Multi-scale Surface Plate Fabrication for Next Generation Fuel Cells

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Planned Completion = August 2, 2005

Research Goals and Objectives

- combine new and existing manufacturing technologies to improve PEM fuel cell collection plate performance
- low-cost, agile feature production from the nanometer to millimeter scales using
  - micro-molding in bulk metallic glass (Vitreloy-1)
  - high-speed machining
  - photolithography
- demonstrate channel production with varying geometries and validate fidelity

Relevance to Current State-of-the-Art

- increased power and efficiency gains possible through improved flow fields and current collection capabilities of PEM fuel cells
- provide mechanism to produce arbitrary channel geometries quickly with low capital investment
- multiple length scales important for miniaturized collection plates
- competing technologies: LIGA, FIB, micro-EDM, excimer/femto-second laser – micro-molding offers 3D metallic component production without high energy x-ray source

Technology	Minimum size/tolerance	Positional tolerance	Material removal rate	Materials
Focused ion beam/2D and 3D	200 nm/20 nm	100 nm	0.5 $\mu m^3/s$	Any
Excimer laser/2D or 3D	6 µm/<1 µm	<1 µm	$40 \times 10^3\ \mu m^3/s$	Polymers, ceramics, metals
Femto-second laser/2D or 3D	1 µm/<1 µm	<1 µm	$>10 \times 10^3\ \mu m^3/s$	Any
Micro EDM (sinker or wire)/2D or 3D	25 µm/3 µm	3 µm	$25 \times 10^6\ \mu m^3/s$	Conductive materials
LIGA/2D	<1 µm/0.02 µm to 0.5 µm	<1 µm	N/A	Electroformable Cu, Ni, permalloy

Relevance to NASA

- activities are synergistic with other ongoing fuel cell research efforts (e.g., thermal management, computational fluid dynamics)
- other applications may arise once capabilities are known

Budget, Schedule and Deliverables

Budget: $70,000

Milestones

- Q1: Modify MTS dual column load frame; control using LabView ✓
- Q2: Provide temperature control for metallic glass micro-molding of various features ✓
- Q3: Reproduce micrometer scale features with aspect ratios >1 ✓
- Q4: Produce plate for tests by Dr. Klausner ✓

