MEMS Piezoelectric Energy Harvesting for Powering Wireless Sensor Nodes

March 16, 2009

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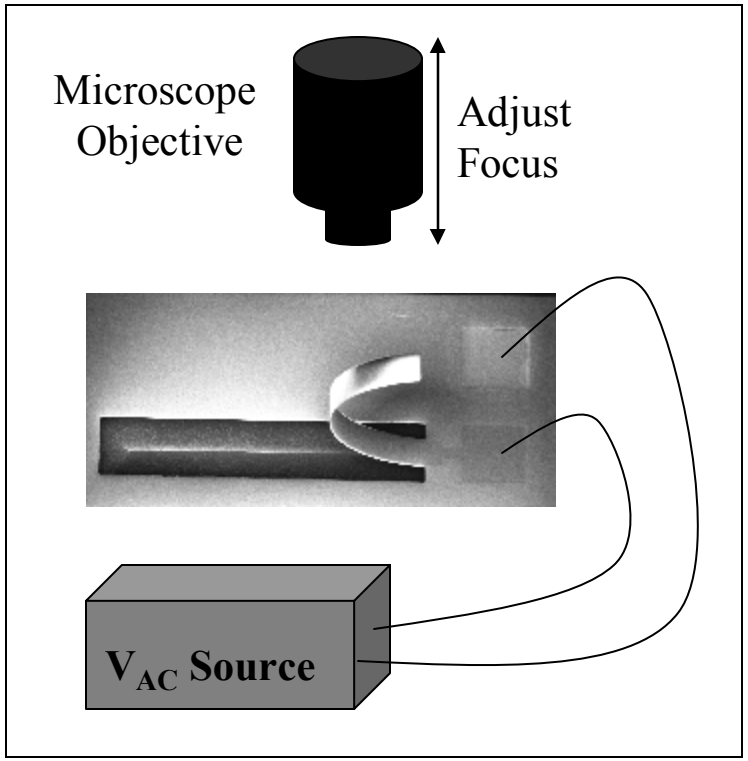
"Cliff Notes" of this talk

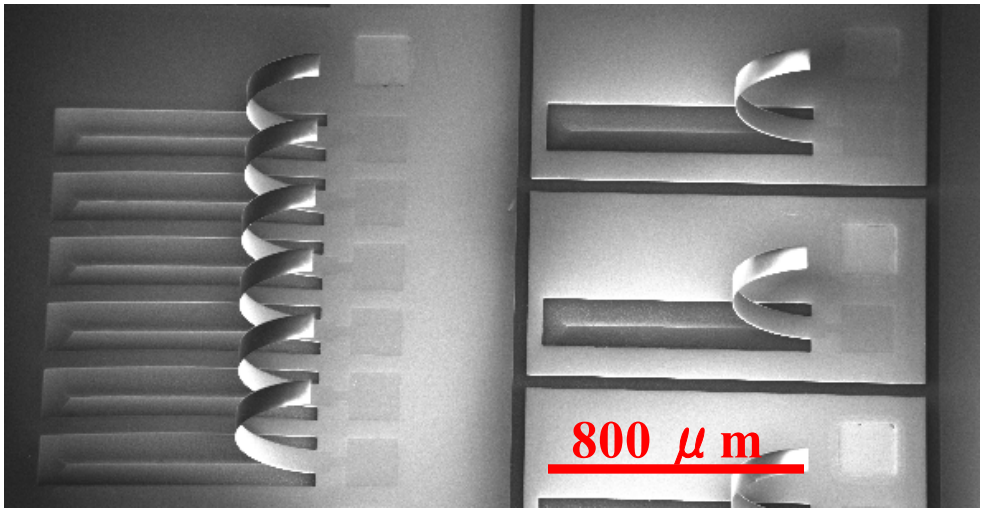
- MEMS energy harvesting is enabling technology for wireless sensor nodes
  - Provides replenishable power
  - Achieves size reductions
  - Reduces required maintenance
- First prototype successfully actuated, but resonance frequency too high, power output not high enough.
- Harvester redesigned, second prototype nearing completion.
- ~ 10 μW/beam predicted output for new prototype.
  - Compared with ~5 nW/beam predicted output from previous devices

