Diamond, CNT and Semiconductor Films**

2. **Advanced Device/Instrumentation/System Design and Manufacturing including**
   - **Vacuum Deposition Systems**
   - **X-ray CT Systems**
   - **Metal scrap Sorting Systems**

3. **Software Development for Industrial Applications using Artificial Intelligence**

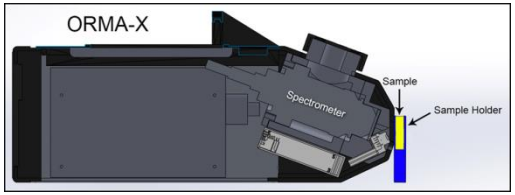
4. **Equipment Manufacturing with In-House Manufacturing Capability**

Current R&D Projects

1. **Mercury Air Continuous Emissions Monitor (CEM) 2013-16**
   - US-DOE Phase II Project + Matching funds from KY
   - Spin-off: nanoRanch Environmental Systems, LLC in Lexington, KY

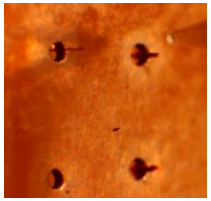
2. **In-Line High Throughput Scrap Metal Sorter 2014-20**
   - Funded by US-DOE ARPA-E Project and Commercial Partners
   - Uses advanced sensors and artificial intelligence; throughput ~ 100M lbs/year

3. **On-Line Real Time Metal Analyzers for Pharma Industry 2015-18**
   - NIH Phase II SBIR Project and KY Matching Grant
   - Real time contamination detection in solid, liquid and gel formulations



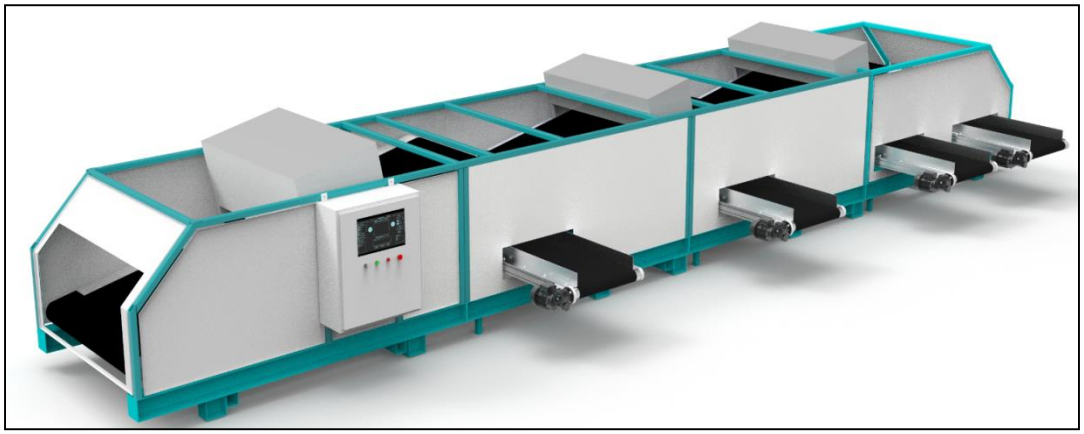
4. **Stationary CT for *In-Situ* Imaging of Roots 2017-19**
   - US-DOE ARPA-E Project

5. **Nano-Crystalline Low-Z Thin Films for X-Ray Windows 2014-17**
   - US-DOE Phase II Project and KY Matching Grant



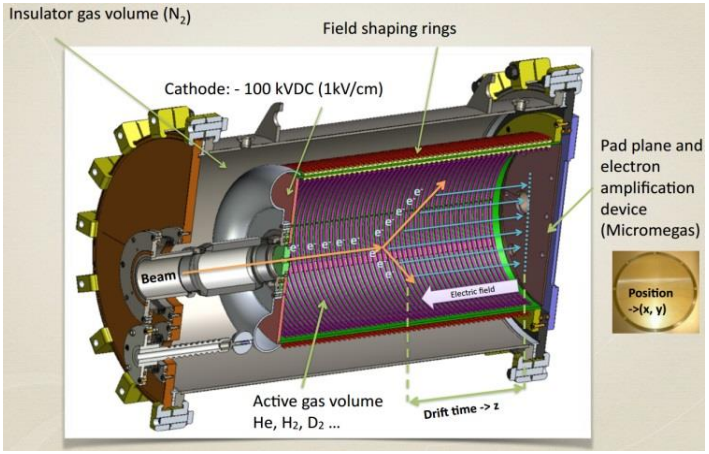
6. **A Scalable Additive Manuf. Technology for Large Area PCBs 2017**
   - US-DOE Phase I SBIR Project

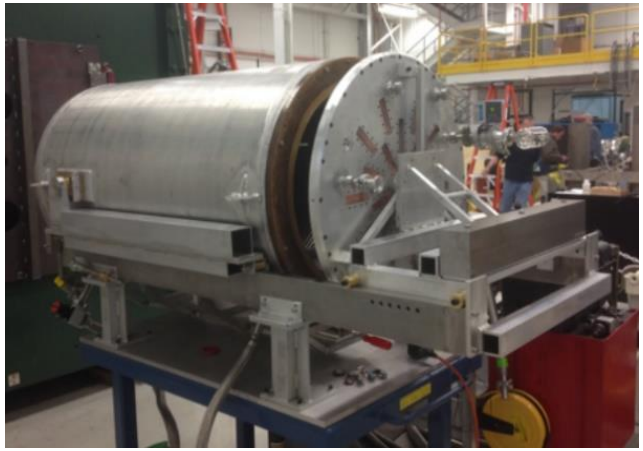
Product Photos

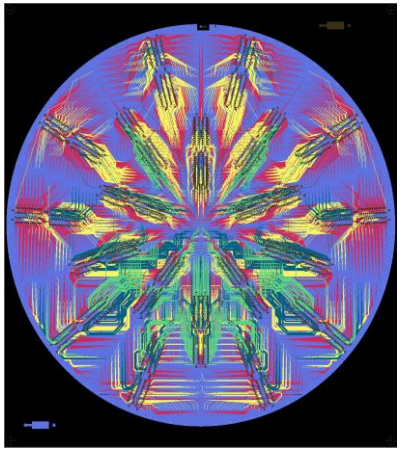


A Scalable Additive Manufacturing Technology for Large Area Printed Circuit Boards

- **US-DOE NP Phase 1 SBIR awarded in Feb. 2017**
- **Collaboration with UT-Dallas and NSCL-MSU**
- **Goal:** To develop a scalable additive manufacturing technology for large area, multiple layer printed circuit boards (15 ft x 15 ft)





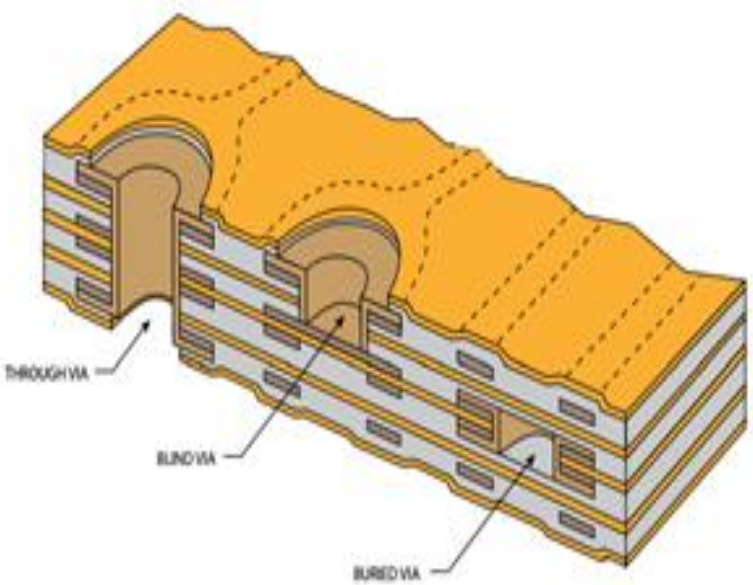


NP Phase II SBIR
Scalable 3D Printed PCBs

- **Team:** UHV, UTD and NSCL/MSU
- **Objectives:**
  1. **Develop, build and demonstrate a large area multi-layer PCB Printer for detector instrumentation used in nuclear facilities**
  2. **Develop and demonstrate innovative novel micro-pattern gaseous detector (MPGD) architectures for higher performance gas detectors**
- **Key Technical Concept**: Confined Electro-Deposition (CED)
- **Enabling Technologies:**
  - ~Bulk conductivity copper feature fabrication at room temperatures
  - Both horizontal and vertical metallic features of 1-3,000 microns.
  - Computer controlled process optimization of multiple print heads
  - AI based path optimization for higher throughput
  - Other metals and alloys can be fabricated

