Microsensors for current measurement

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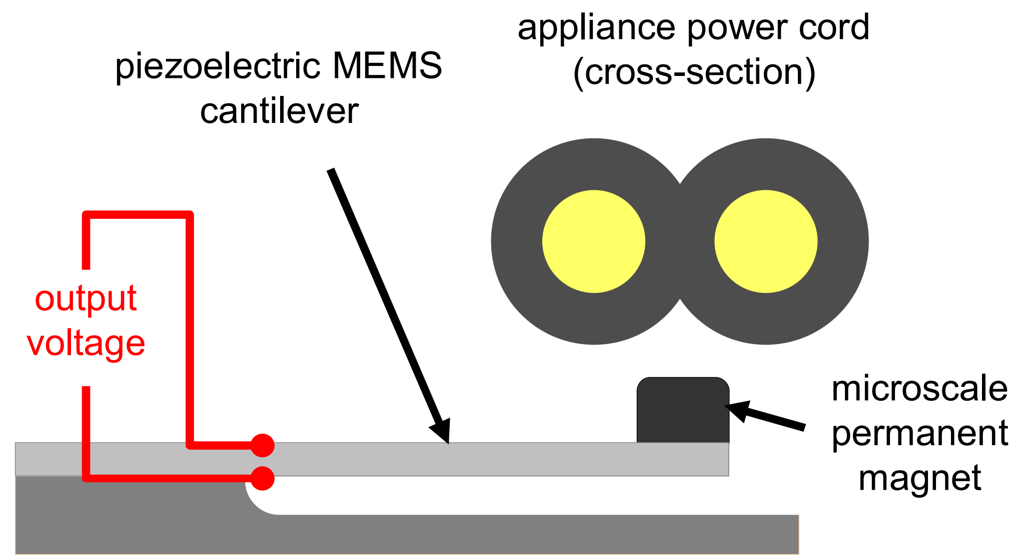
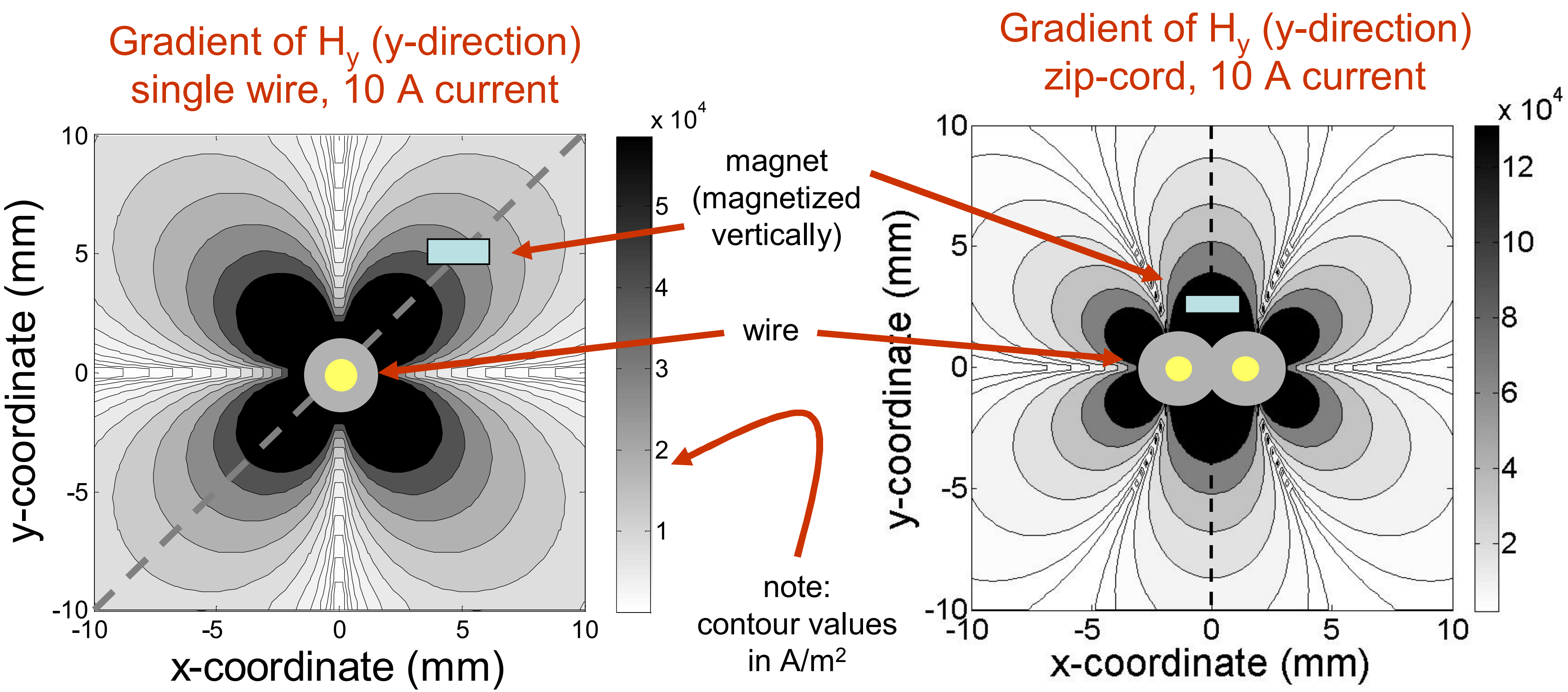
Design concept: Piezoelectric cantilever and a permanent magnet