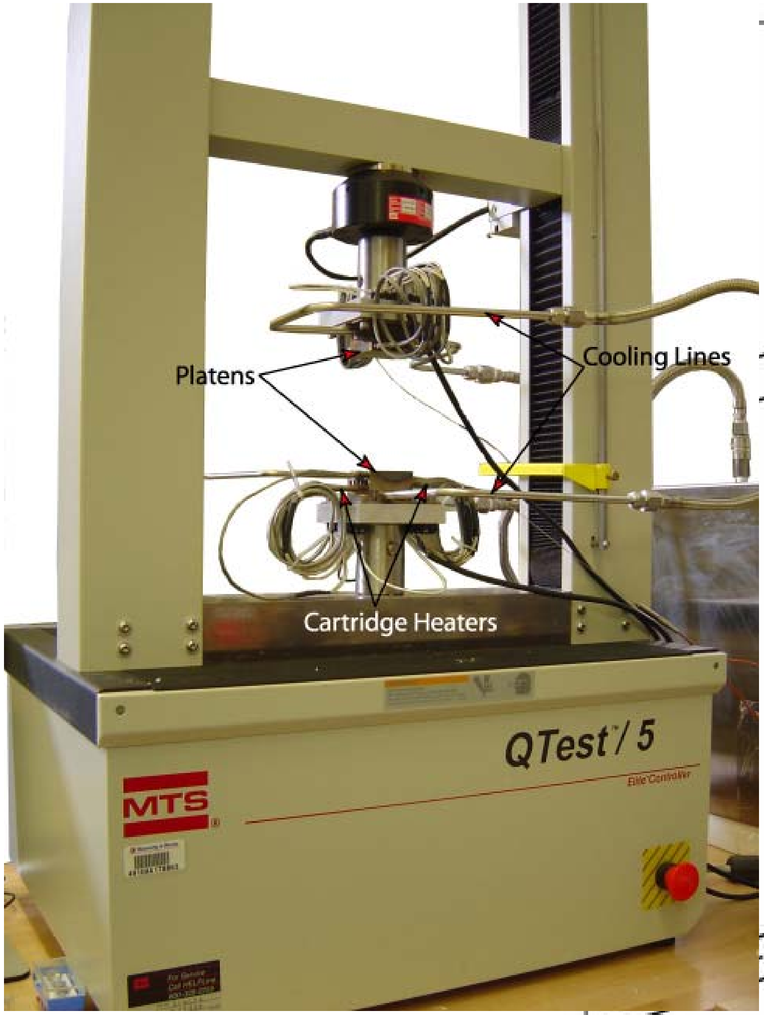
Deliverables

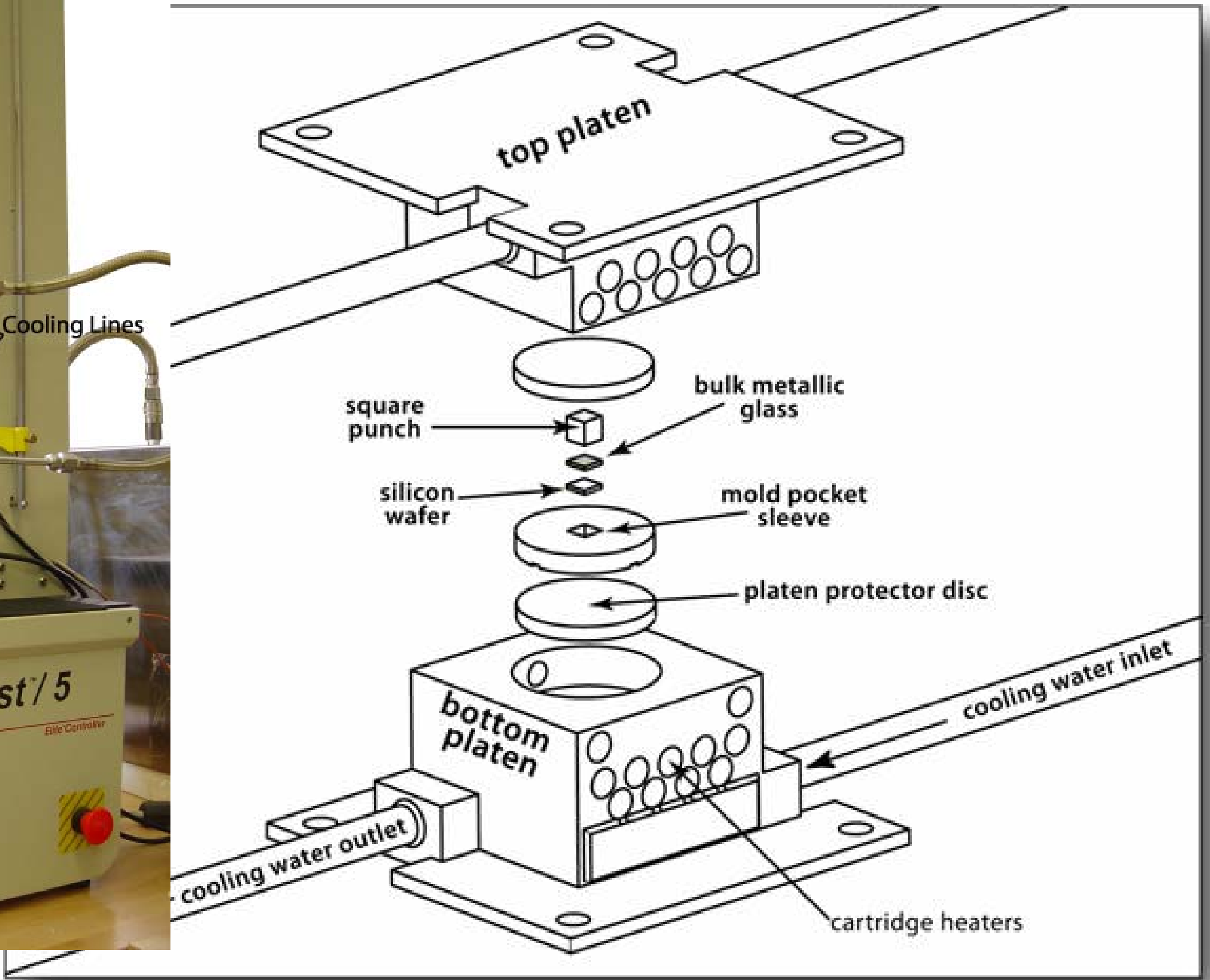
- Q1: Demonstrate force and position control of MTS load frame ✓
- Q2: Ramp and hold temperature to >400 deg C for micro-molding experiments ✓
- Q3: Obtain silicon wafers with combinatorial features, reproduce, and measure surfaces ✓
- Q4: Establish micro-molding capability ✓

Anticipated Technology End Use

- initially – convenient platform to evaluate models
- future – friendly to shop floor implementation (low molding temperatures, clean room not required)
- other application domains
  1. optics – flexible mirrors/arrays, diffraction gratings, waveguides
  2. medical – micro-textured scaffolds for tissue engineering
  3. thermal systems – micro-scale heat exchangers
  4. fluidic systems – 3D channel patterns, turbines, valves
  5. electronics – high-Q solid oscillators, final step in CMOS
  6. mechanical systems – MEMS packaging, monolithic micro-scale pumps, compressors, fuel injectors