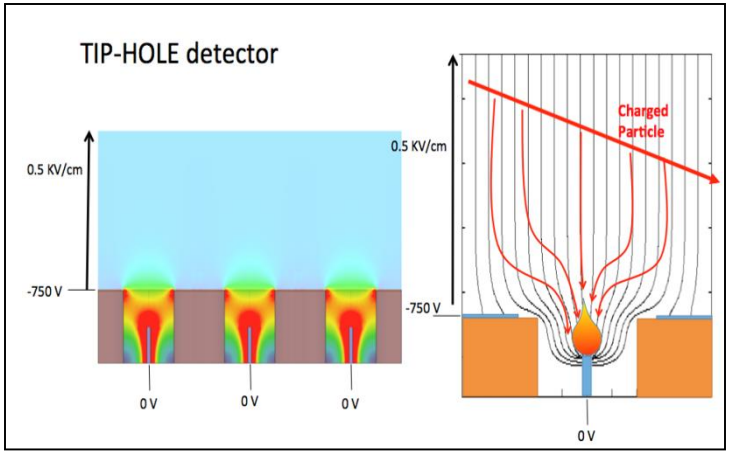
Phase II Goals

Very Large Area PCBs for NP Detectors



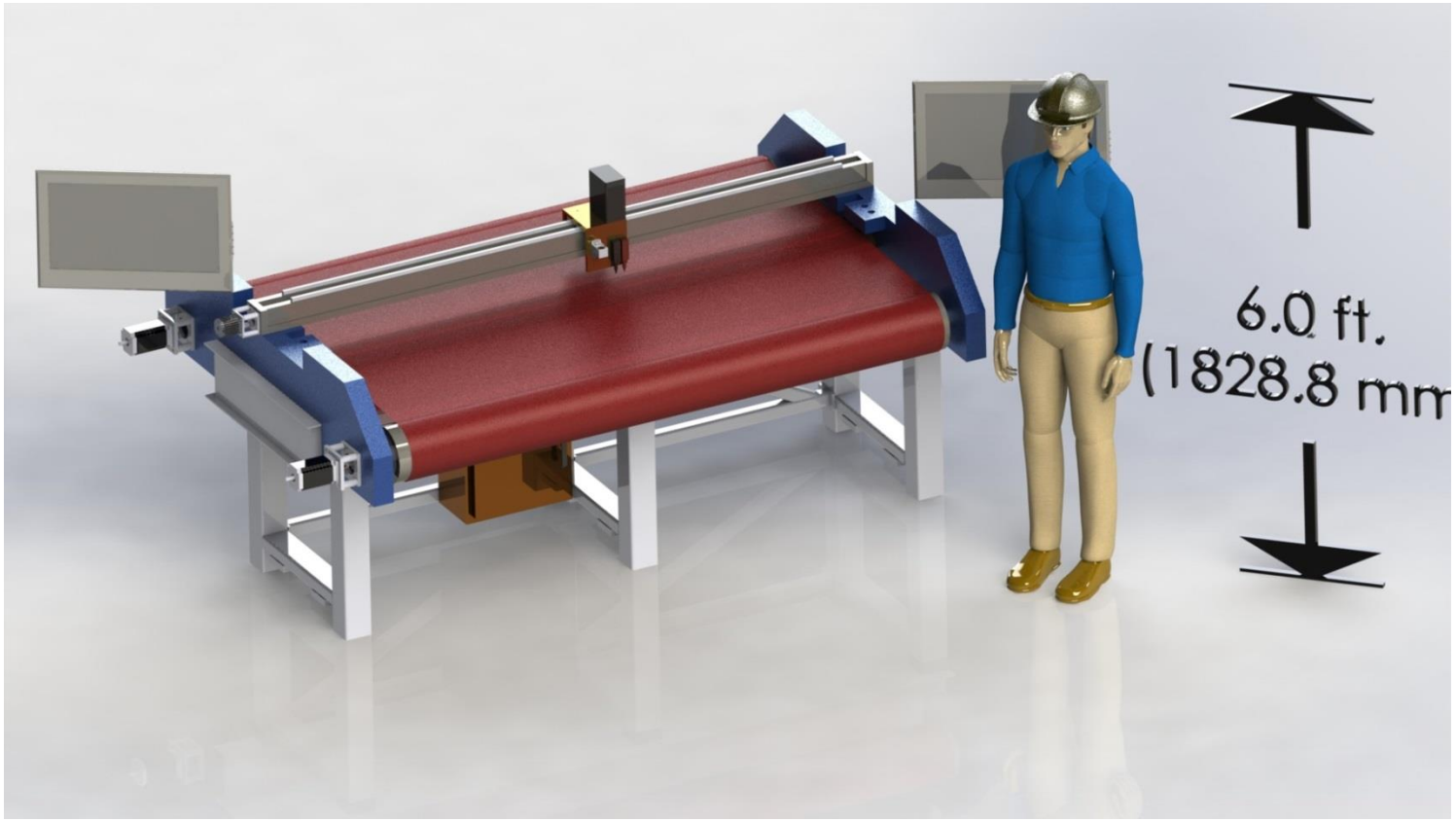
Develop Novel NP Devices enabled by Low Temperature 3D Metal Printing

TIP-HOLE DETECTOR



Cortesi and Mittig, NSCL

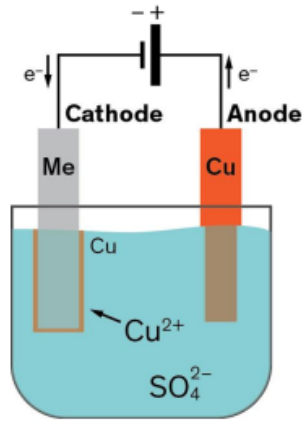
Phase II 3D Printer Under Construction at UHV



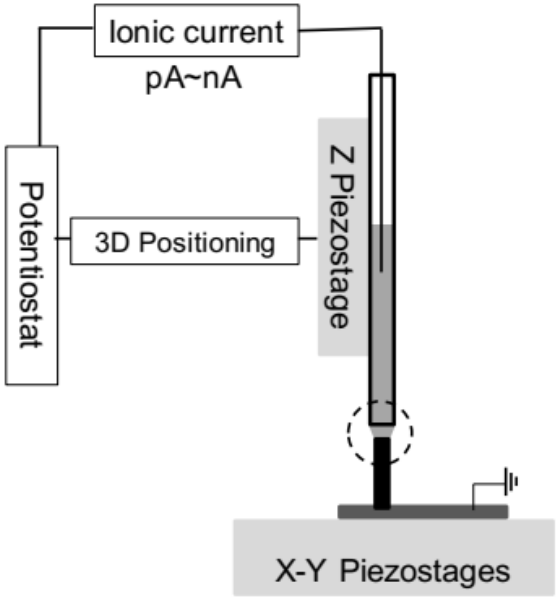
Large Area 3D Printer designed for 2 meter PCBs

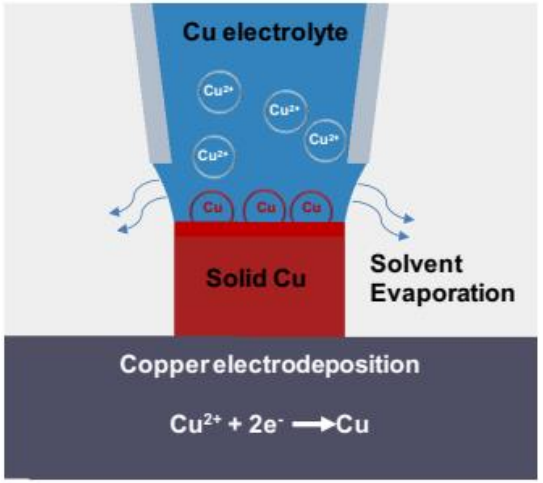
2 Meter PCB Printer under Construction

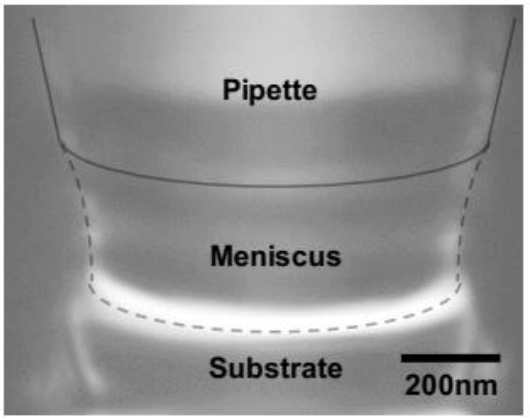
Confined Electrodeposition (CED)