- Permanent magnets can couple to the magnetic fields surrounding AC current carriers
- Piezoelectric materials can transduce the forces on the permanent magnet to an output voltage
- Sensor device does not require power supply or physical encirclement of conductor

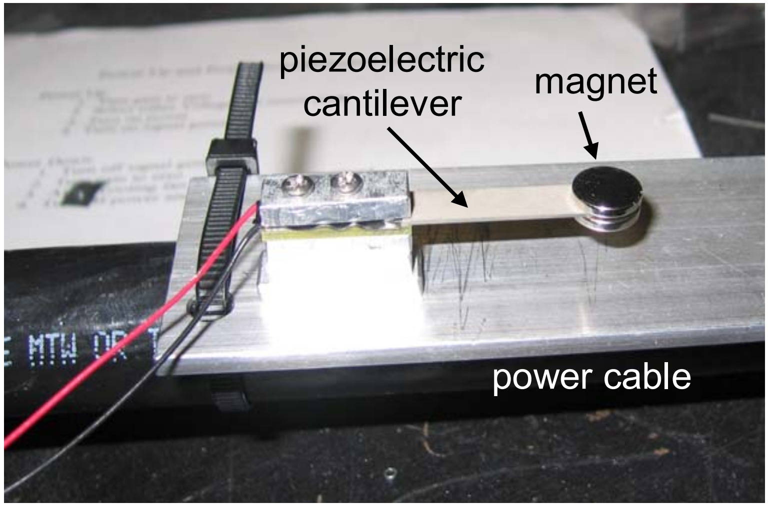
Theoretical background



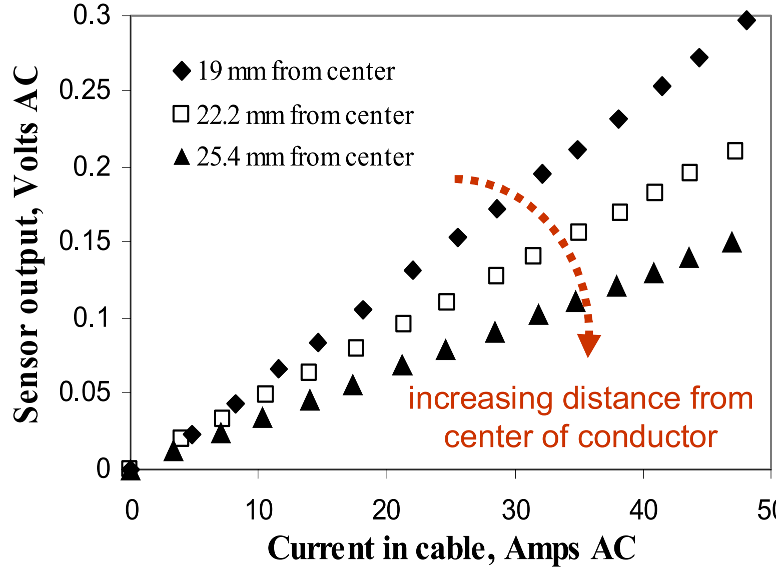
- Force on the magnet, and thus sensor signal, is proportional to the gradient of the magnetic field surrounding the wire
- On a single wire, magnet must be oriented at 45 degrees to wire
- Device functions on a two-wire zip-cord without splitting wires apart, unlike a current transformer