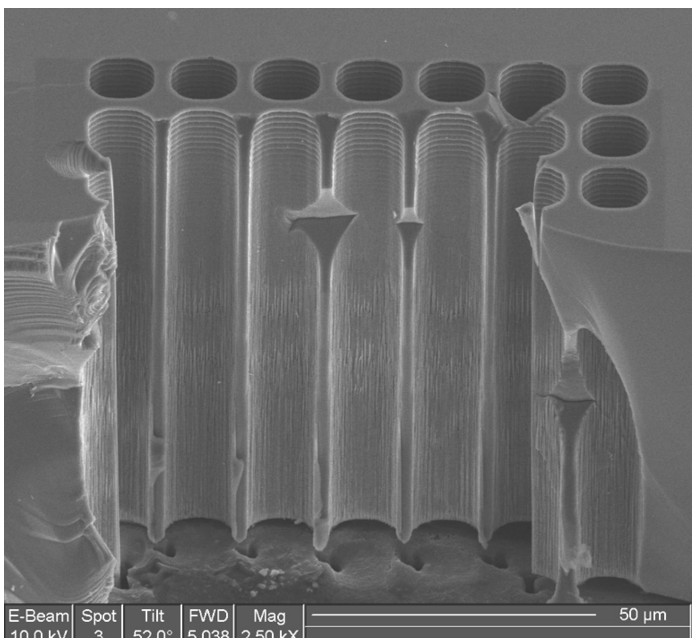
Accomplishments and Results

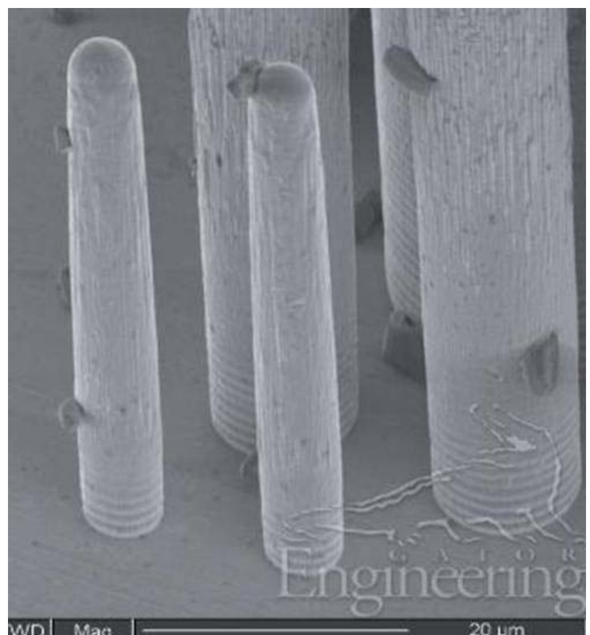


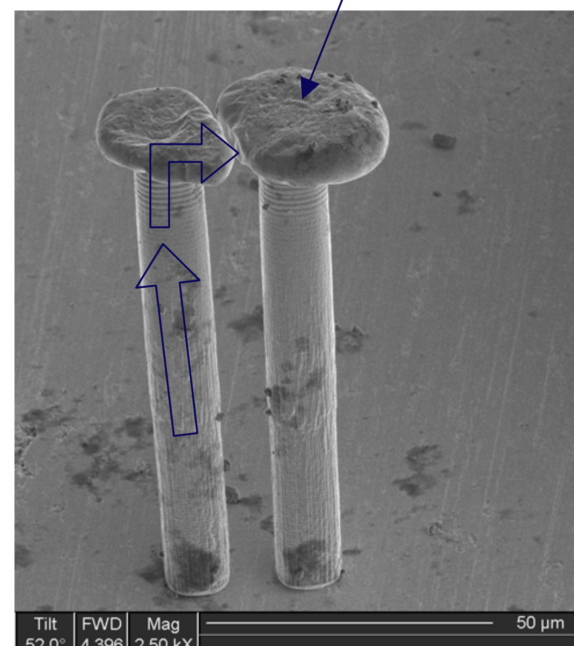


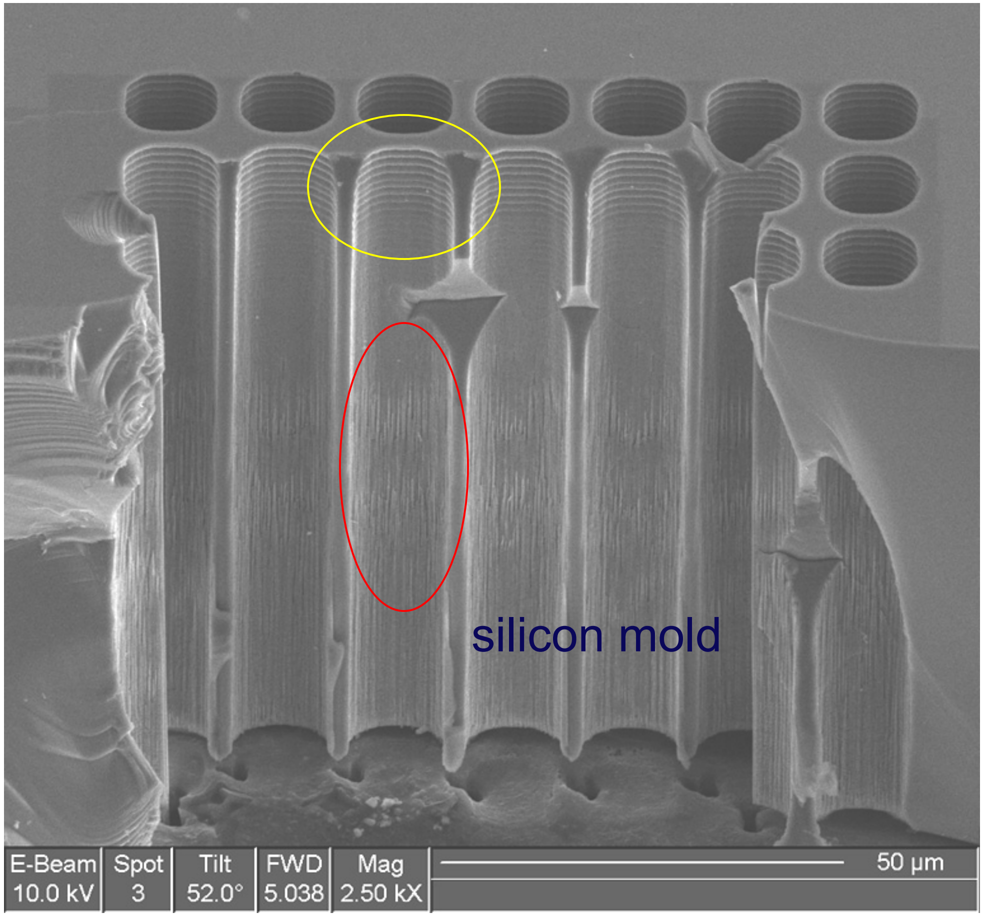
- process steps
  1. design mold layout in CAD
  2. pattern silicon wafer using DRIE (sacrificial mold)
  3. separate wafer into 5 mm x 5 mm molds
  4. insert silicon mold and bulk metallic glass into mold pocket
  5. heat, mold, cool (400 – 475 deg C, 100 to 150 MPa)
  6. dissolve silicon mold in KOH bath

