



Fully Embedded Electroplated Metals in Silicon

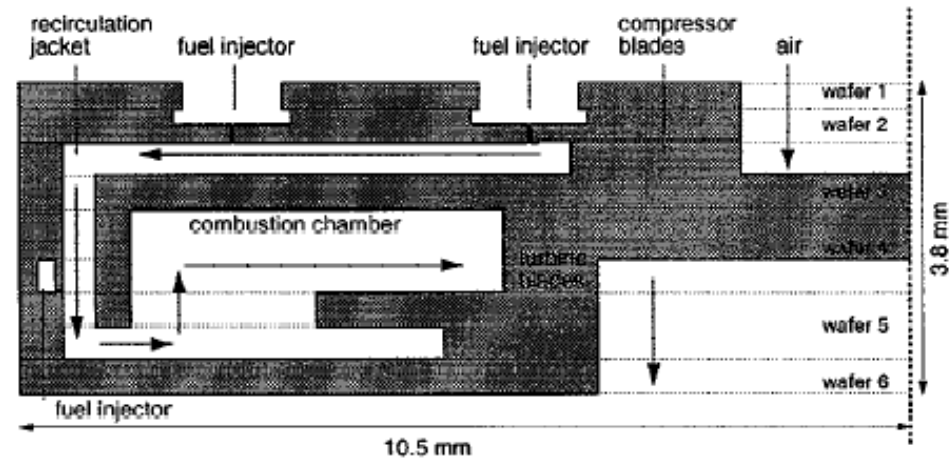
David Arnold

November 20, 2002
ECE6450

ARO/ARL Portable Power

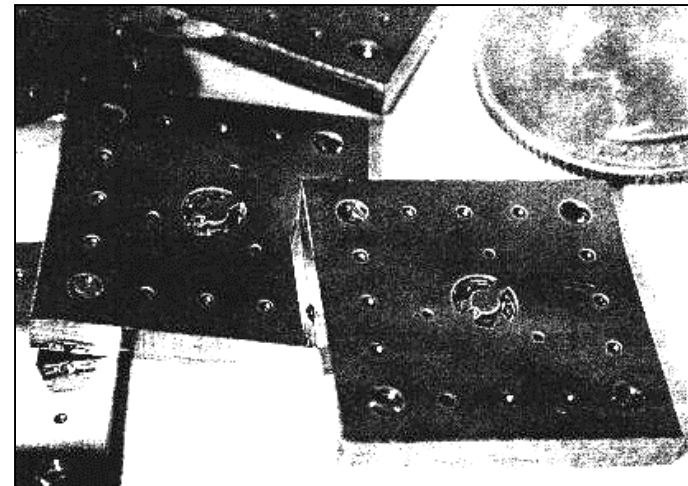
■ Goal

- 10-50 W
- $< 1 \text{ cm}^3$
- Renewable

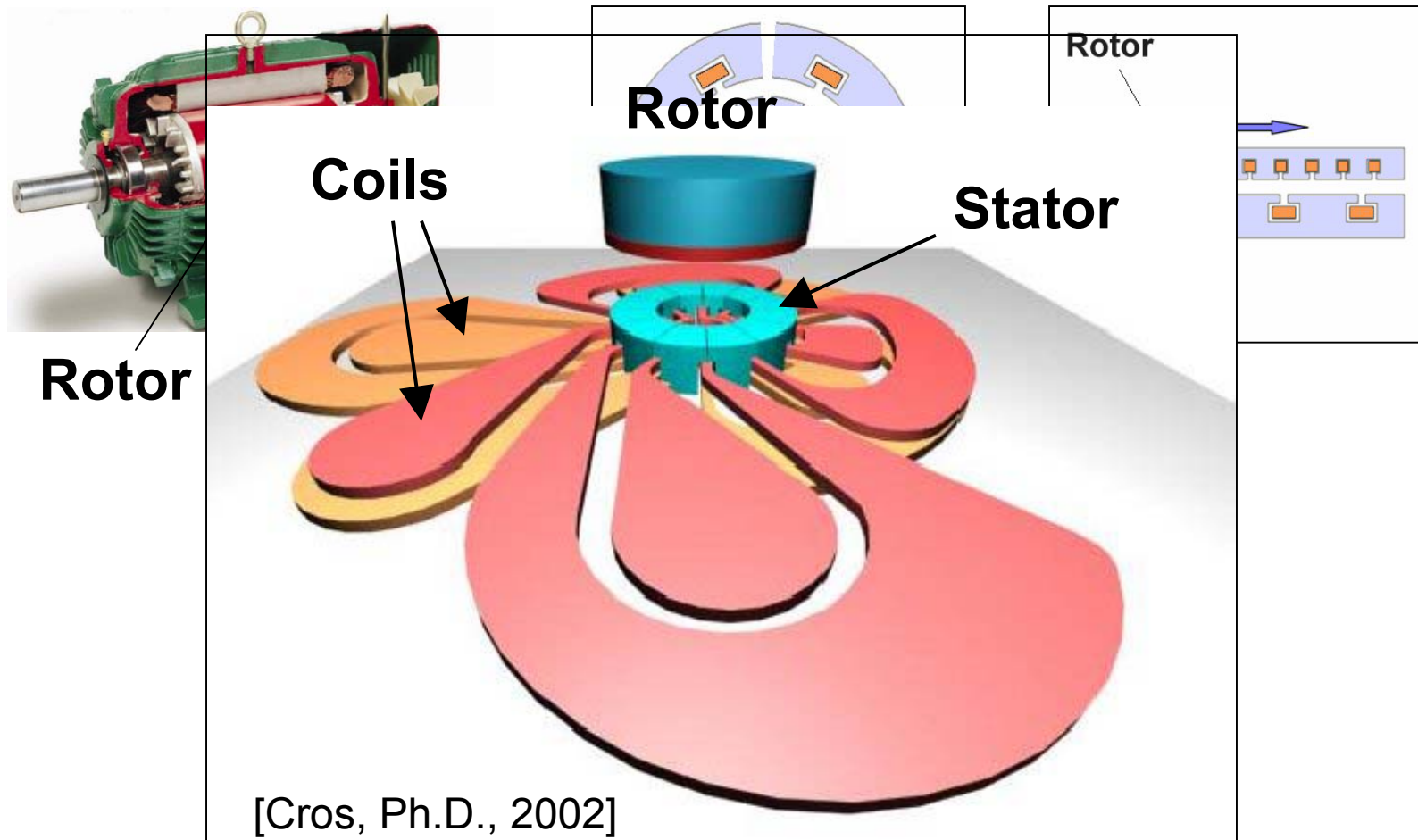