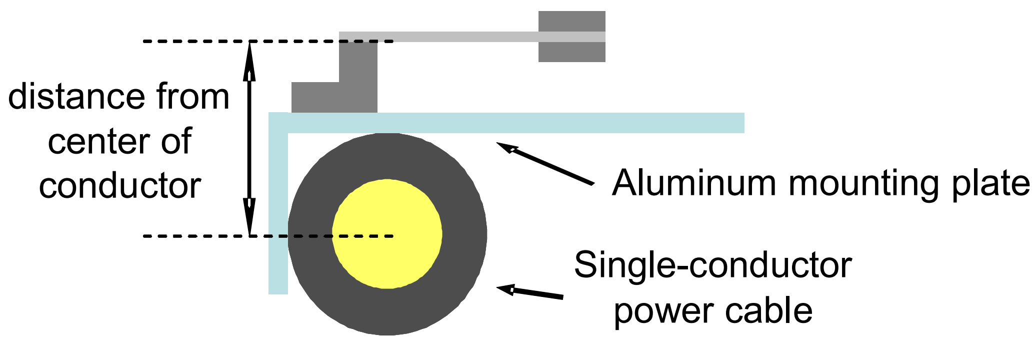
Meso-scale proof of concept

Sensor mounted on a single-conductor power cable



Linear response of current sensor

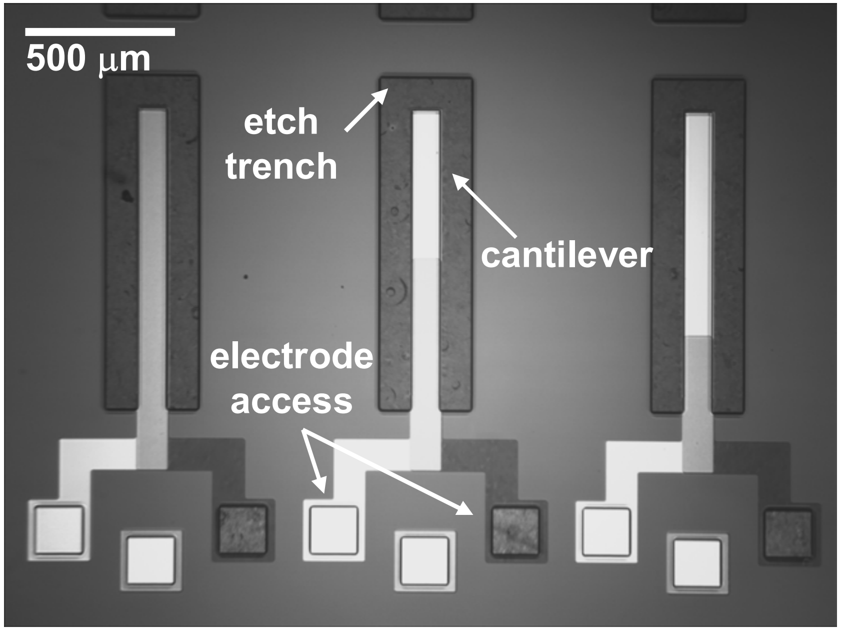




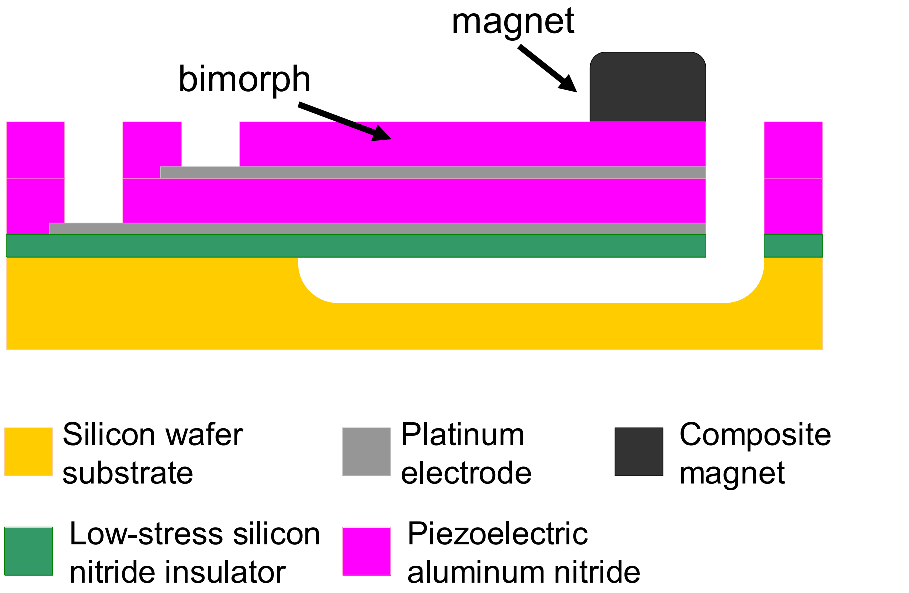
Sensor response is linear and decreases predictably with increasing distance from center of conductor

MEMS device overview

MEMS device layout (top-down)