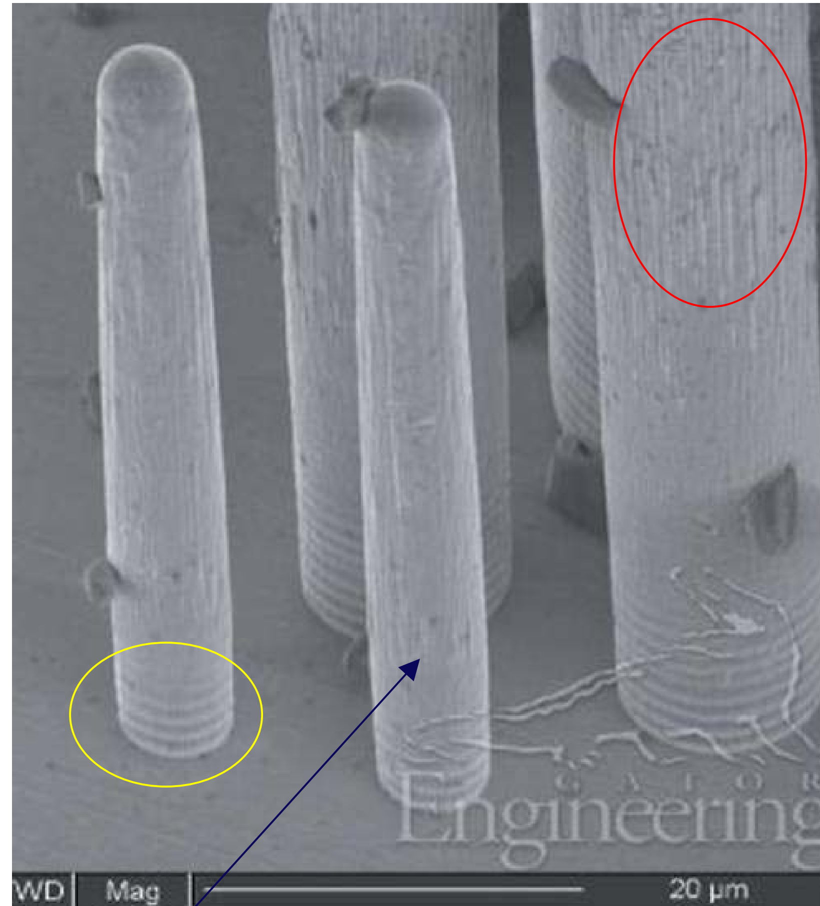
non line-of-site flow







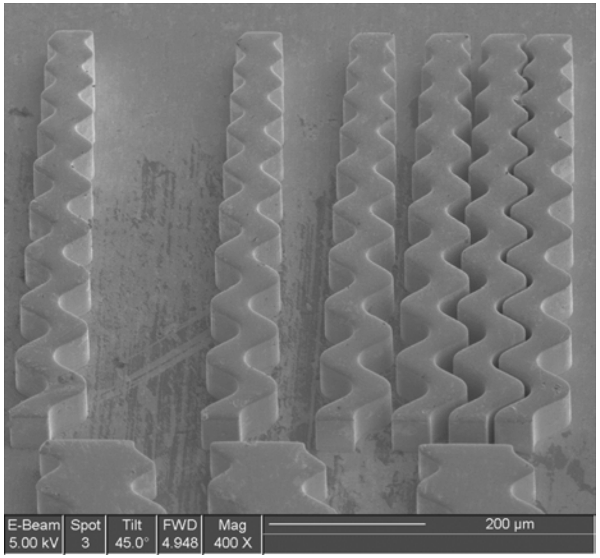


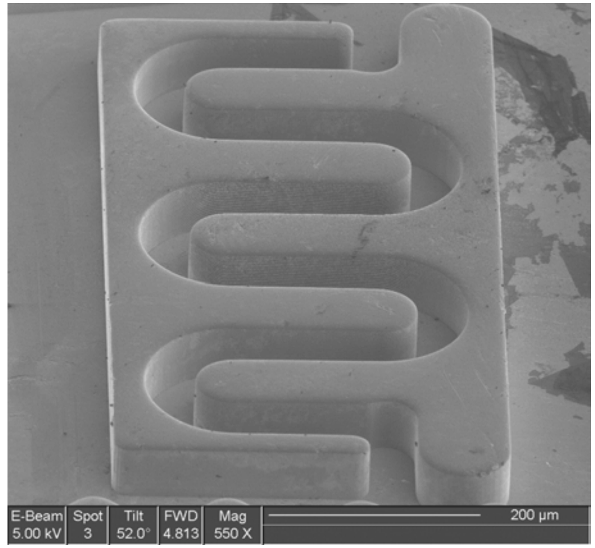


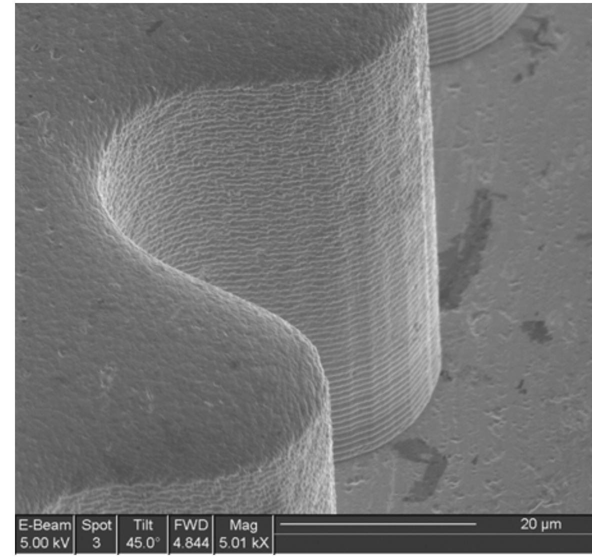
- 5 µm dia. x 60 µm tall (12:1)
- Scallop and striation reproduction at µm level