■ MIT Micro-Turbine

- 6 wafer Si stack
- 0.2 cm^3
- 200 W (mechanical)
- 7 g / hr. fuel

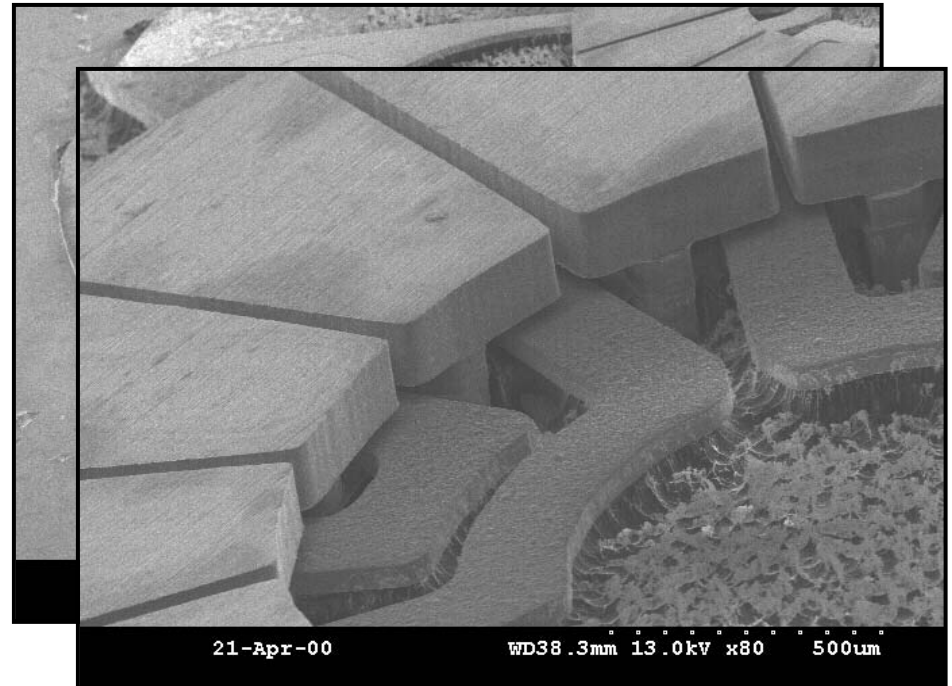


Micro Induction Machine



Micro Induction Machine

- SU-8 Epoxy
- Electroplated Cu, NiFe

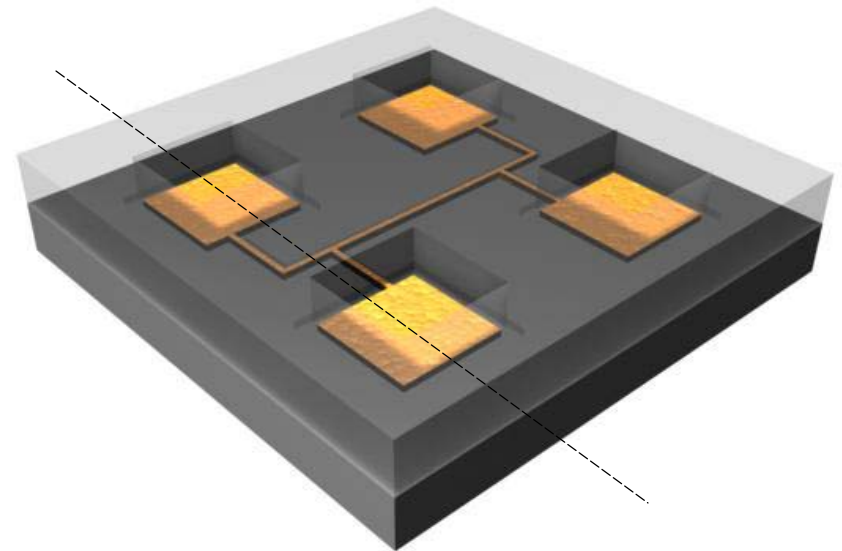
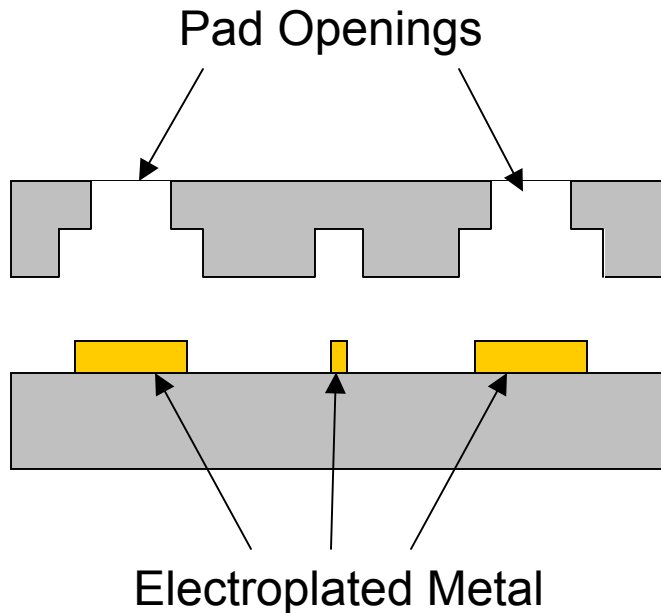


Challenges

- High Current (~ 15 A) and Magnetic Flux
 - Low Resistivity, Thermomigration
 - High Permeability, B_{sat}
- High Temperature ($\sim 500 - 1000^{\circ}\text{C}$)
 - Curie Temperature
 - CTE Mismatch
 - Diffusion, Oxidation
- Integration with MIT Micro-Turbine
 - Direct Si-Si Wafer Bond