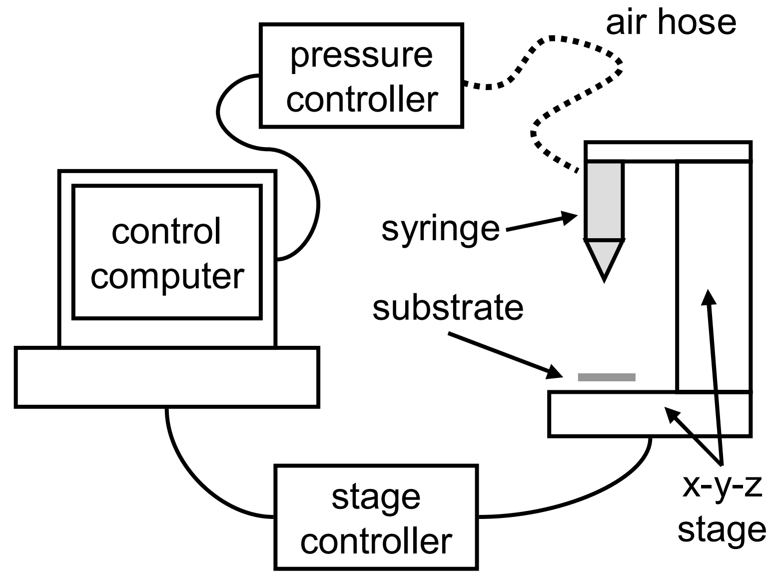
MEMS device schematic

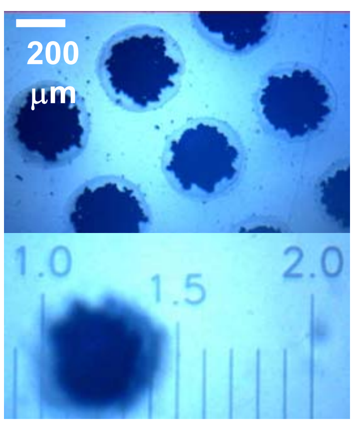


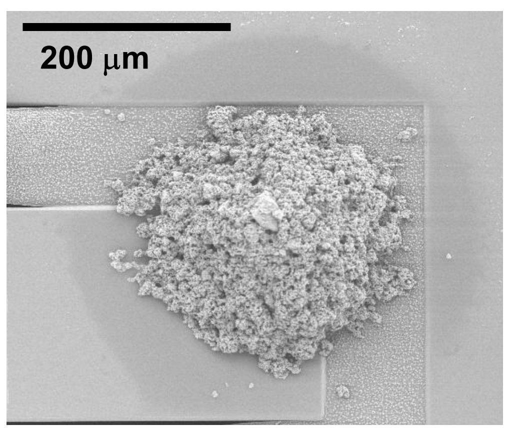
- MEMS piezoelectric cantilever using aluminum nitride as the active piezoelectric material
- Dispenser-printed composite permanent magnet using magnetic powder in a polymer matrix
- Piezoelectric behavior verified through device actuation