First Generation Prototype

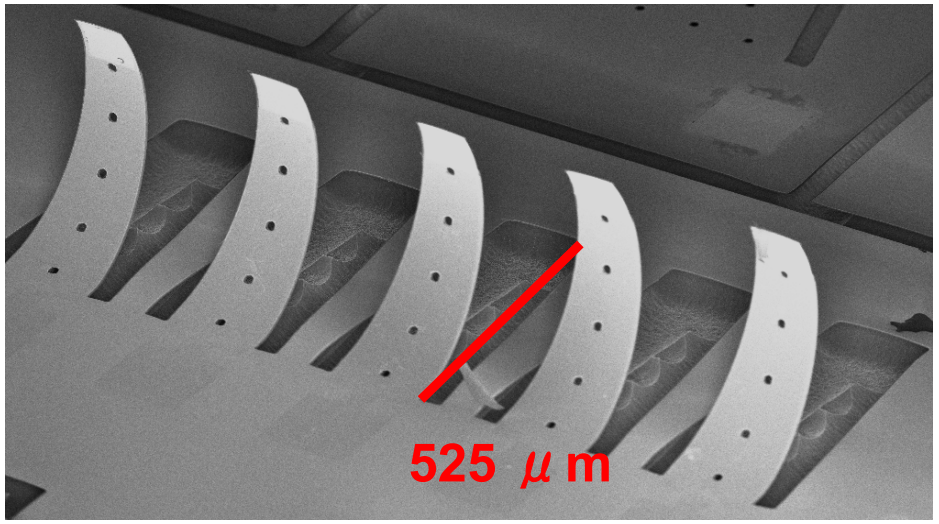


Simplified deflection test setup: movie

Array and isolated rectangular cantilevers



Array of trapezoidal cantilevers



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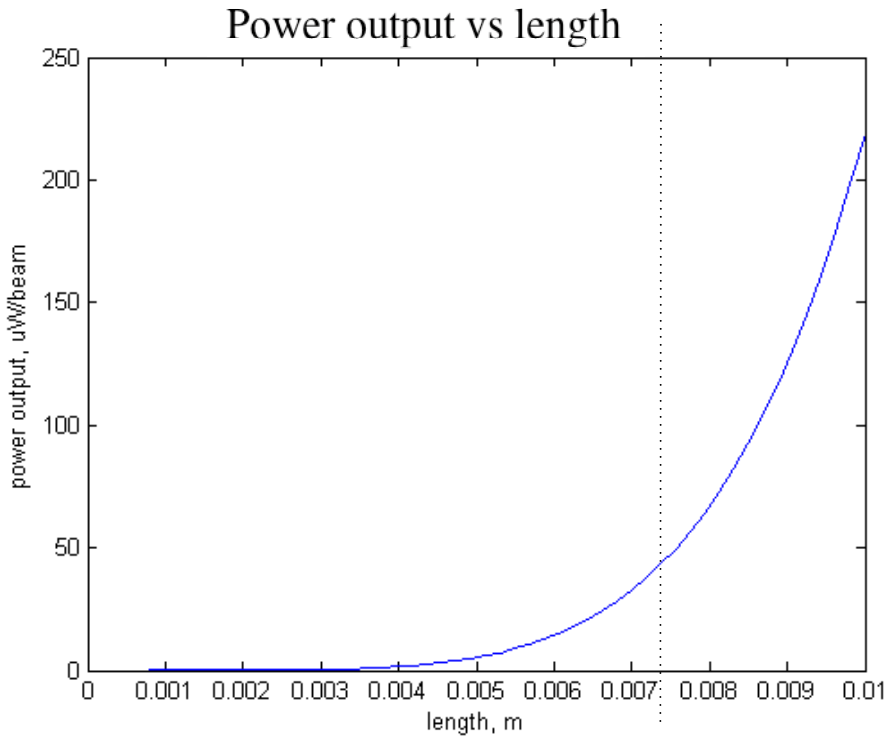
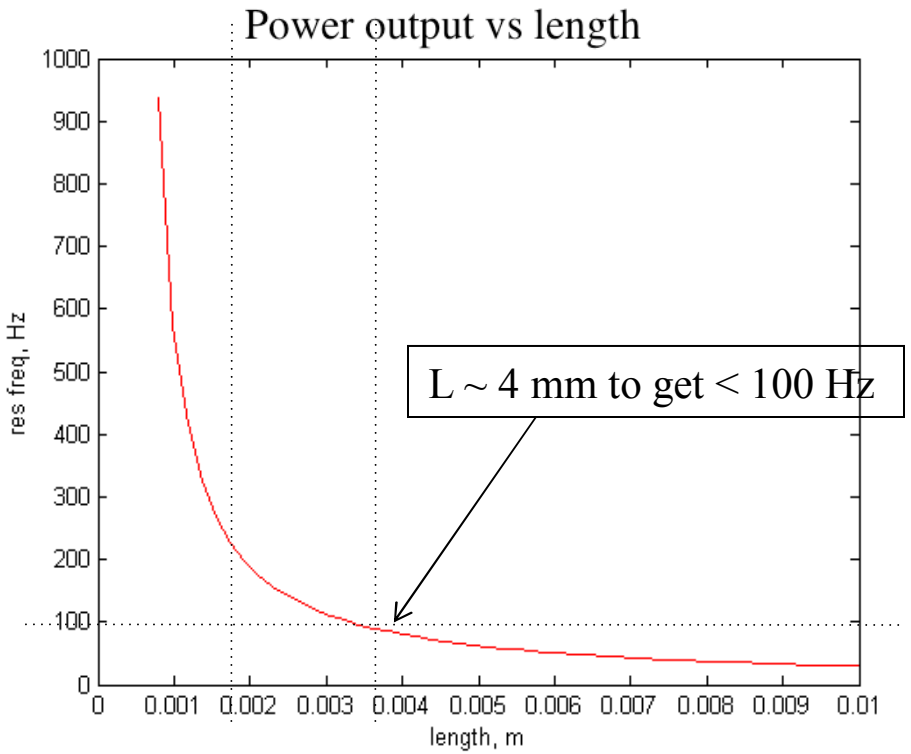
Second Generation Prototype: Design