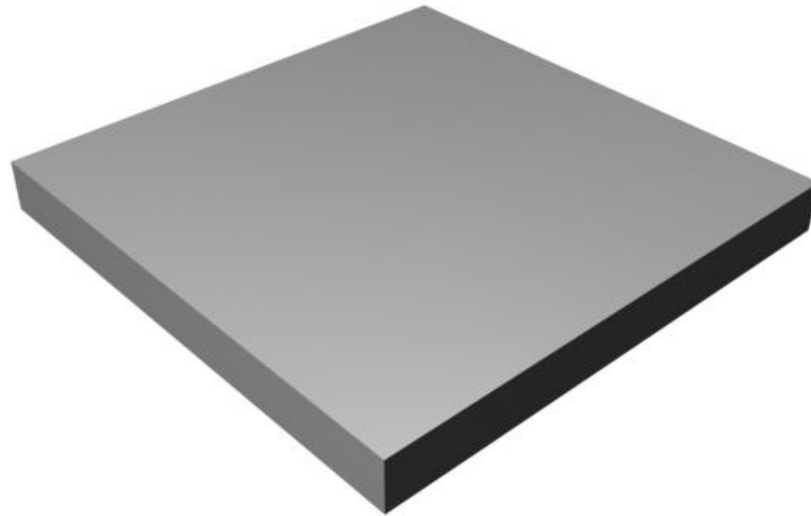
Potential Solution

- Electroplated Metals Embedded in Silicon
 - Thick Structures
 - High Temp.
 - Compatible with MIT Micro Turbine



Fabrication

- 1st Silicon Wafer (Conductors)



