

Micromachining for X-ray Microcalorimeter Arrays

Gene Hilton

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Carl Reintsema, Yizi Xu, Kent Irwin

NIST, Boulder and [†]PTB, Berlin

- Bulk and Surface Micromachining
- Surface Micromachining Processes
- Array Results



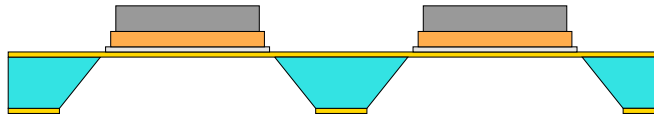
This work has been partially funded by the NASA Cross-Enterprise Program

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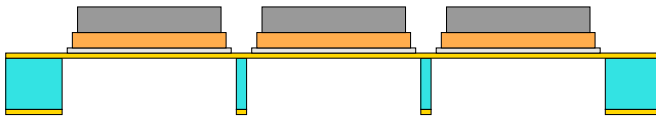
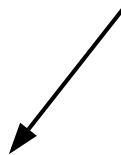
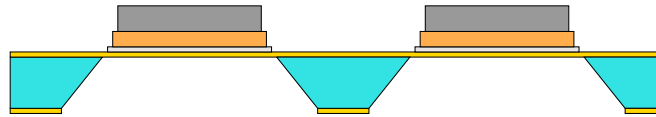
Micromachining for Arrays

Single detector method KOH anisotropic wet etch on 100 Si



Micromachining for Arrays

Single detector method
KOH anisotropic wet etch on 100 Si



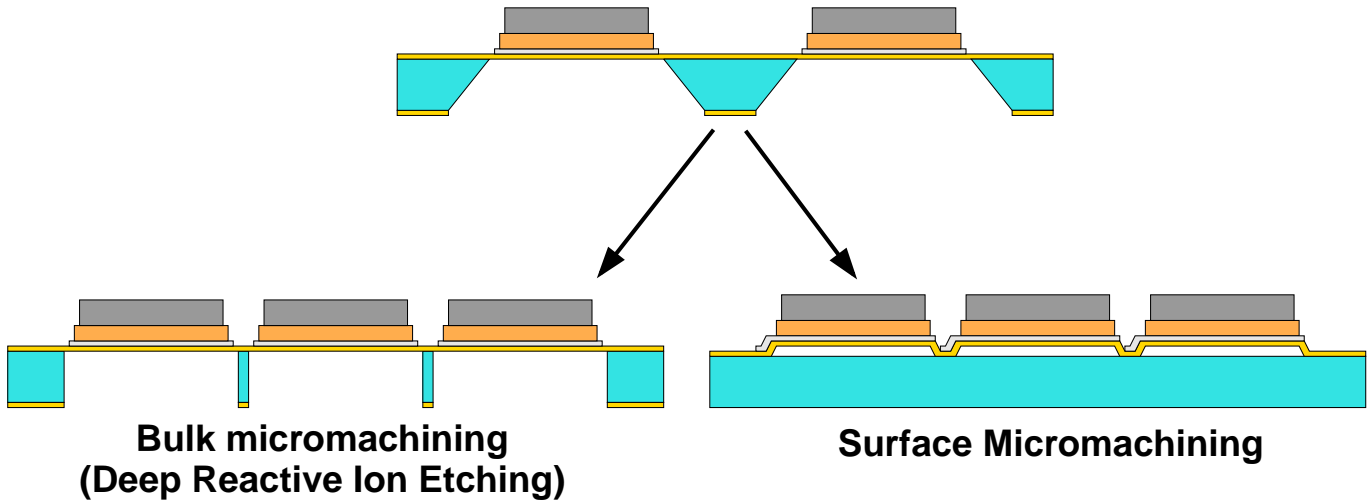
Bulk micromachining
(Deep Reactive Ion Etching)

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Micromachining for Arrays

Single detector method
KOH anisotropic wet etch on 100 Si



Bulk vs. Surface Micromachining

Bulk Micromachining

- Similar process to KOH single pixels
- Thermal conduction understood (somewhat anyway)
- Little substrate to absorb x-rays
- Additional equipment very expensive
- Little substrate to carry heat, leads, and forces



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Surface Micromachining

- New process - new problems
- Thermal conduction not understood
- Plenty of substrate to absorb x-rays
- Additional equipment cheap (NIST XeF₂ dry plasma-less etch) or (SRON wet-etch TMAH)
- Plenty substrate to carry heat, leads, and forces
- **Potential for on-wafer in-plane multiplexing**