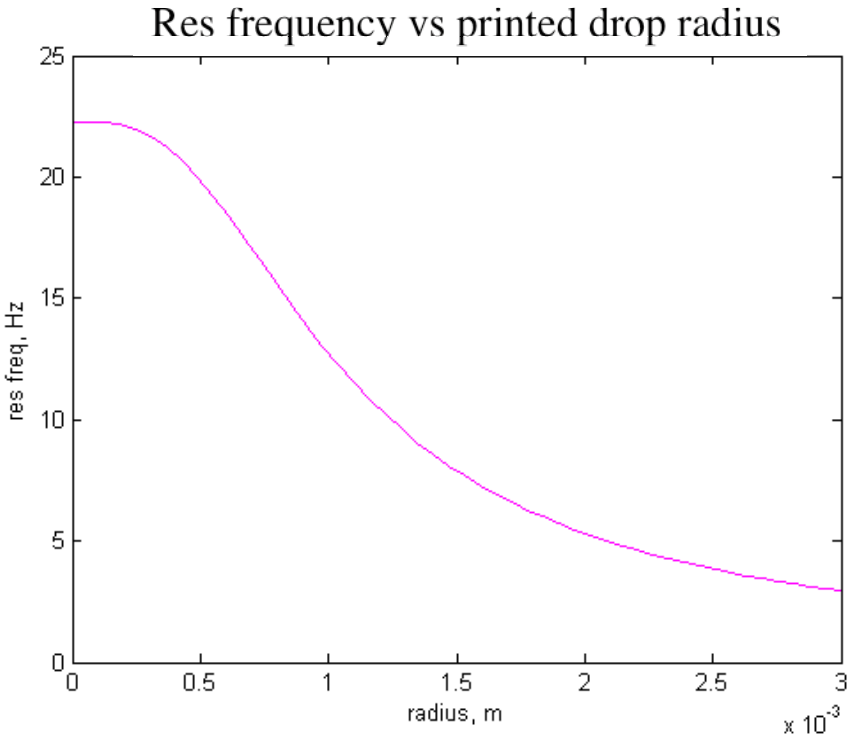
- Goals:
  - ➔ increase power output
  - ➔ reduce resonance frequency
    - ➔ increase m_{proof} & L_{beam}
- Constraints
  - ➔ Maintain die size ~1 cm^2
  - ➔ ~1 cm^2 for printed storage
  - ➔ Retain advantages of MEMS fabrication