Electroplating of Cu

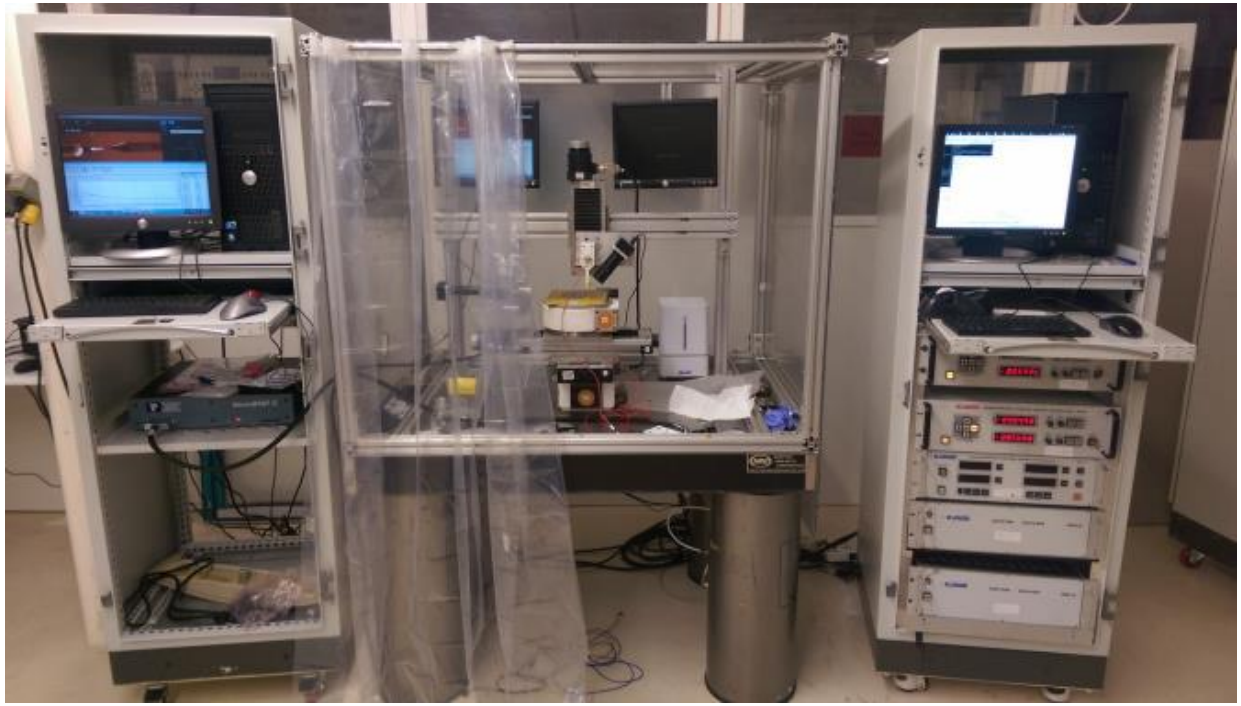


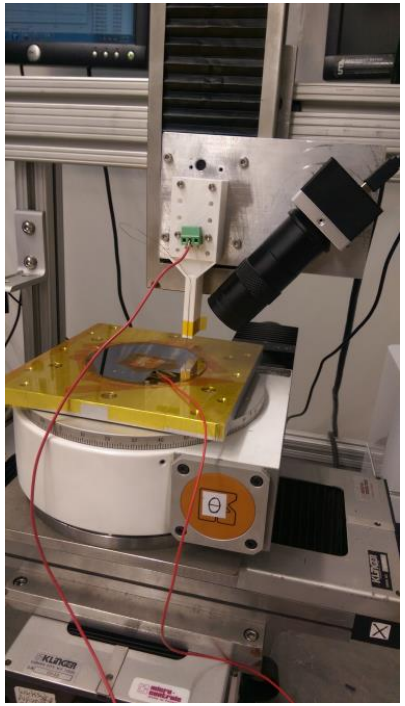




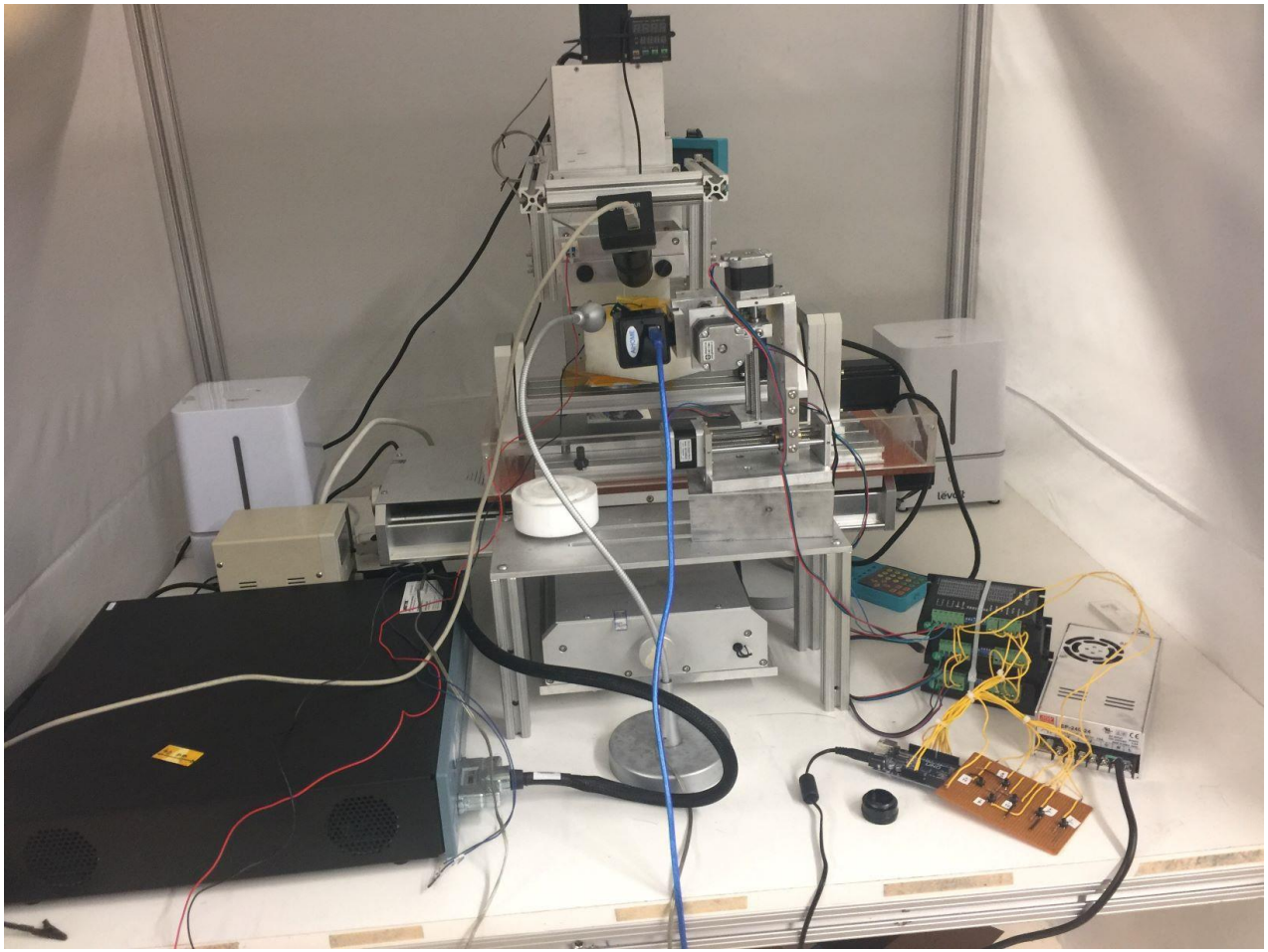
UHV's 3D Printer R&D Lab

UHV's Phase I Computer Controlled 3D Printer

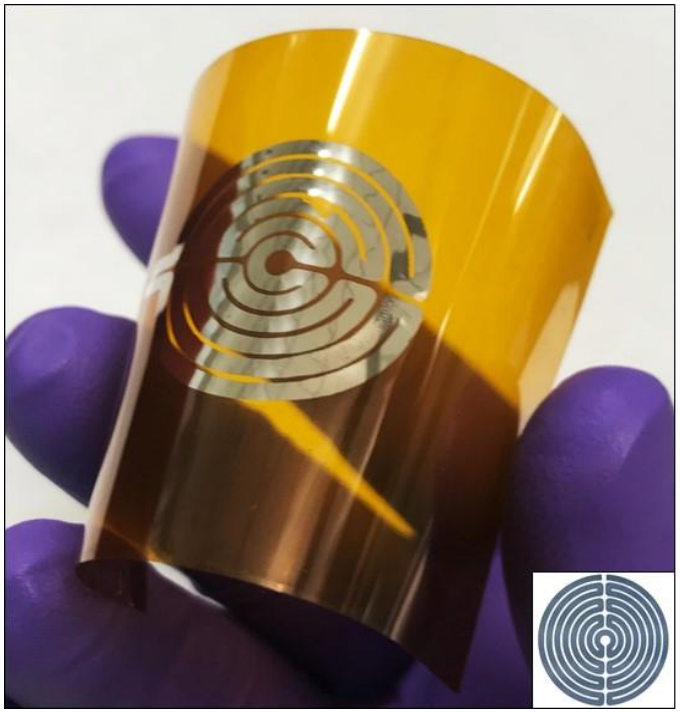


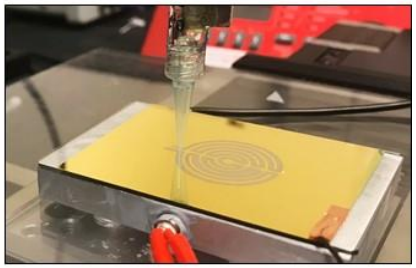


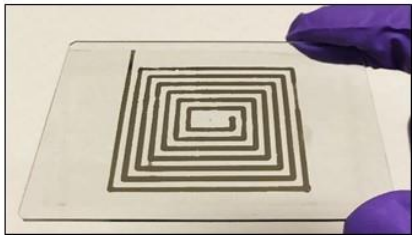
6 Axis R&D Printer

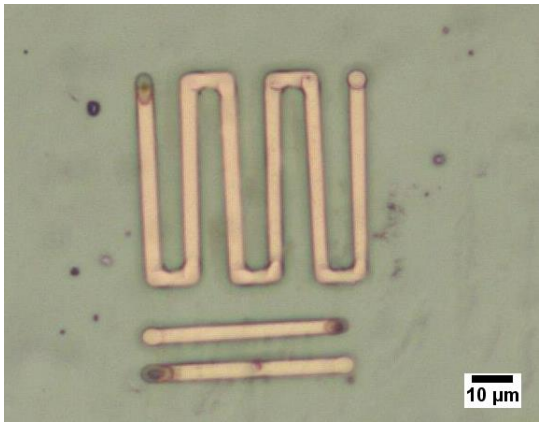


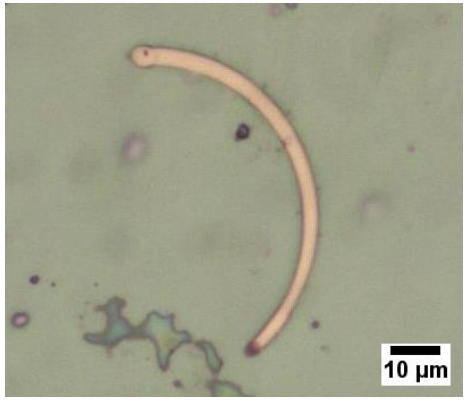
Ni and Cu patterns



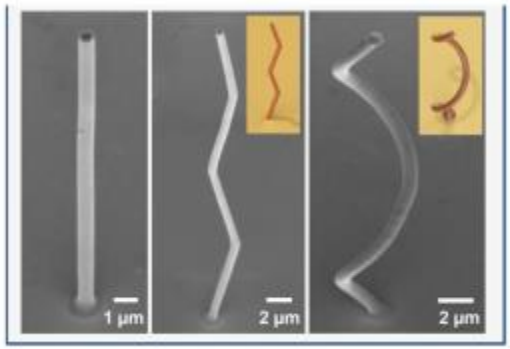