Dispenser-printed micromagnets

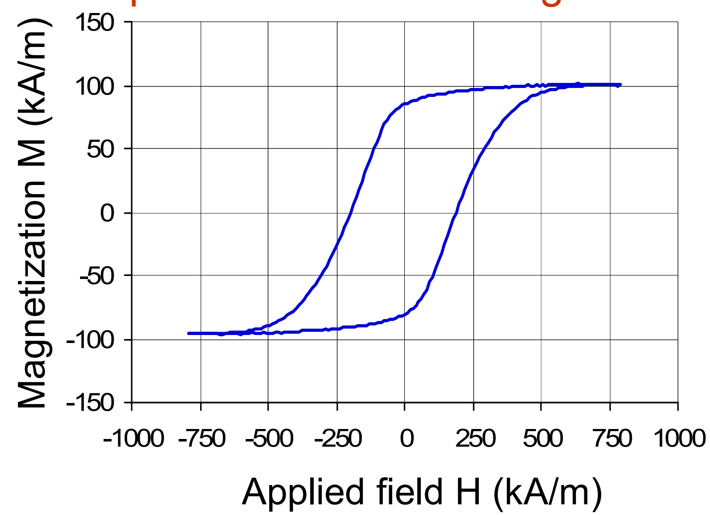
- MEMS-scale permanent magnets were printed using a dispenser-printer process developed at UC Berkeley
- Magnets consist of strontium ferrite (SrFe) magnetic powder in a PVDF polymer matrix
- Magnetic properties should improve with the use of higher-energy magnetic materials (samarium cobalt, neodymium iron boron)