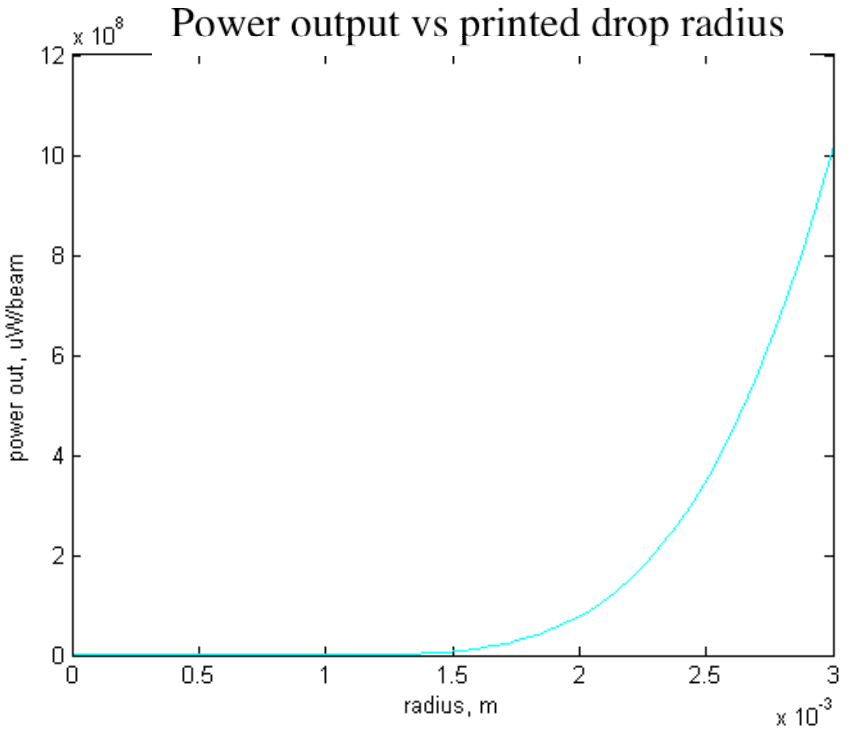




Second Generation Prototype: Design

- Goal: frequency tuning
  - ➔ add a variable printed mass
- Goal: integrate energy harvesting & storage
  - ➔ leave space on-chip

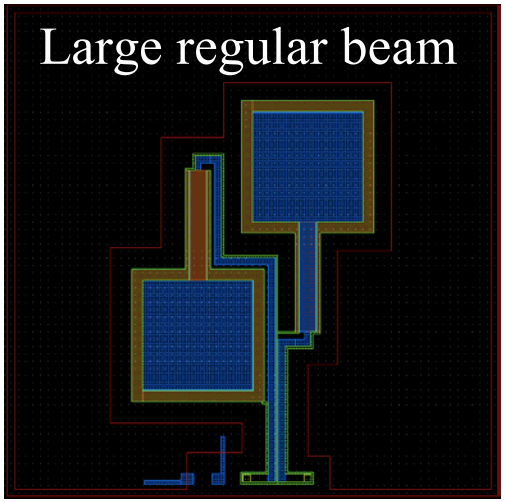




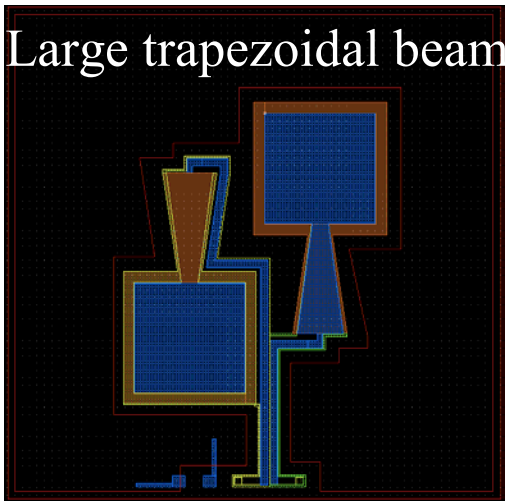
Second Generation Prototype: CAD

New die (1.3 cm^2):