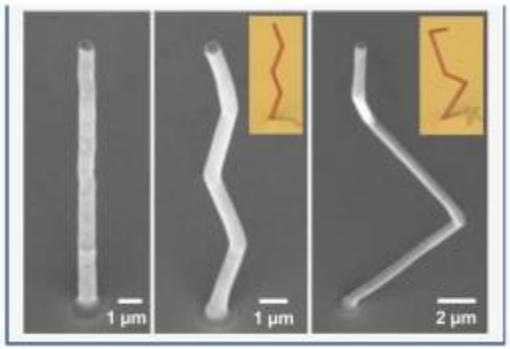


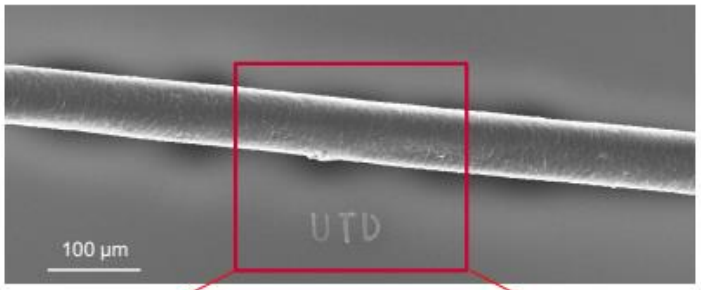


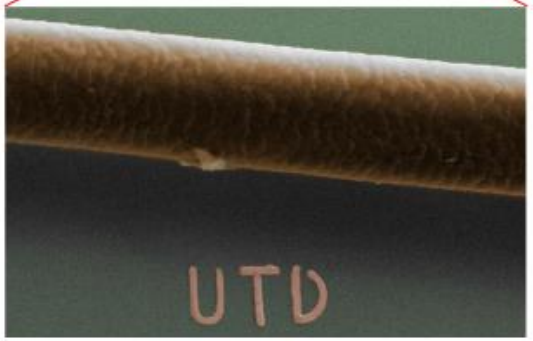


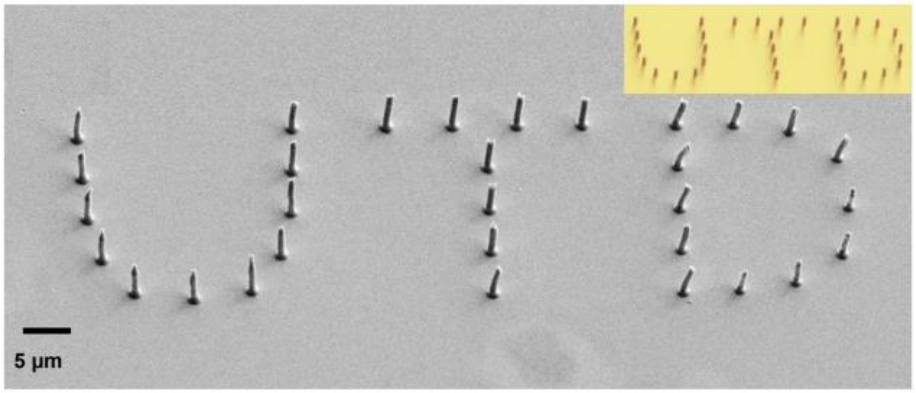
Fabricated structures



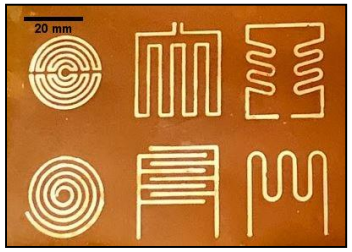


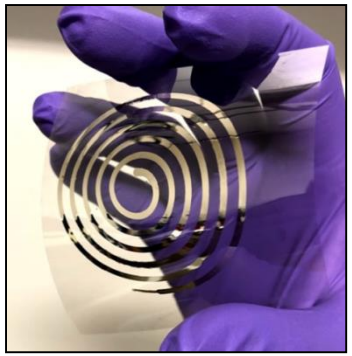


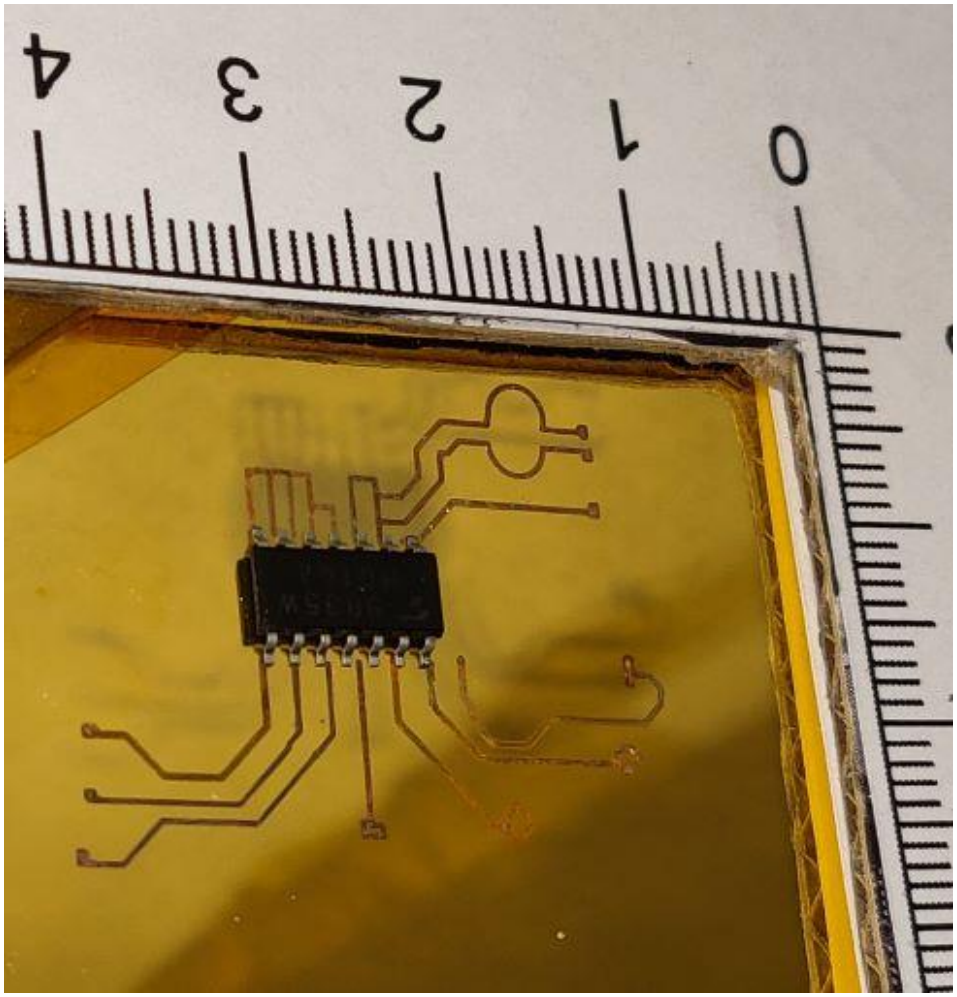


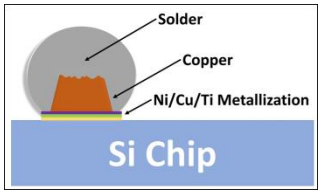


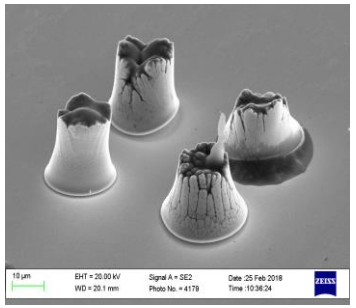
Video of PCB Fabrication by CED