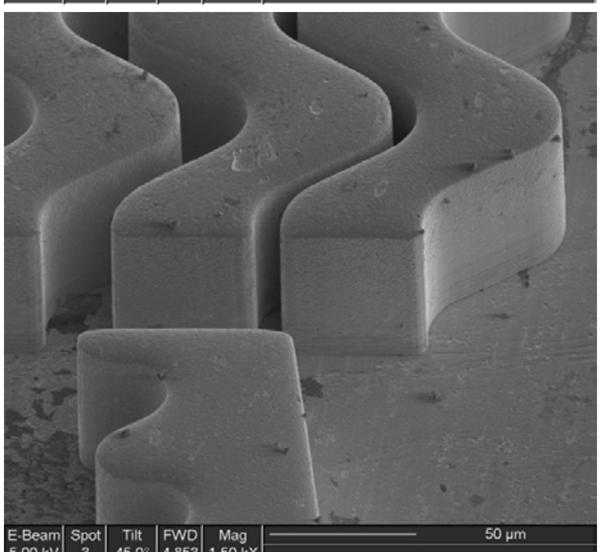
- channel production

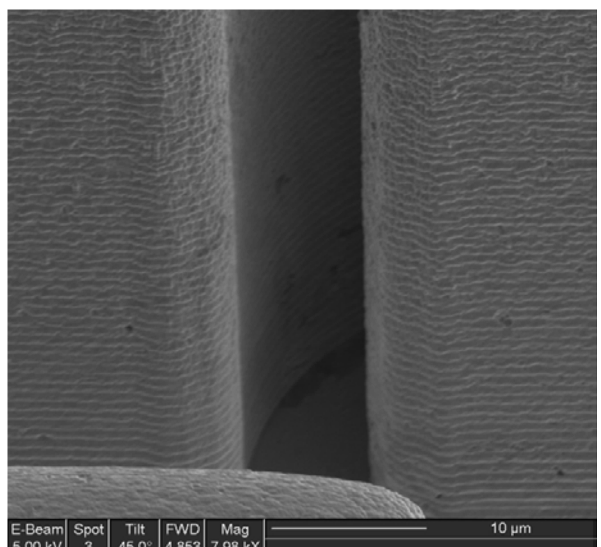
60 μm cavity depth in wafer

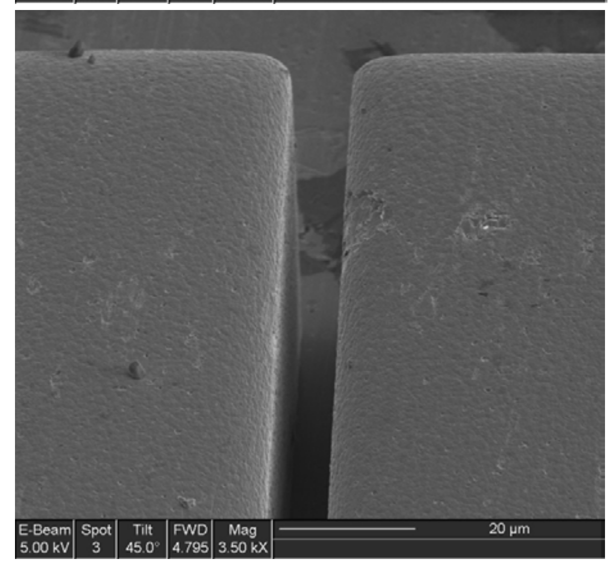


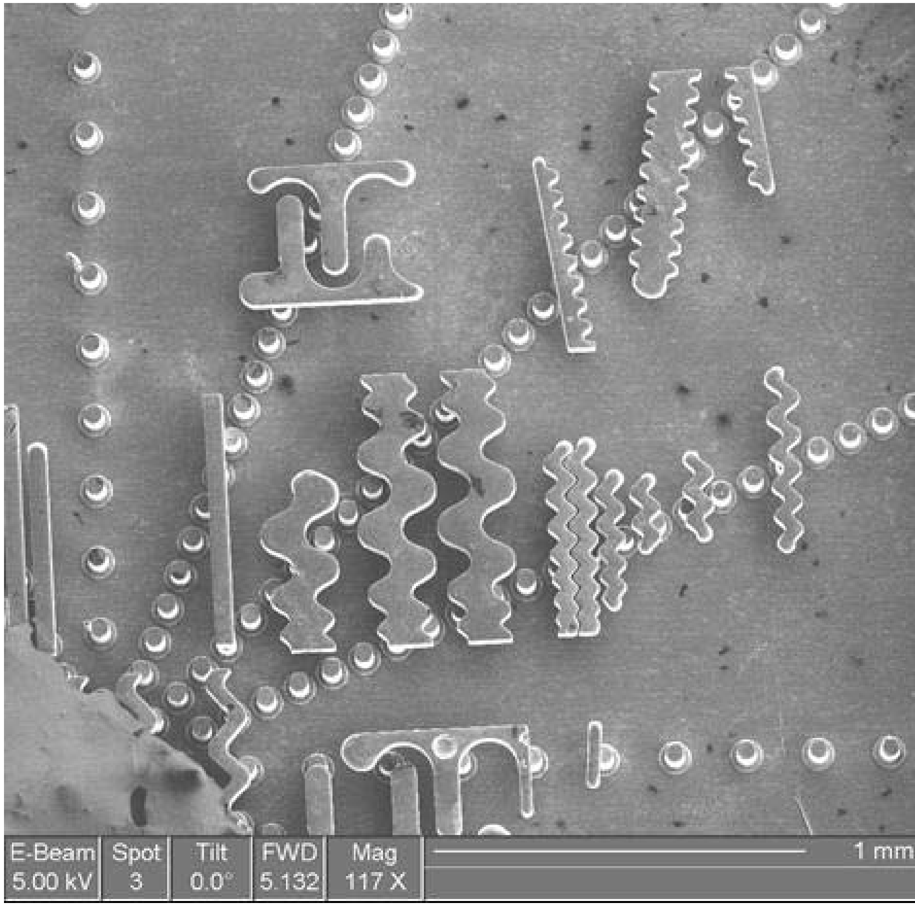


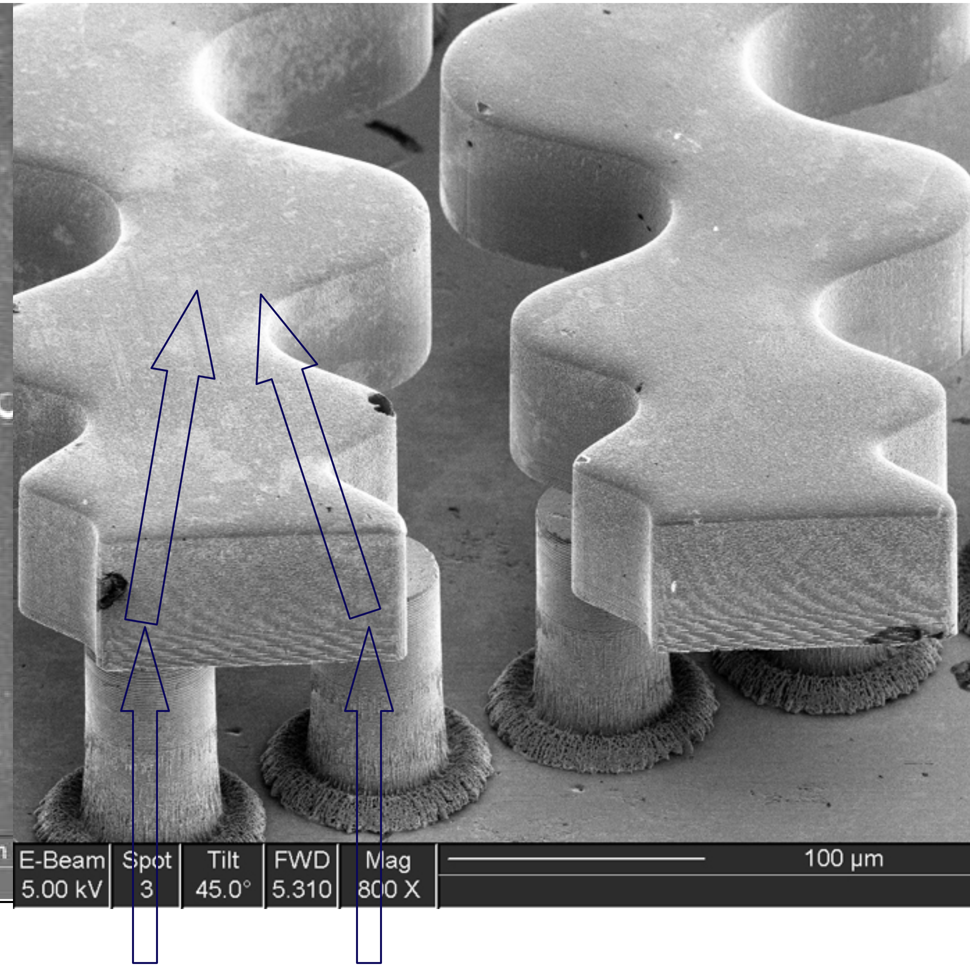