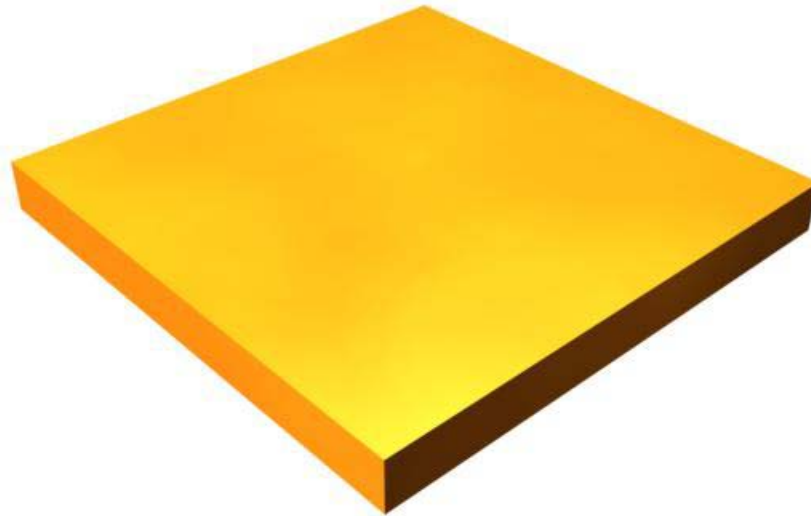
Fabrication

- Sputter Diffusion Barrier (Ta, Ti, TaN, TiN)
 - Reactive Sputtering



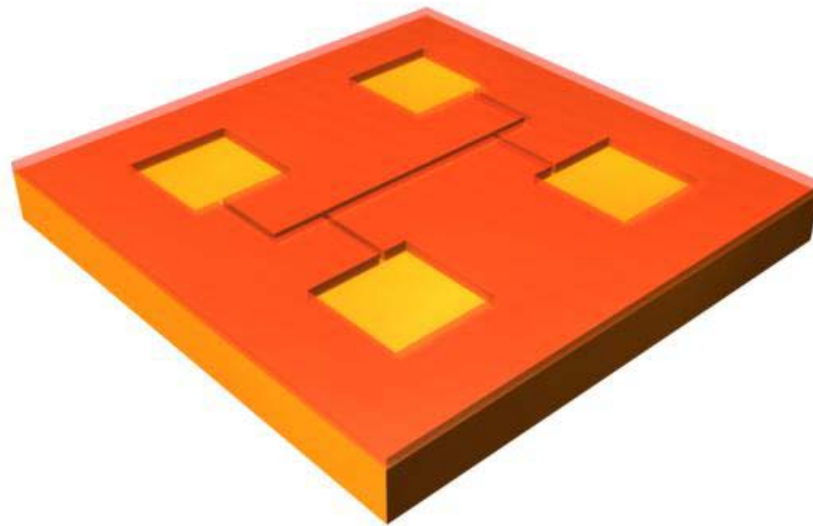
Fabrication

- Sputter Seed Layer (Cu)