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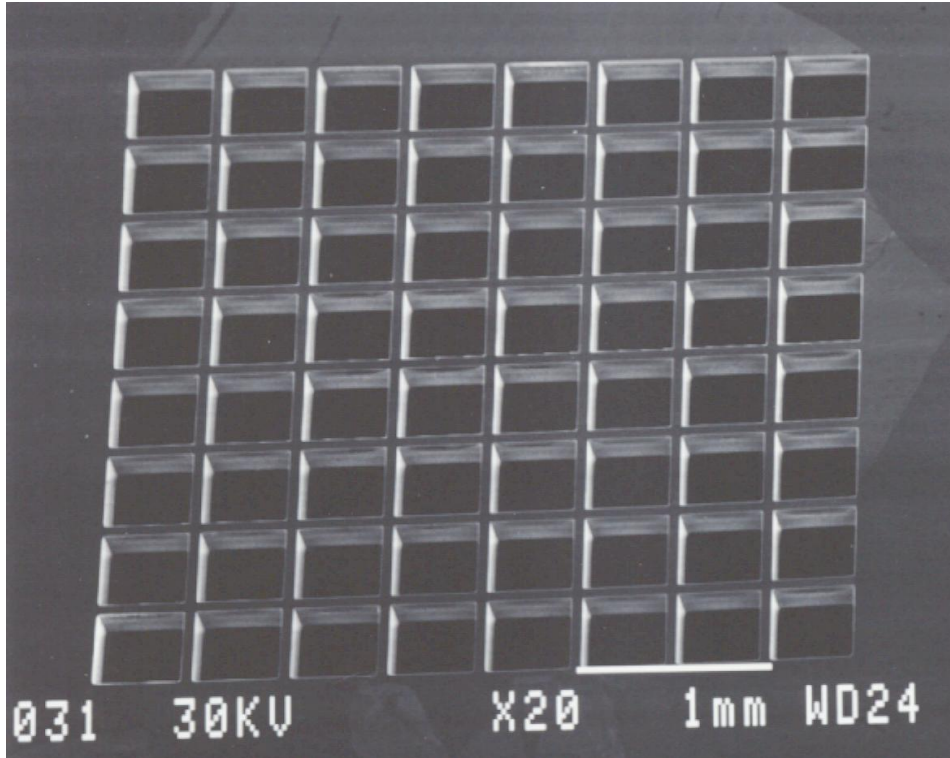


Surface Micromachining

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Let's do both! (But only talk about surface micromachining)

Bulk Micromachining - Deep Reactive Ion Etch



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Surface Micromachining Fabrication



Poly-Si sacrificial islands

Si_3N_4 Membranes

Mo/Cu TES bilayers

Cu normal metal "banks"

Nb wiring

Bi absorber

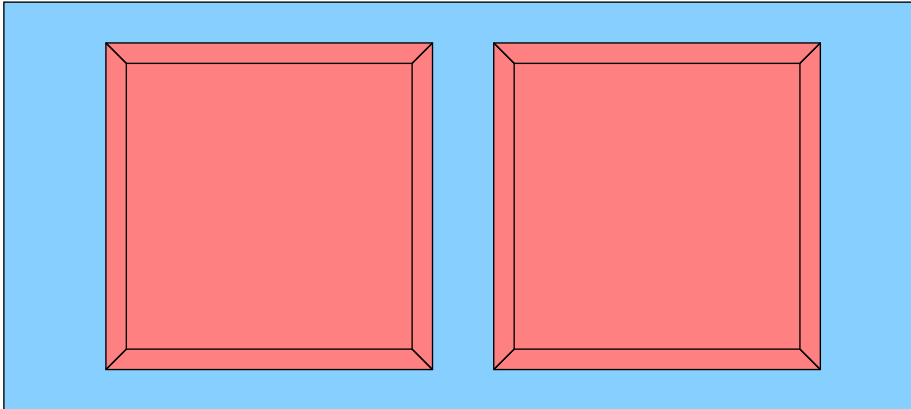
Membrane perforation

Membrane release (XeF_2 etch)