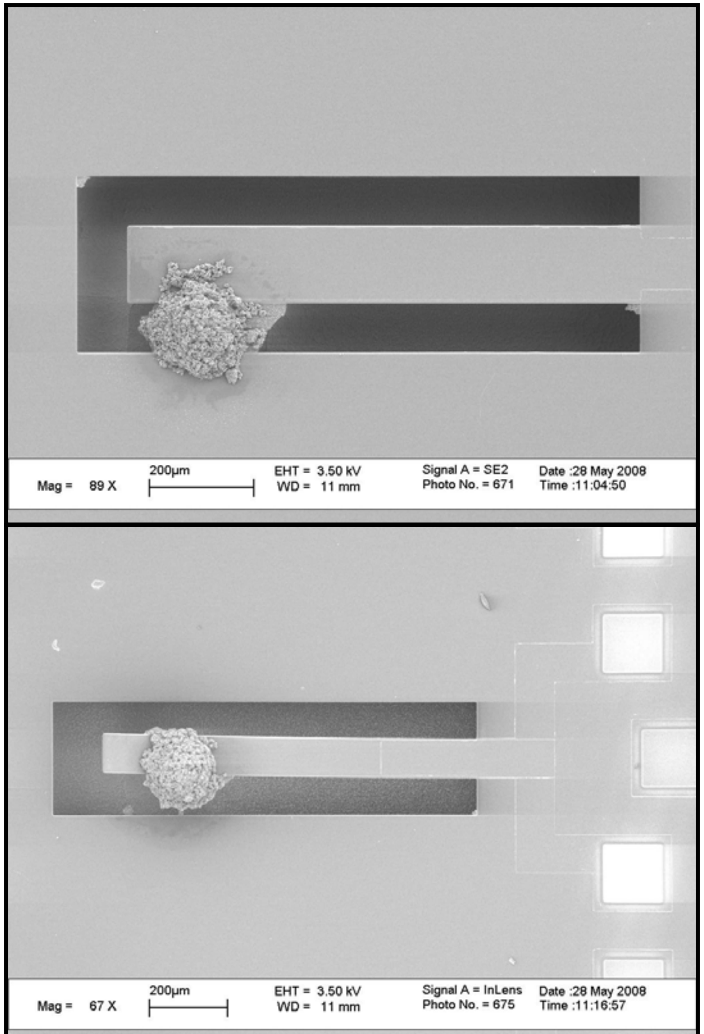


M-H hysteresis curve for dispenser-printed SrFe micromagent

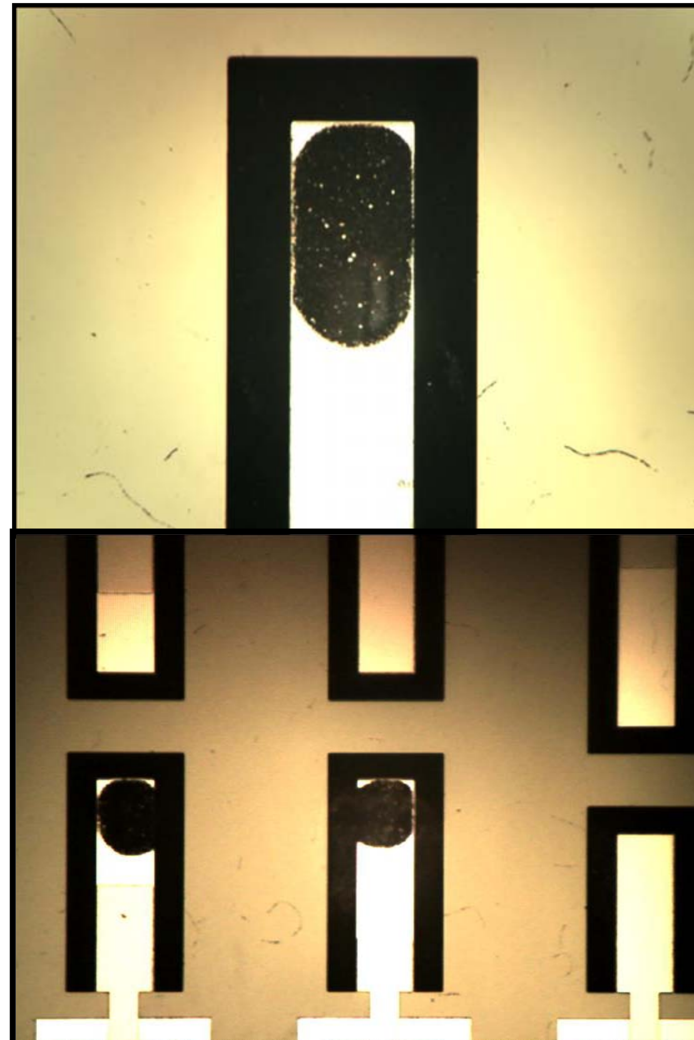


Magnet process improvement: Better aim

Before

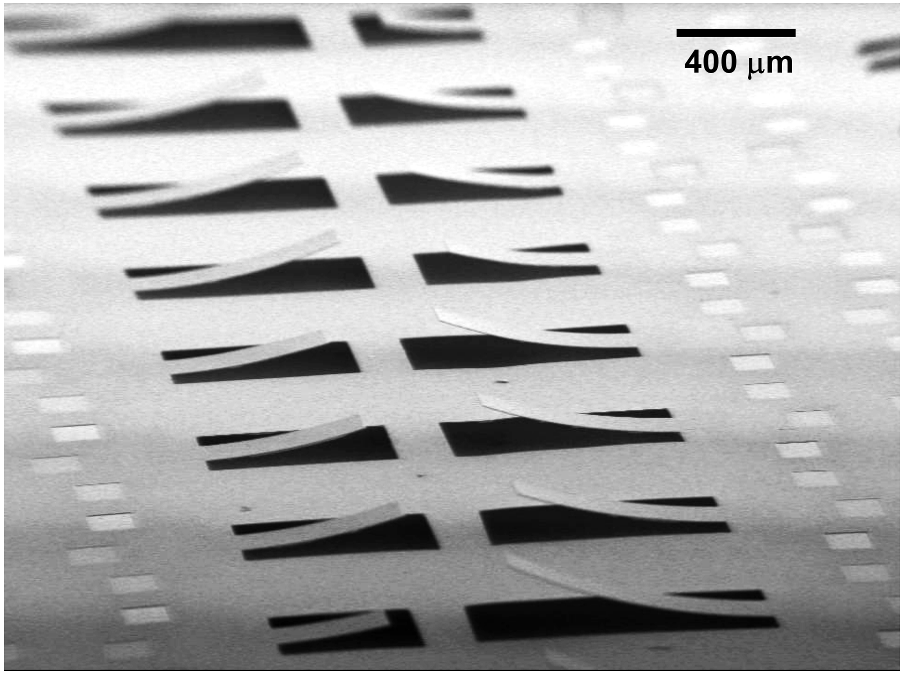


After

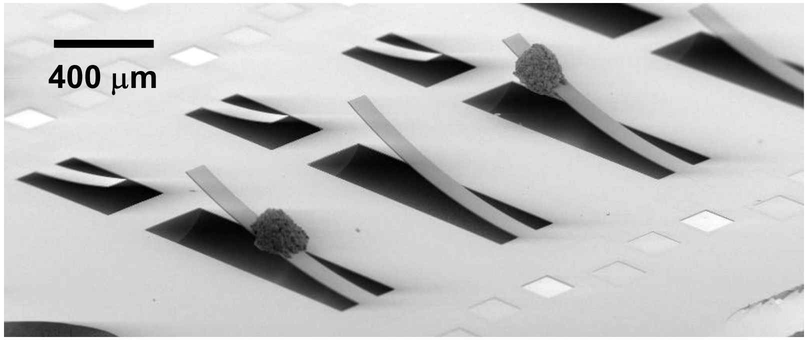


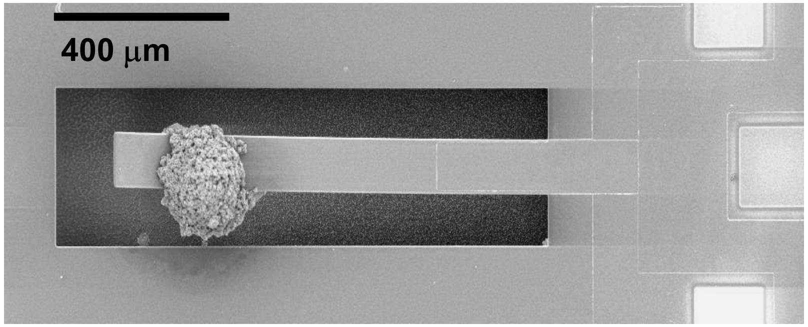
Fabricated MEMS devices

Released aluminum nitride MEMS cantilevers



Initial MEMS prototypes with dispenser-printed micromagnets