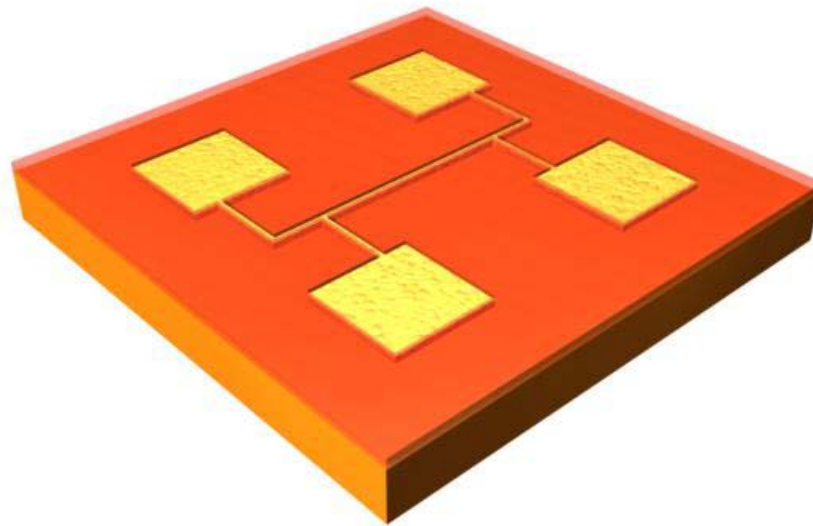
Fabrication

- Pattern Thick Photoresist Mold
 - Futurrex NR9-8000



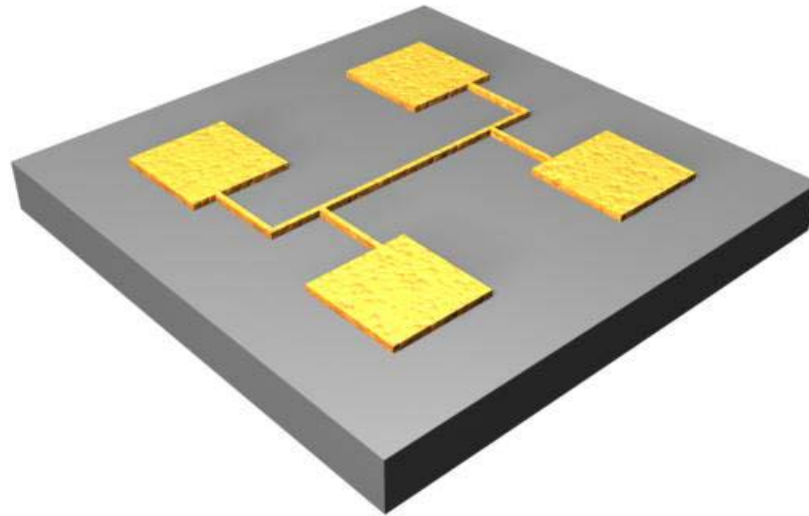
Fabrication

- Electroplate Copper
 - CuSO_4 , H_2SO_4 Bath



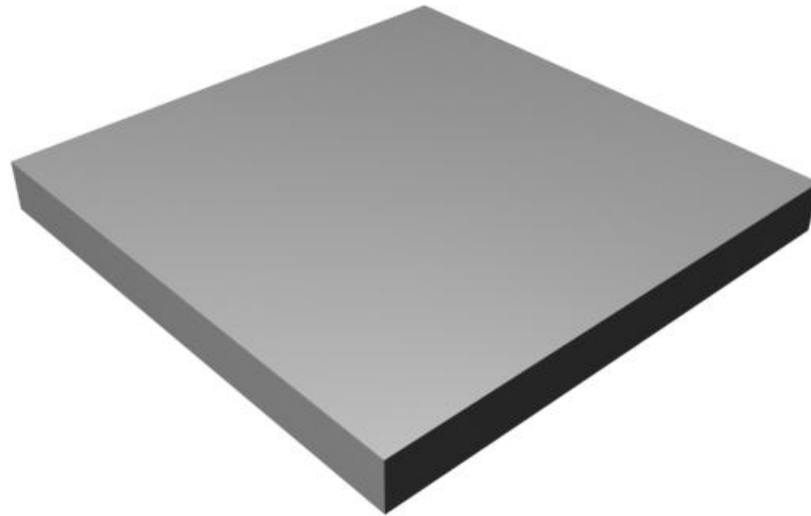
Fabrication

- Remove Mold, Seed, and Diffusion Barrier
 - RR4 Resist Remover, Blue Etch, SF_6 Plasma



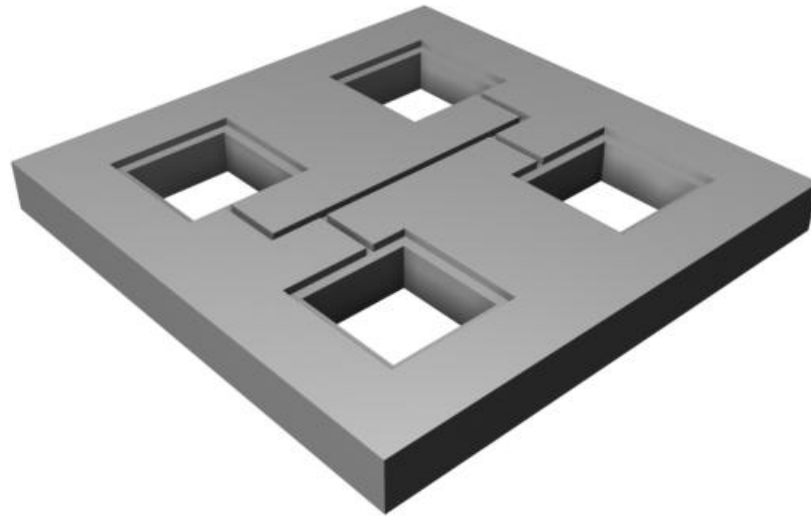
Fabrication

- 2nd Silicon Wafer (Cap)