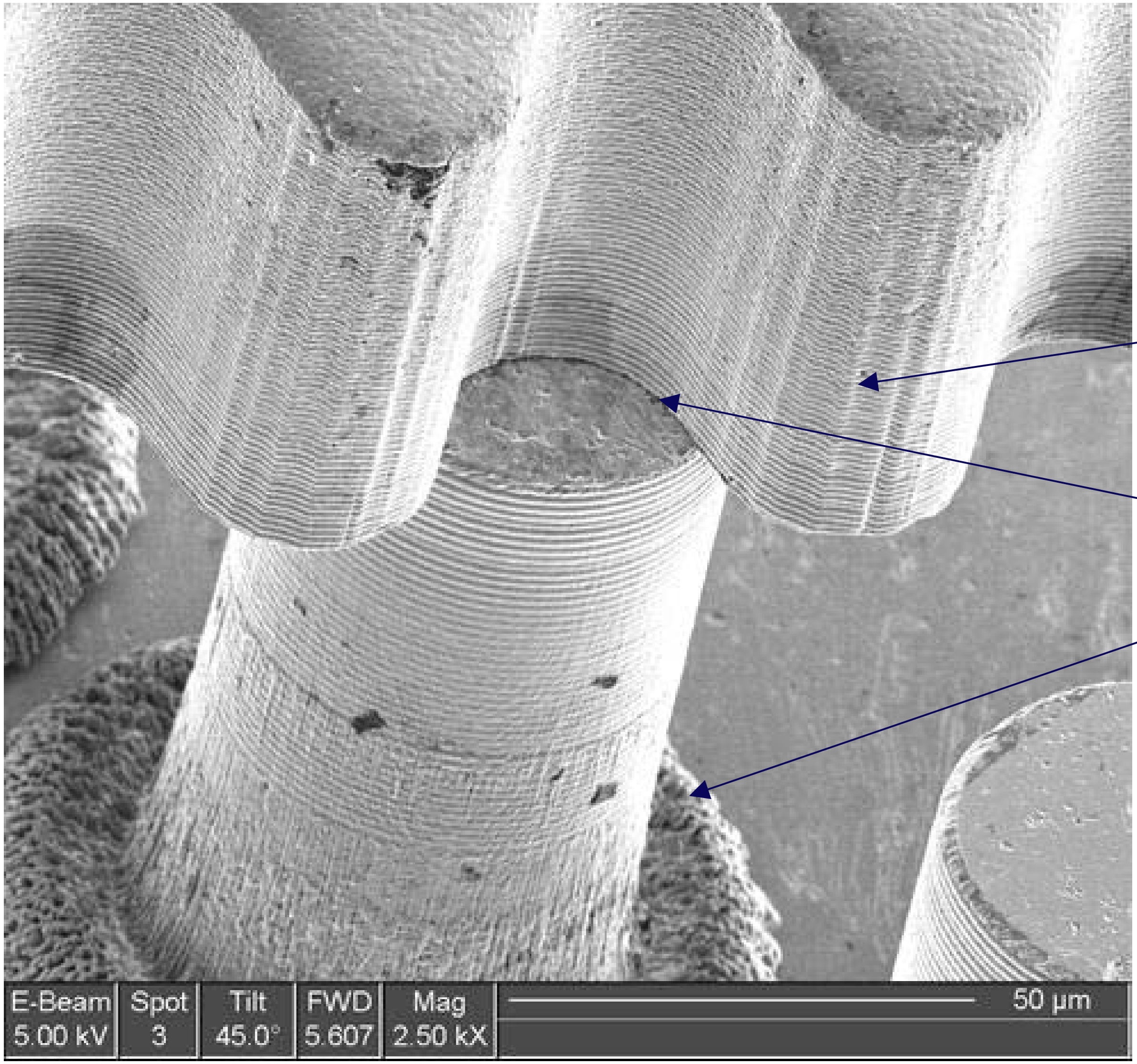






- two layer mold stack
- flow through pins to fill cantilevers

metallic glass flow through two wafers



- two layer junction
- no wafer bonding

scallop reproduction

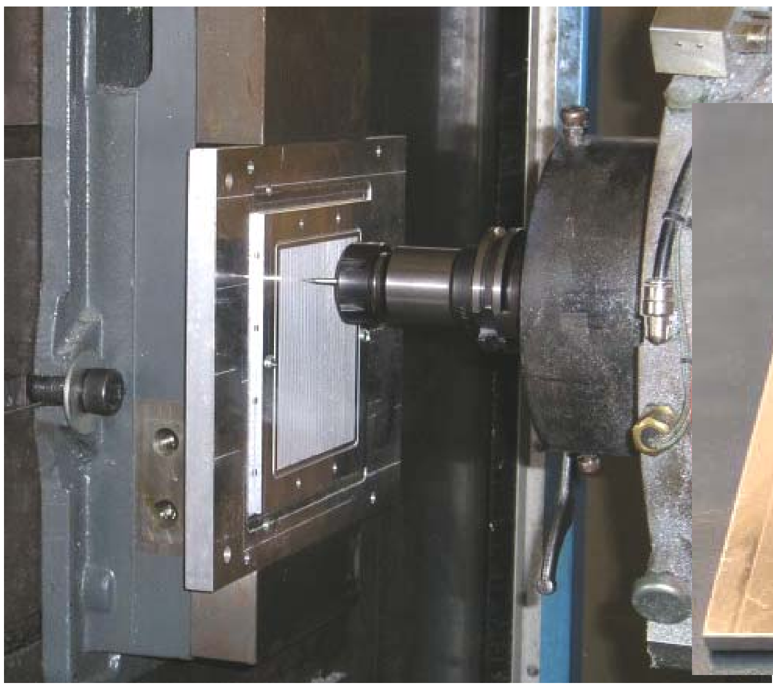
no flash

footing from etching

Note: shrinkage normally associated with molding is not present – bulk metallic glass

Future Plans

- process concept validated
- micro-mold polymers
- add layers
- continue high-speed machining; move to 100 μm dia. endmills (channels for Chung)



Cooling plate with 56, 1 mm channels for Dr. Klausner