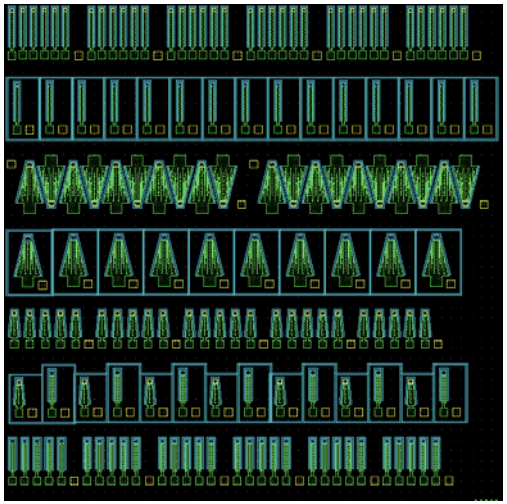
Large regular beam



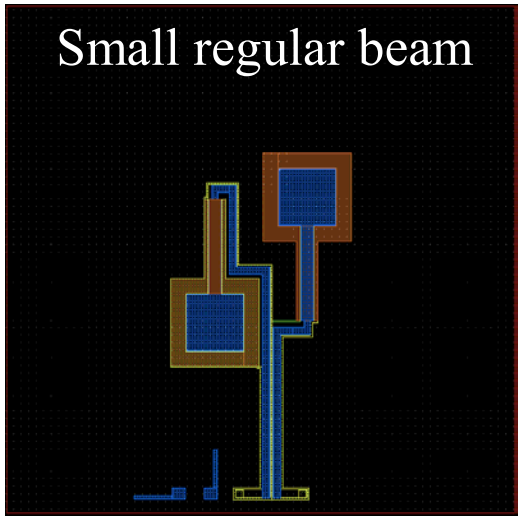
Large trapezoidal beam



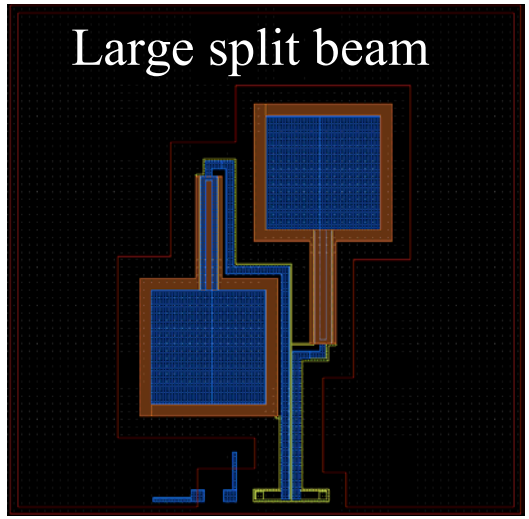
Old die (1 cm^2):