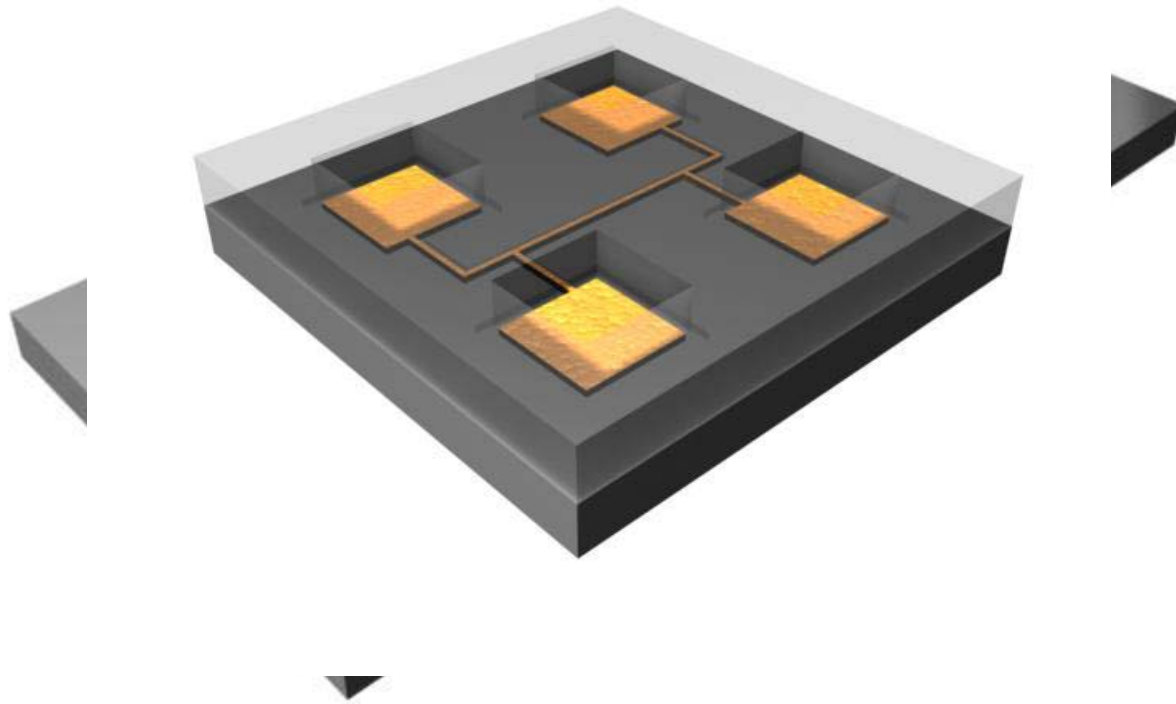
Fabrication

- Si Etch, Front and Back
 - Bosch Process

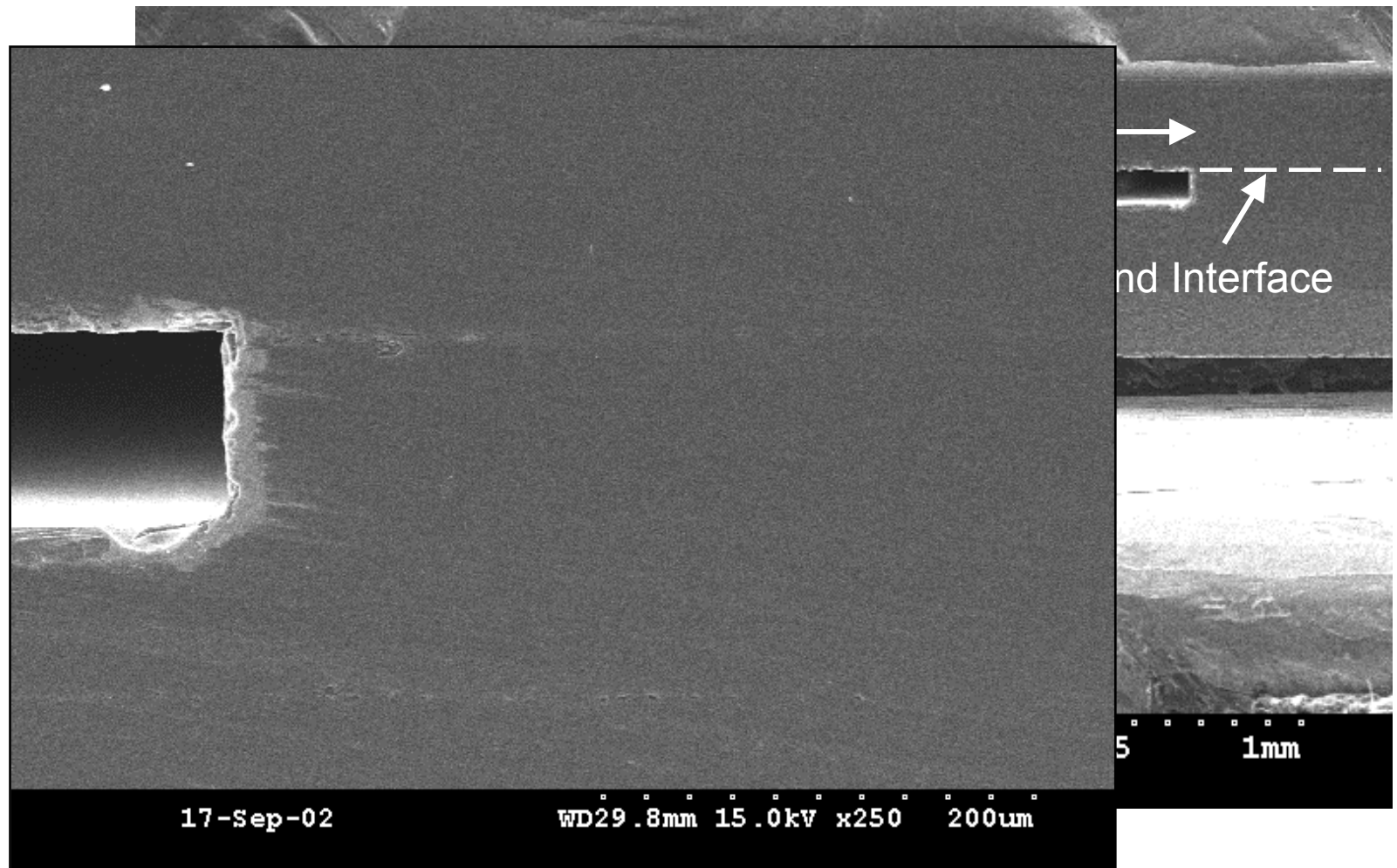


Fabrication

- Bond Wafers



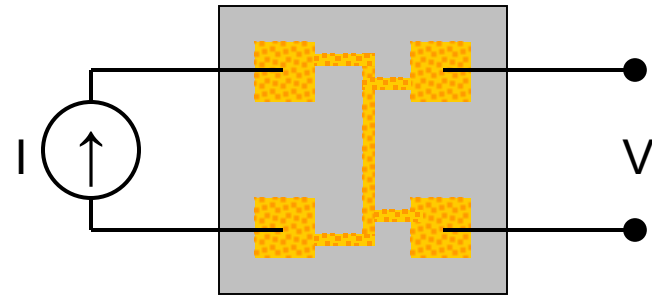
Cu Embedded in Si



Characterization

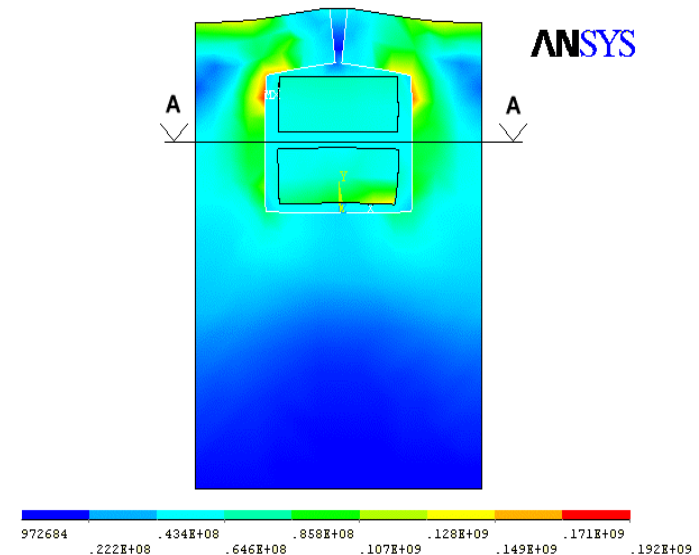
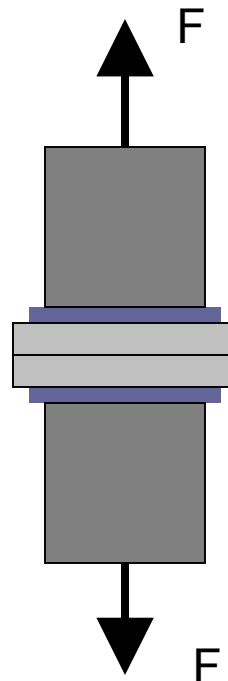
■ Electrical

- ☐ Conductance Testing
- ☐ Magnetic Testing



■ Mechanical

- ☐ Tensile Testing
- ☐ Thermal Stress Analysis



Future Work

- Characterization
- High Temperature Studies
- Multi-level Magnetic Device