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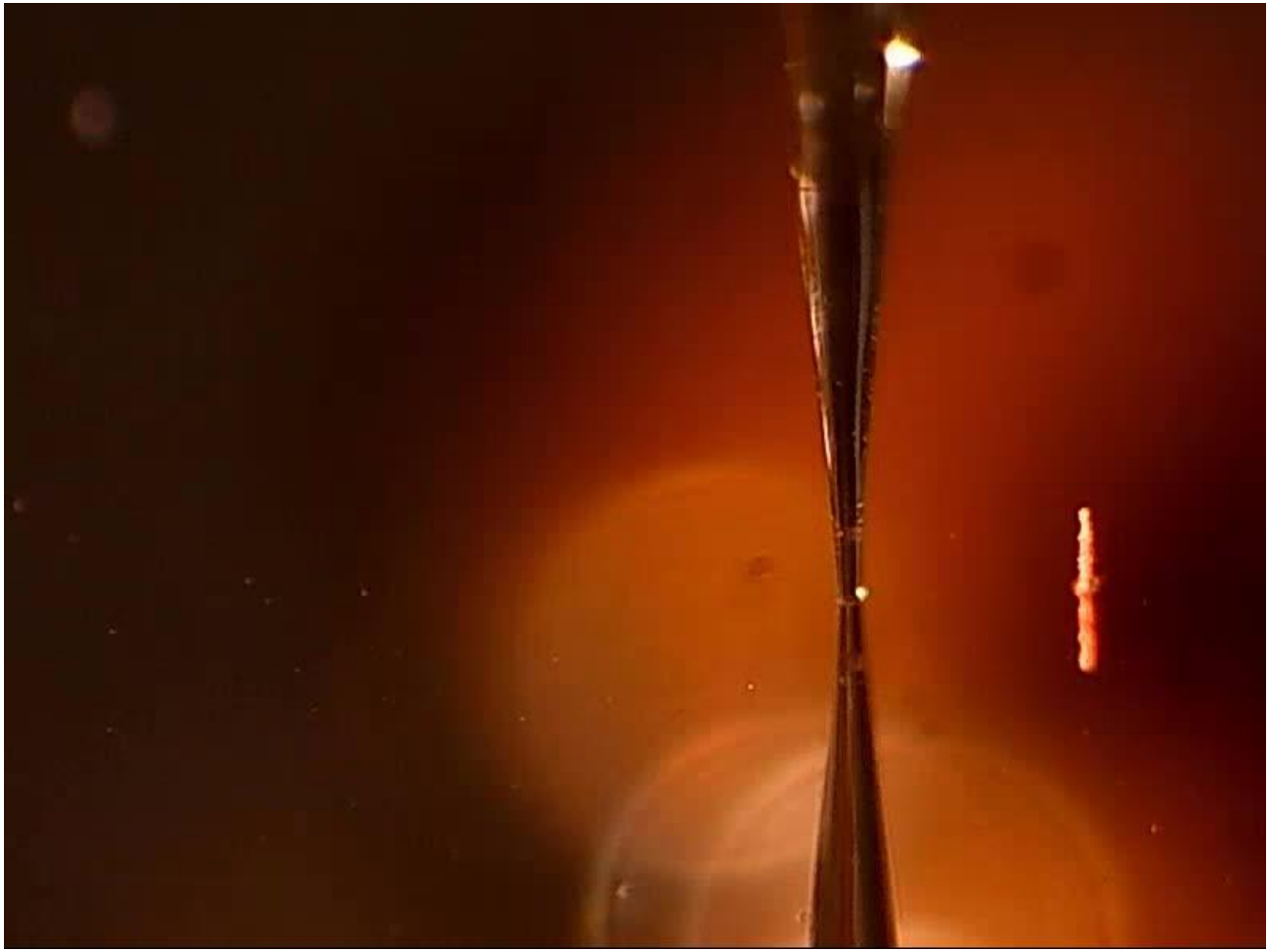
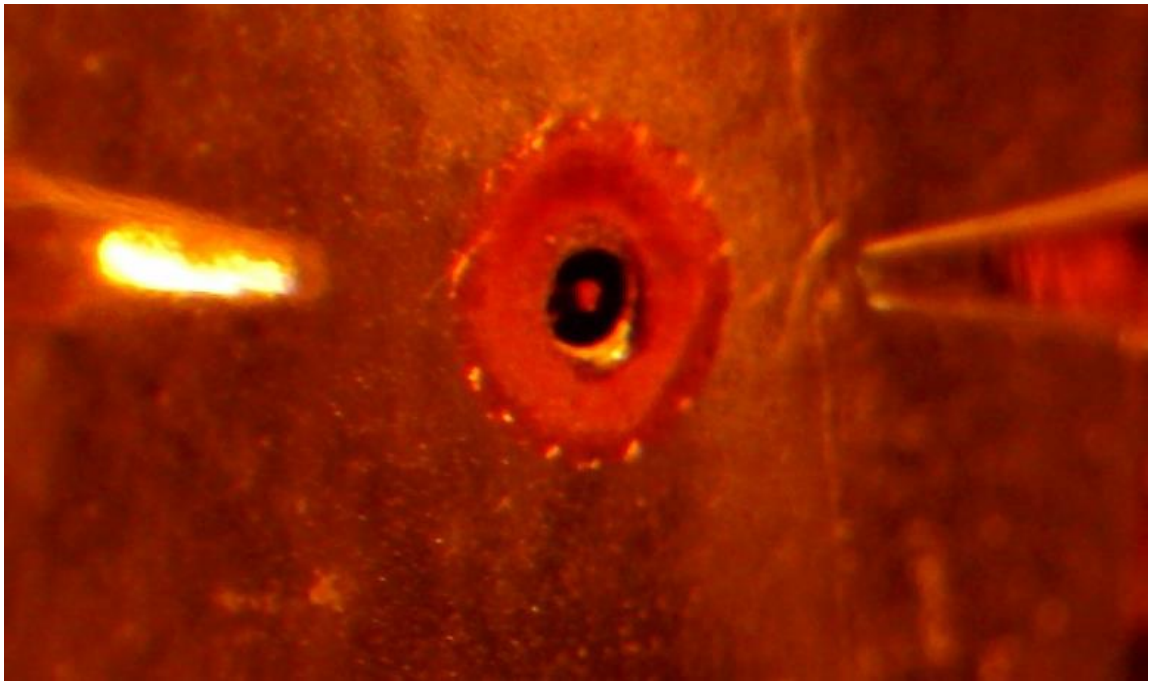
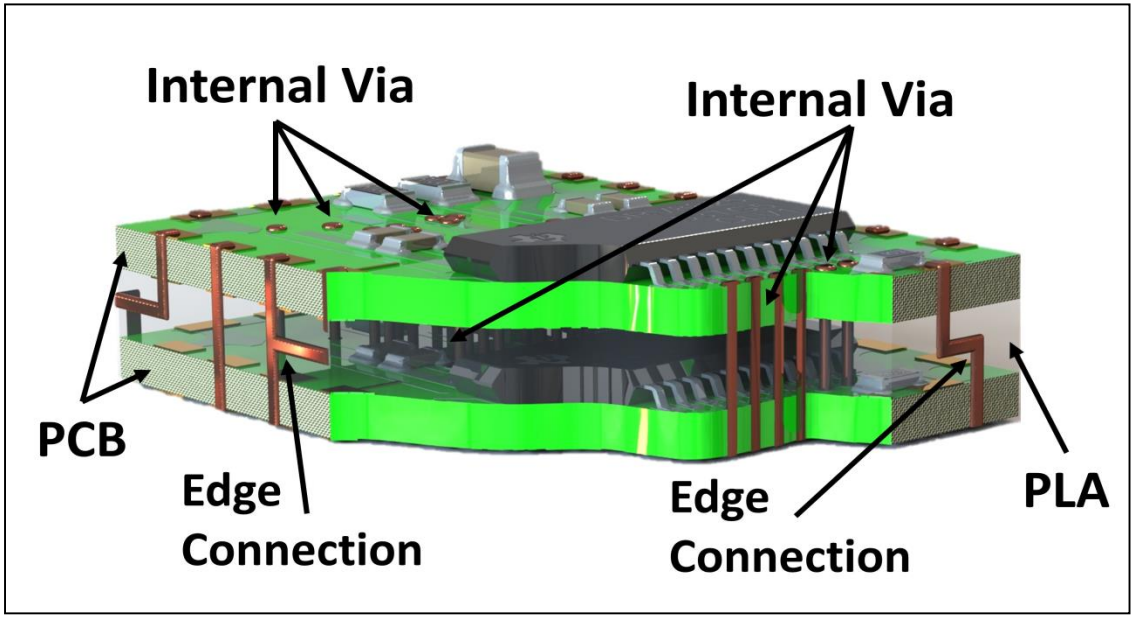
Video of 80 Micron Pillars

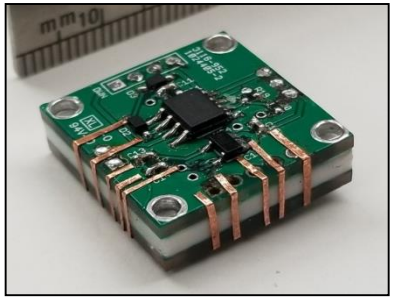


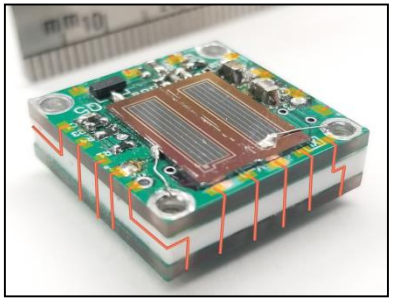
Tip-Hole Detector Photographs



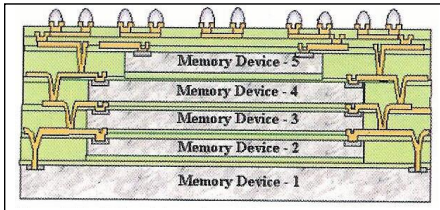
Advanced 3D Instrumentation



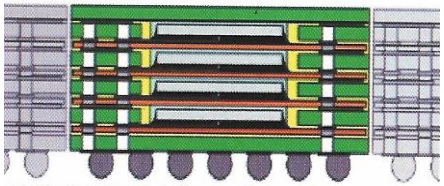




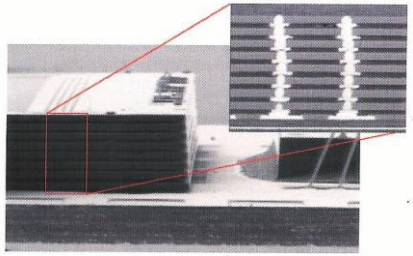
DOE Office of Science Funded SBIR 3D-Chips