Small regular beam

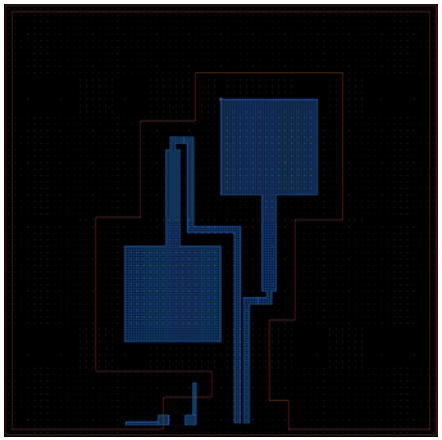


Large split beam

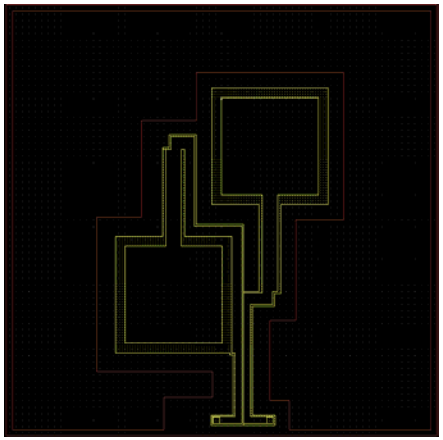


Photolithography Layers

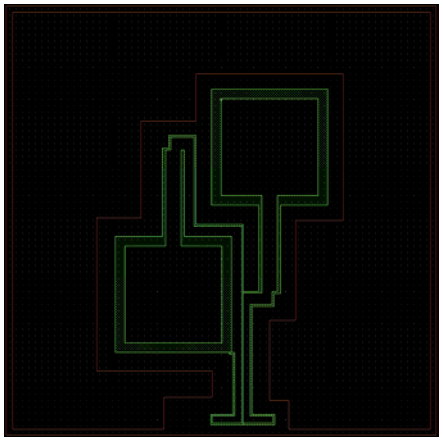
Deposit top electrode



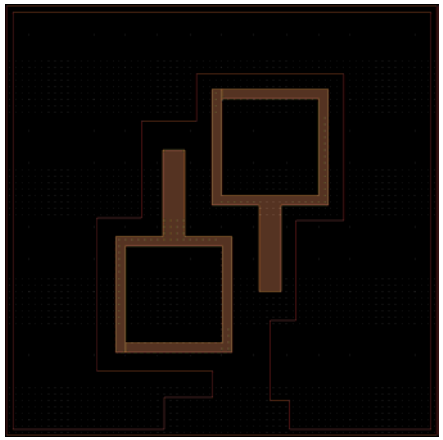
Define beam, vias



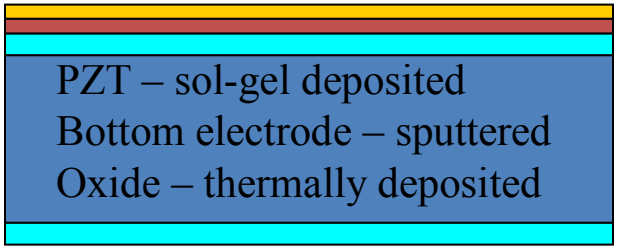
Define beam

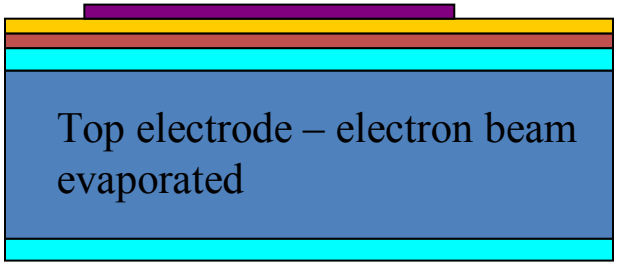


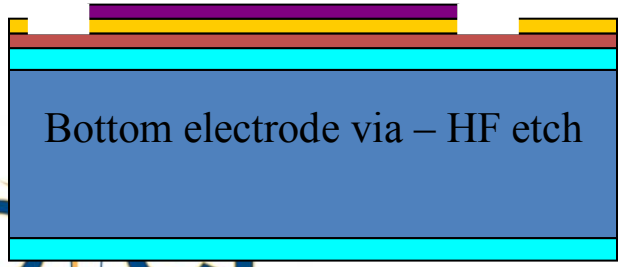
Release beam, form mass

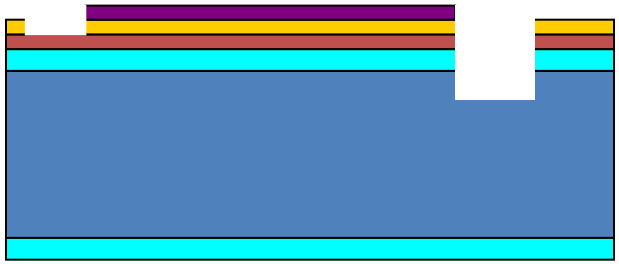


- Silicon – wafer
- SiO_2 – dielectric
- Ti/Pt – bottom electrode
- PZT – piezoelectric
- Cr/Pd – top electrode
- SrFe – printed mass