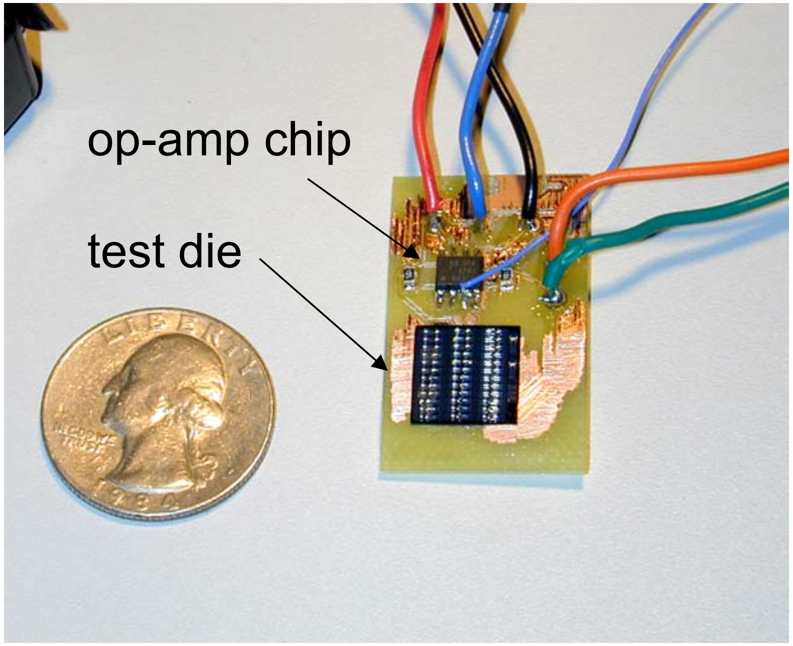


- Experiment with new composite magnet formulations using higher energy magnetic powders and stronger polymers
- Integrate MEMS device with test platform to characterize sensor performance

MEMS testing continues

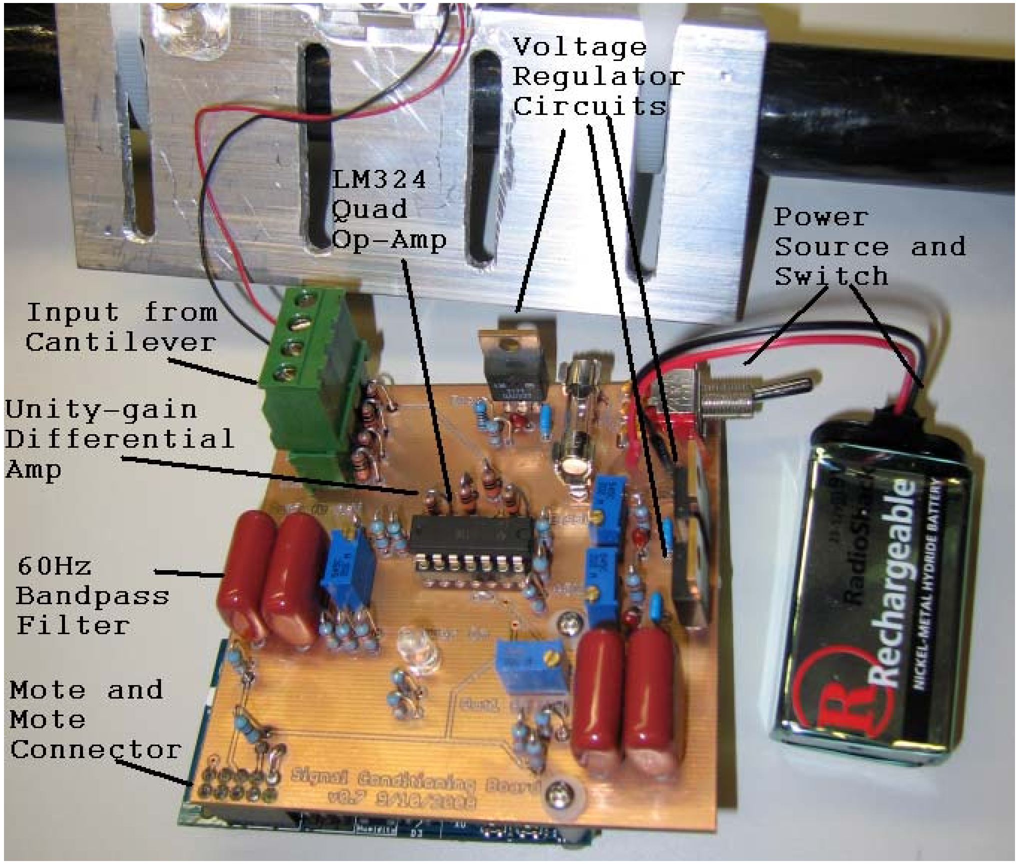
- The challenge is to read a signal from these high-impedance MEMS devices
- Fabricated test circuit using highly sensitive op-amp
- Constructing a probe station test setup inside a faraday cage for noise isolation

Test circuit



Wireless sensor device for distribution-level voltages

- Experimental data acquisition complicated by location of sensor on 25kV line (dangerous to direct-wire).
- Developed code to sample sensor output and transmit to a remote computer
- Custom circuit board designed to house signal conditioning circuits and power supplies for conditioning circuits and the mote.



Questions?

Thanks to the CEC and all the students who have contributed to this project!