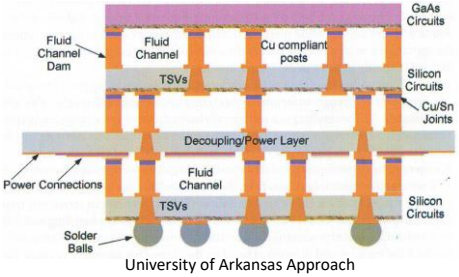
Fujitsu 3D IC Approach



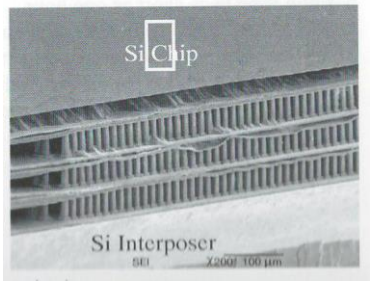
Toshiba 3D IC Approach

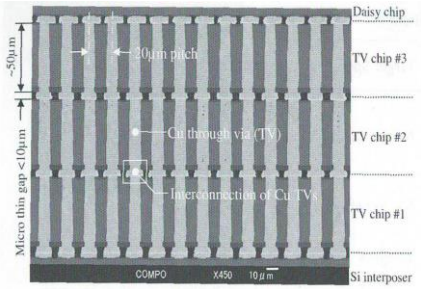


Samsung 3D IC Approach



University of Arkansas Approach





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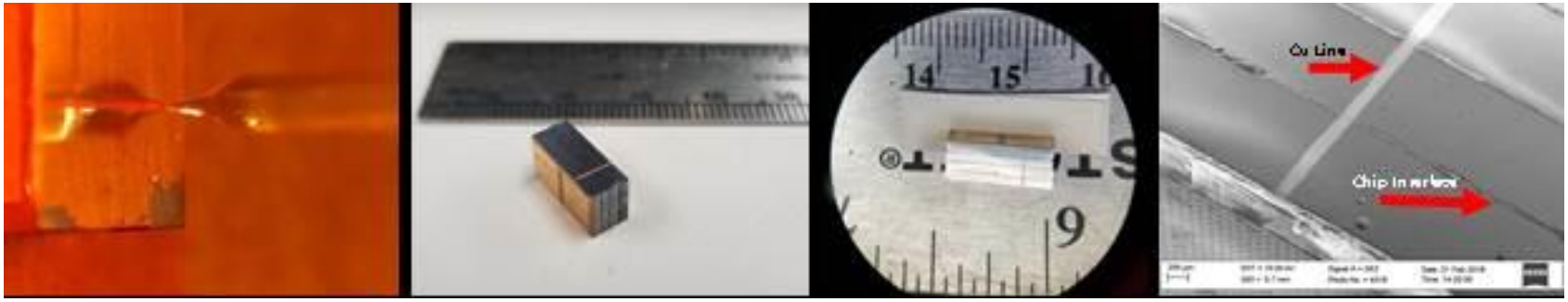
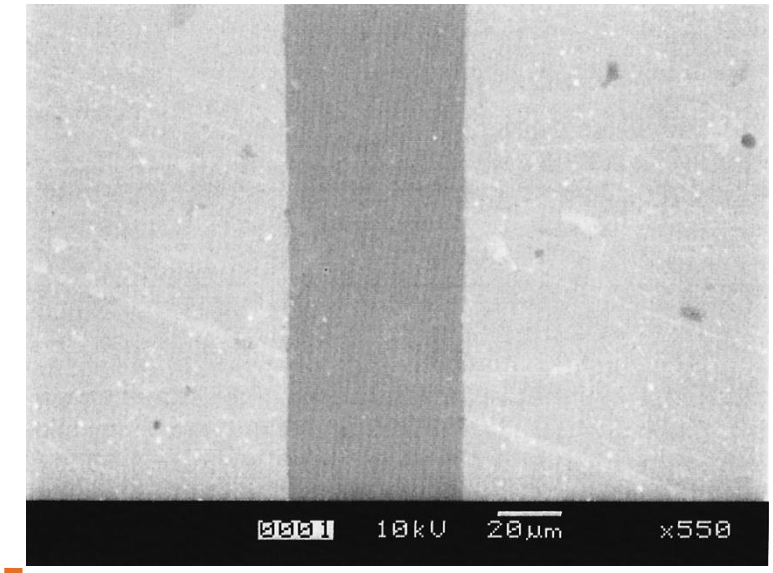
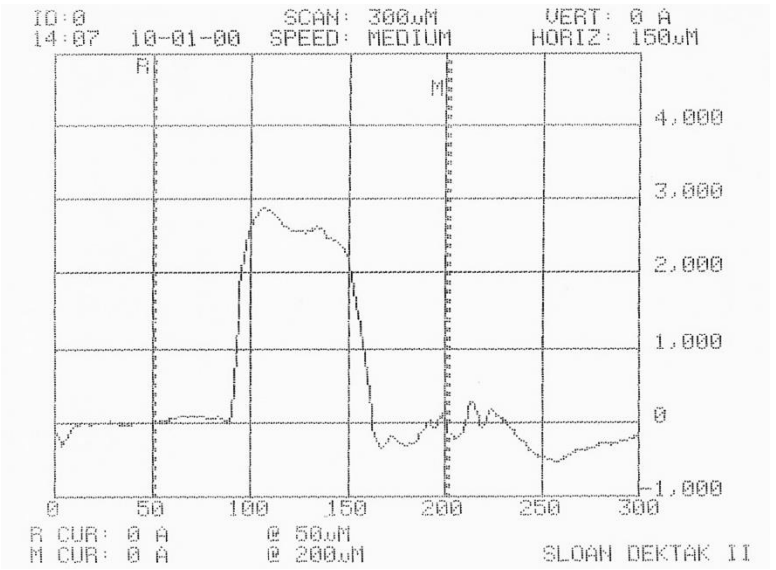
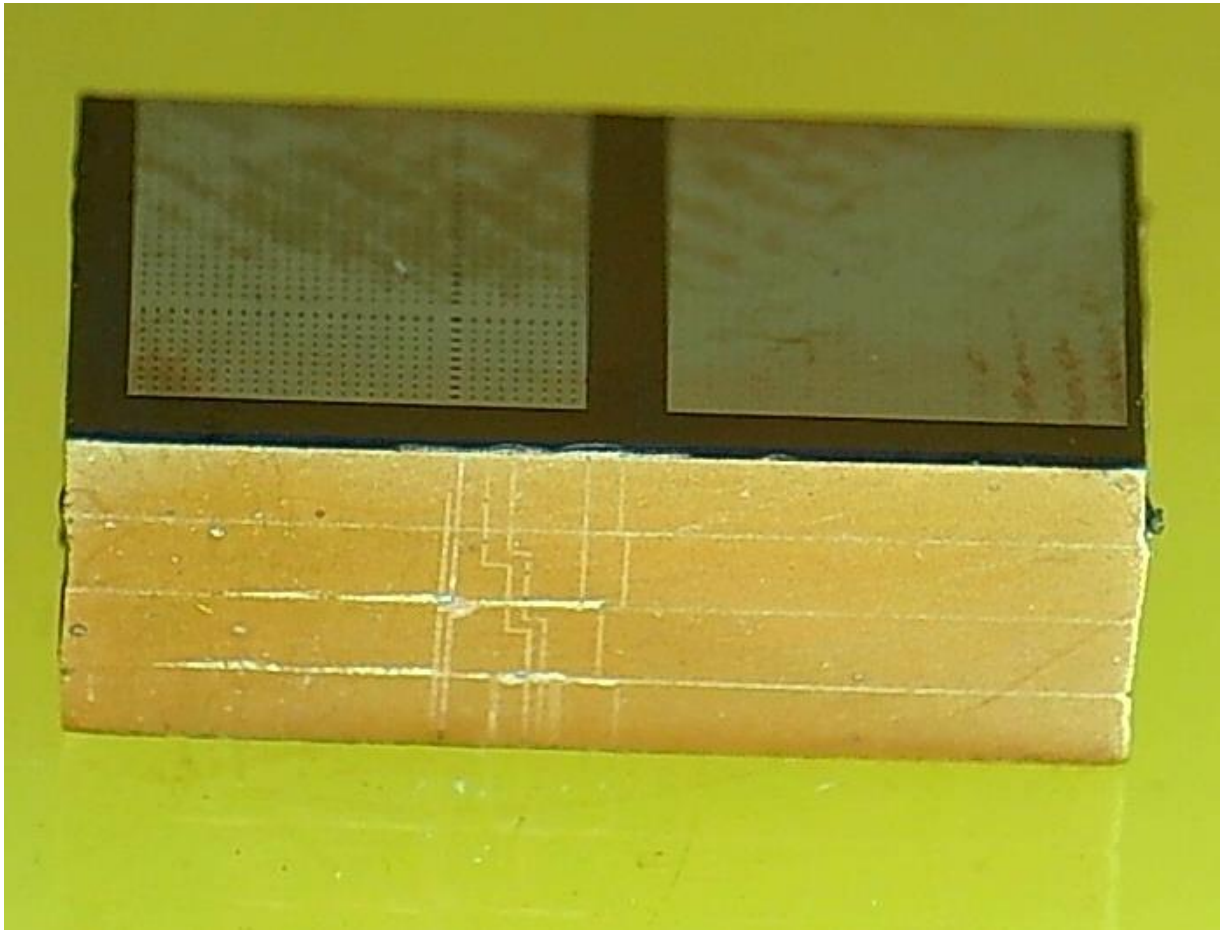
Photos of High Density Interconnects