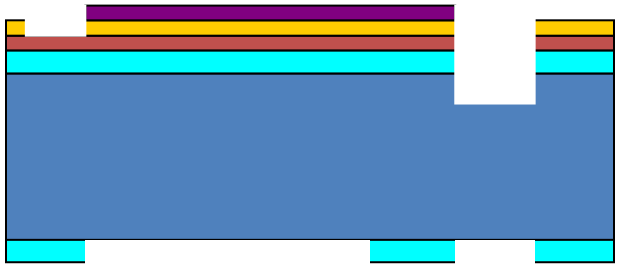




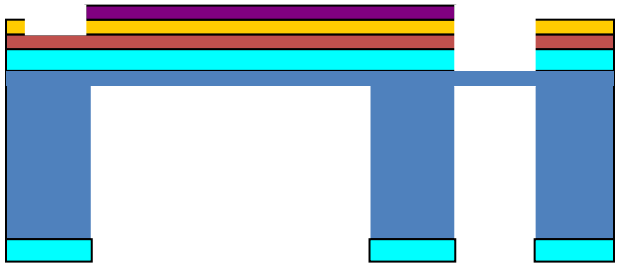




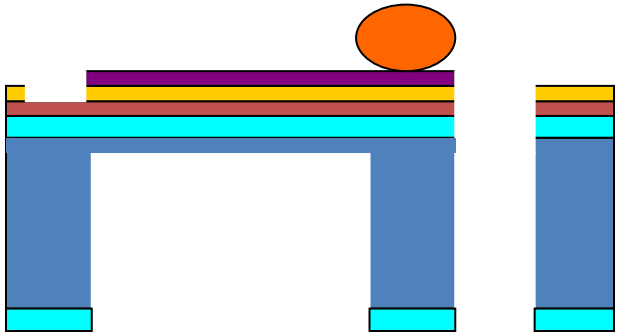
Beam definition – Ionmill etch to Si



Oxide etch to expose backside silicon



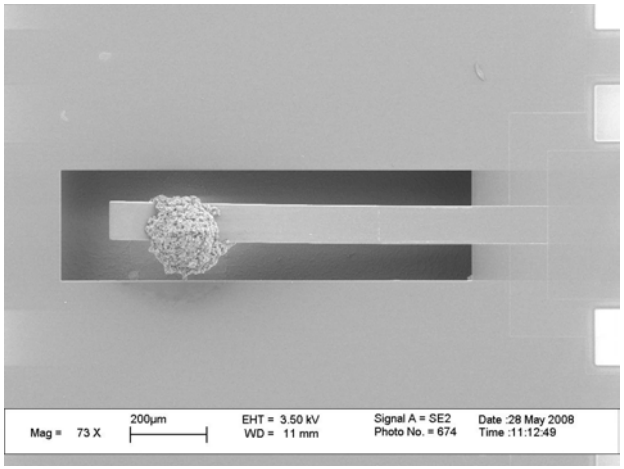
Release beams, form mass – DRIE Si etch



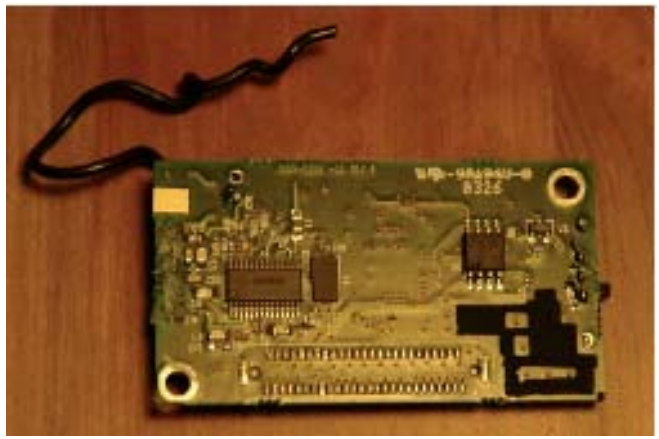
Print mass

Next Steps

- Print masses on completed devices
- Characterize 2nd generation devices
  - V_{AC}, ω_n, Impedance
- Print micro energy storage on-chip
- Integrate with power conditioning circuit and load



E. Leland & P. Minor



D. Steingart & C. Ho

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