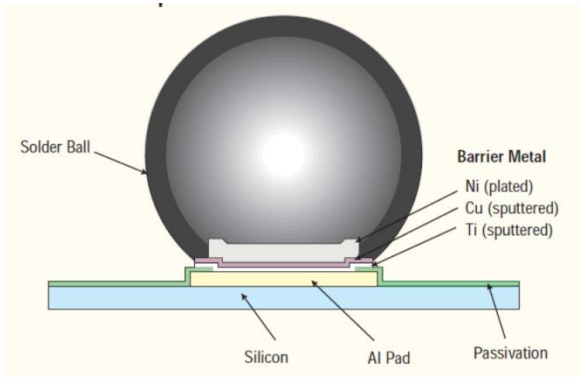


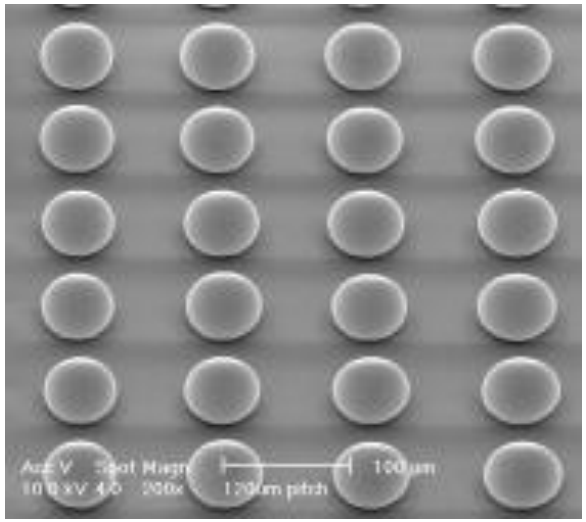


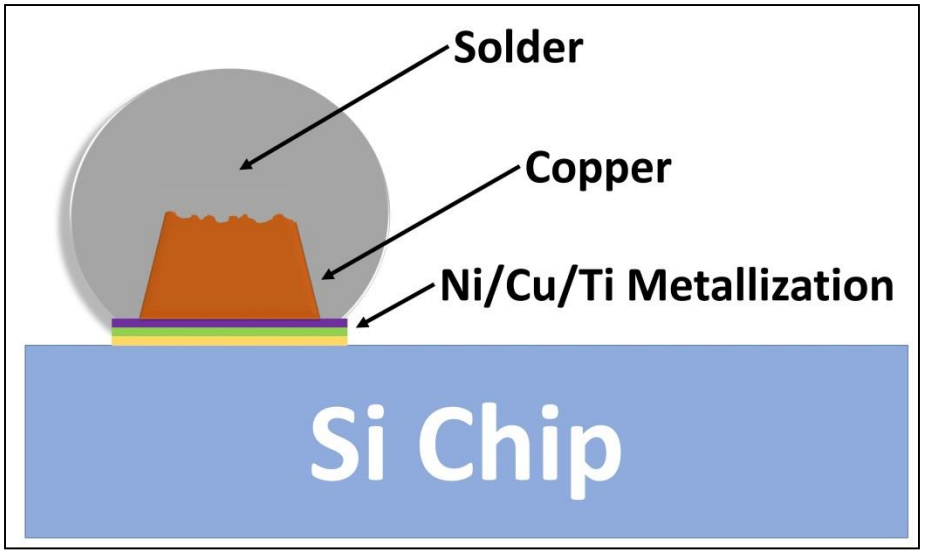
Photos of High Density Interconnects



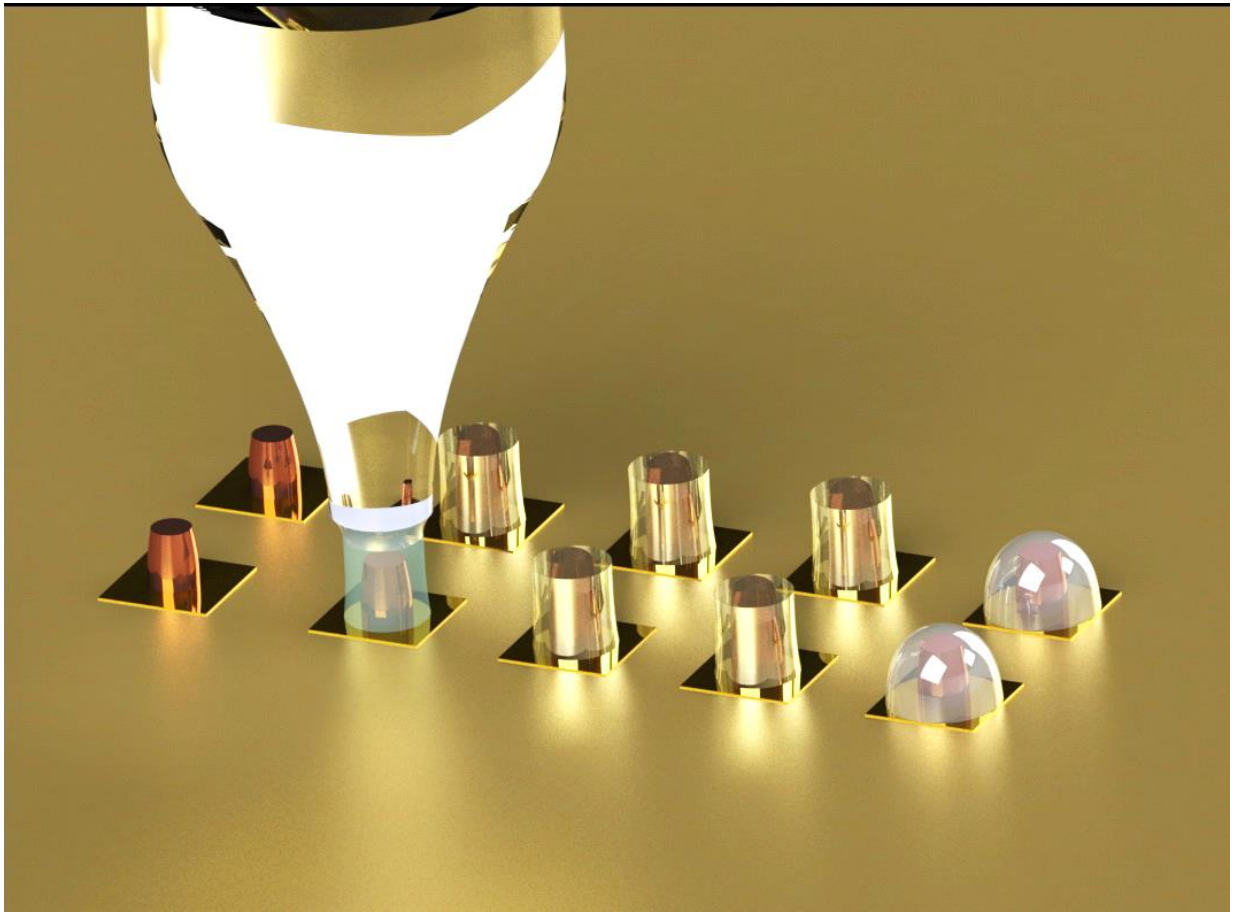
What Are We Making
Solder Bumps



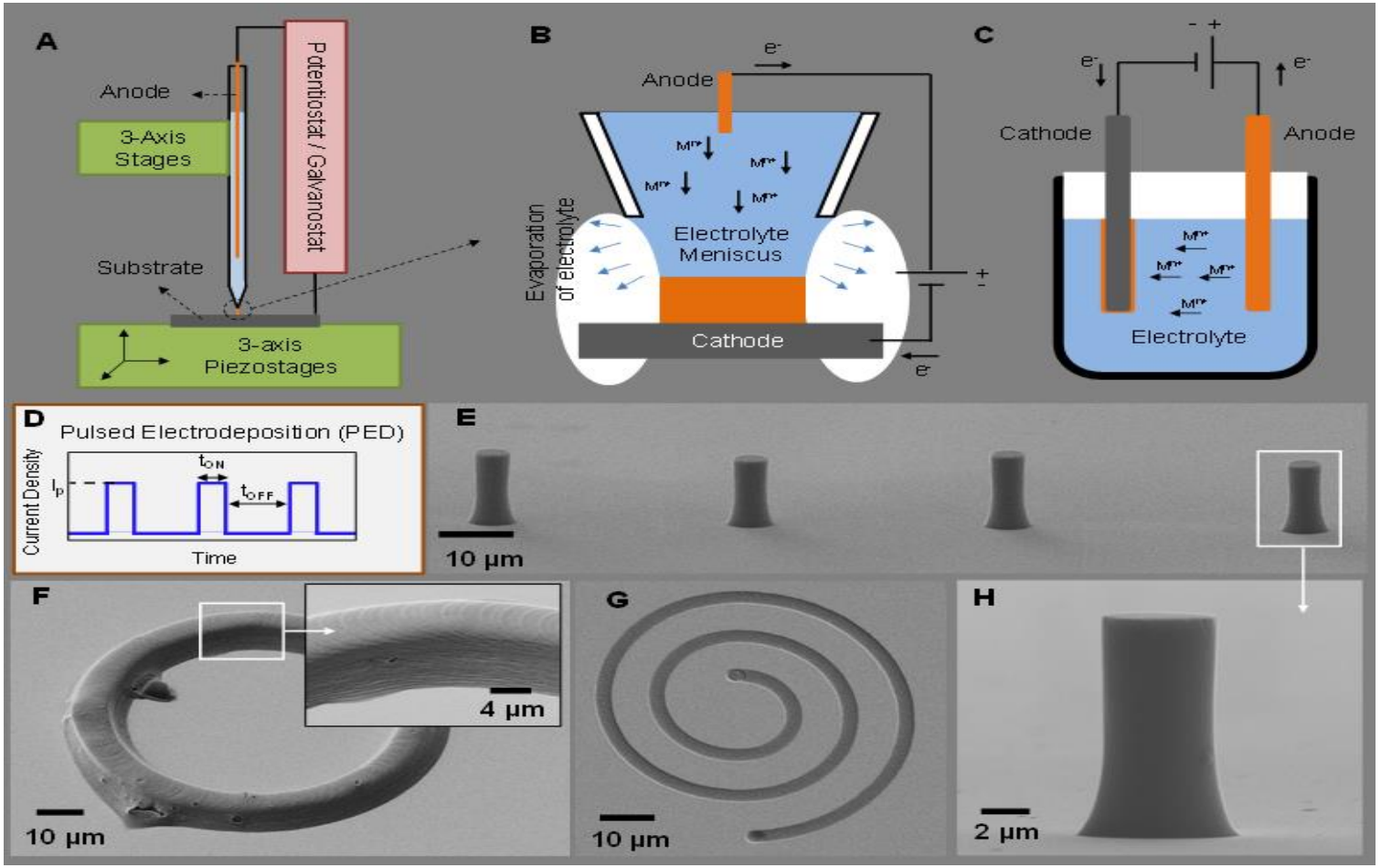




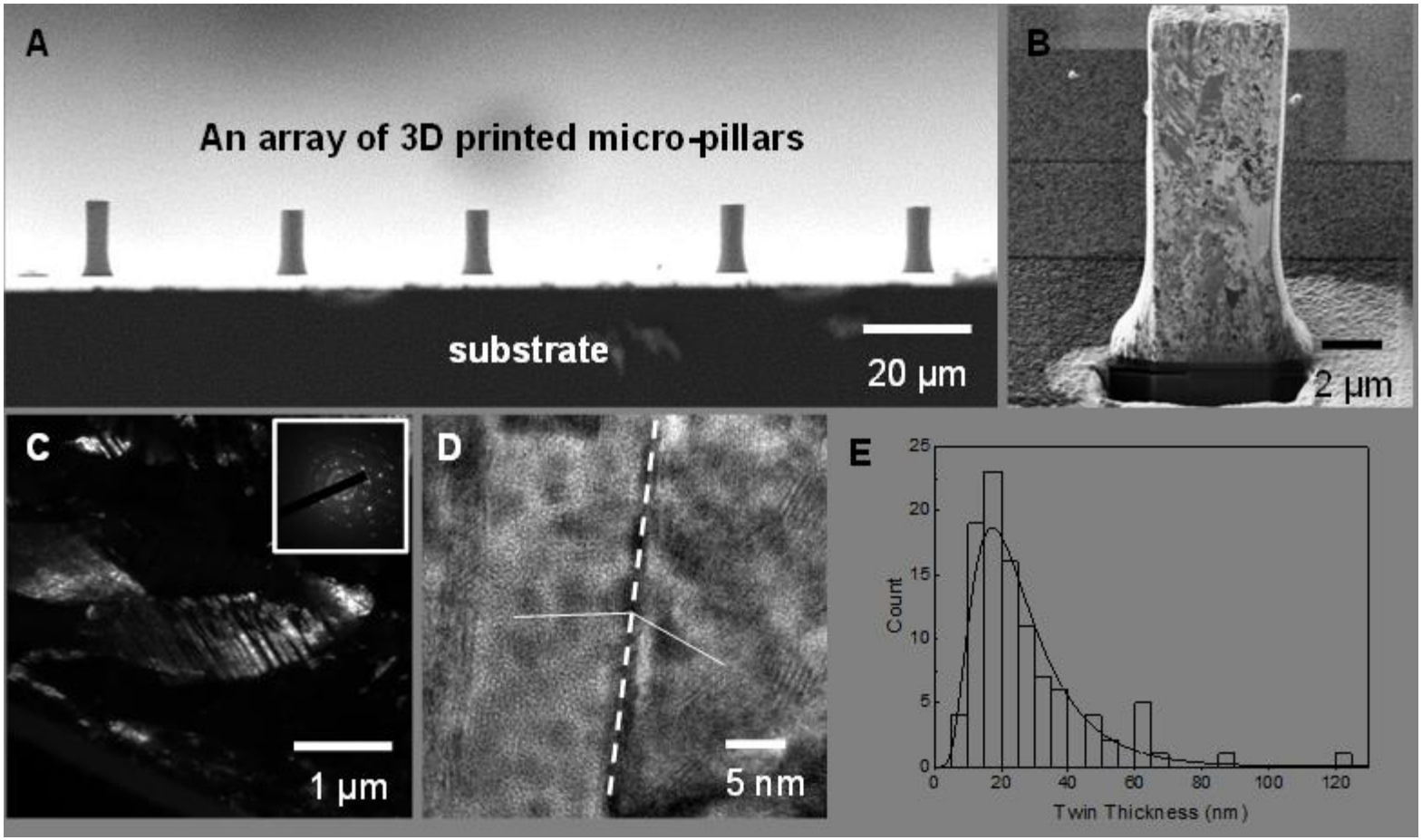
Approach for 3D Printed Bumps



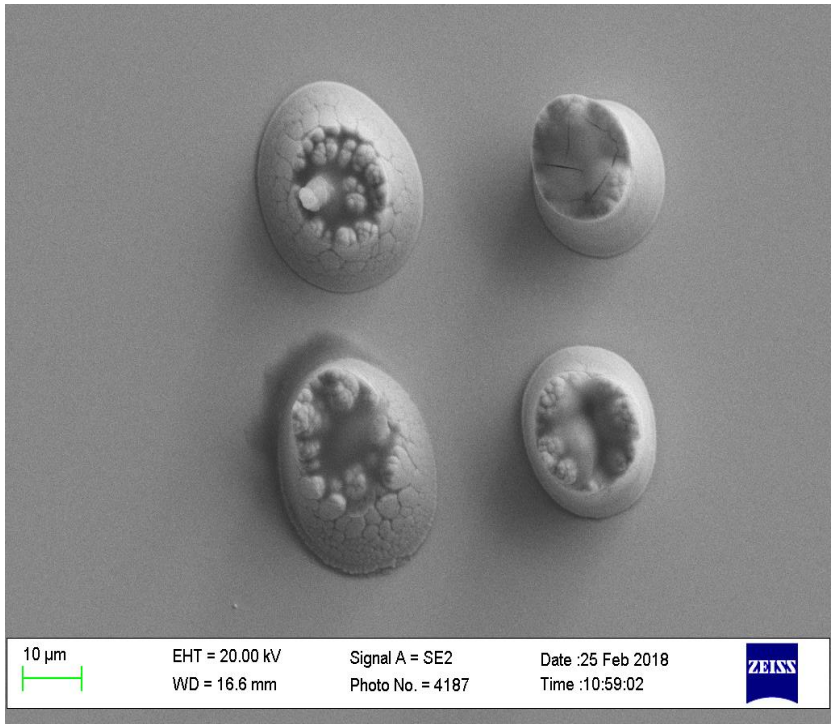
Photos of 5 Micron Cu Pillars for Solder Bumps

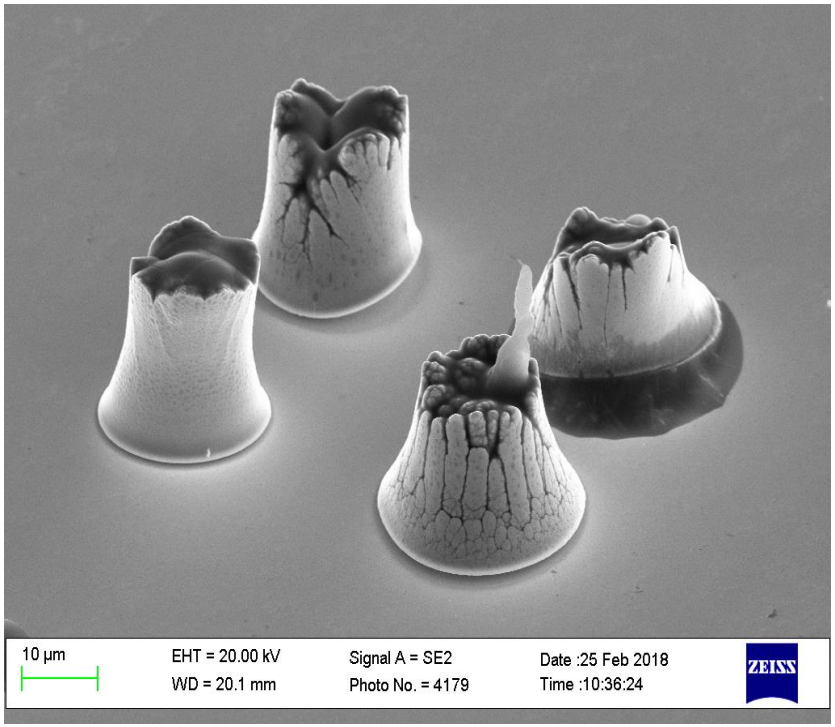


Photos of 5 Micron Cu Pillars for Solder Bumps



Photos of 20 Micron Cu Pillars for Solder Bumps





Advantages

1. **Low Temperature Manufacturing**
2. **Low Power Requirements**
3. **AM of High Conductivity Metals such as Copper, Silver and Gold**
4. **Other Metals and Alloys Possible such as Pb, Sn, Cr, Ta, steel, solder etc.**
5. **Adjustable Microstructure with Pulse Plating etc.**
6. **Potentially High Throughput with Multiple Heads**
7. **Flexible Substrates**
8. **Low Cost as Compared to Current Metal Printers**
9. **Higher Throughput at Higher Temperatures**
10. **Compounds and Insulators may Also be possible.**
11. **AM of Plastics and Metals in ONE PRINTER**

Potential Applications

1. Large Area Custom PCBs
2. Single Chip and Multi-Chip Packages
3. 3D integrated Circuits
4. Solder Bumps and Interconnects
5. Conformal Antennas
6. Micro-fludic Devices
7. Environment and bio-medical sensors and Electronics
8. Space On-Board Electronics Manufacturing
9. Military Munitions