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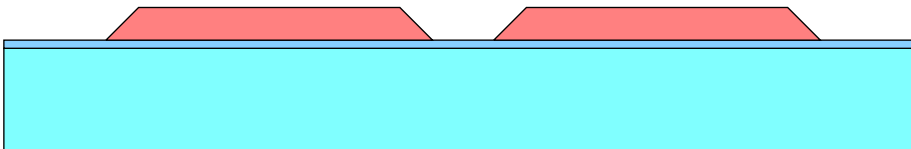
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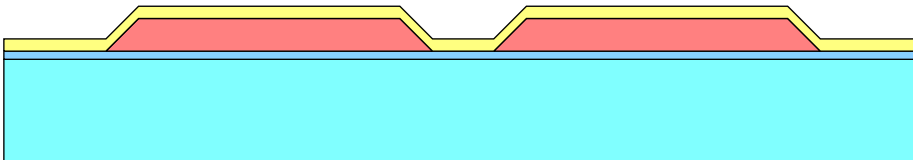
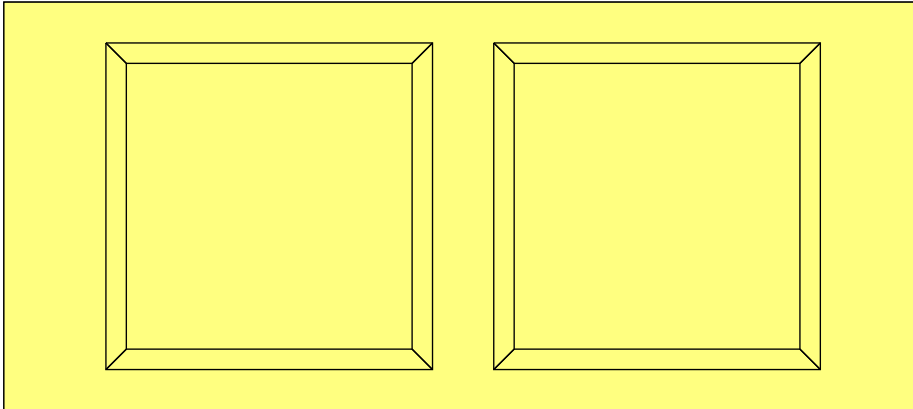
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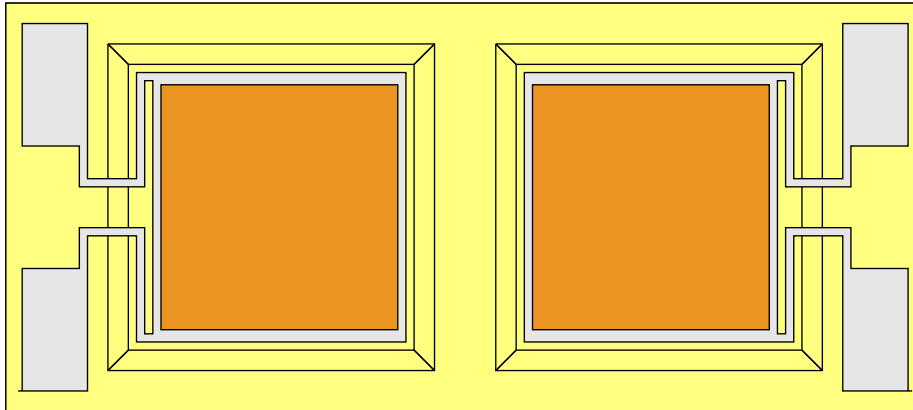
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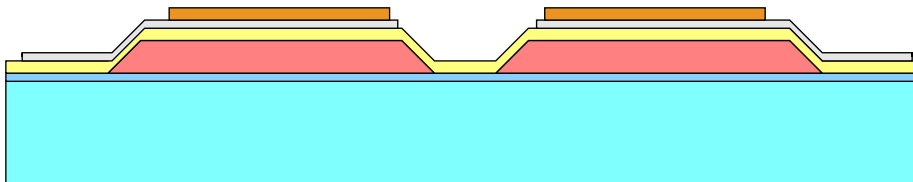
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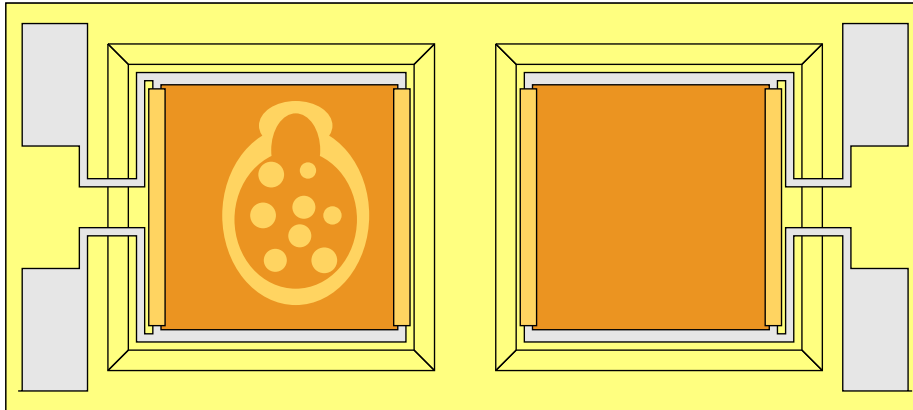
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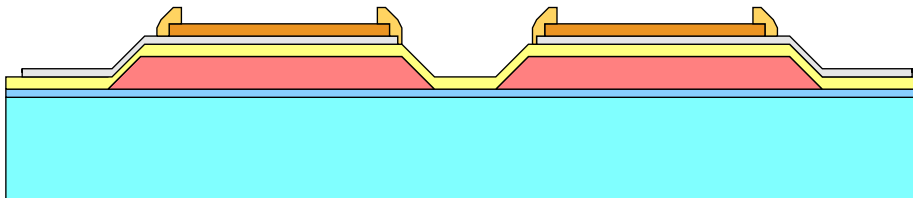
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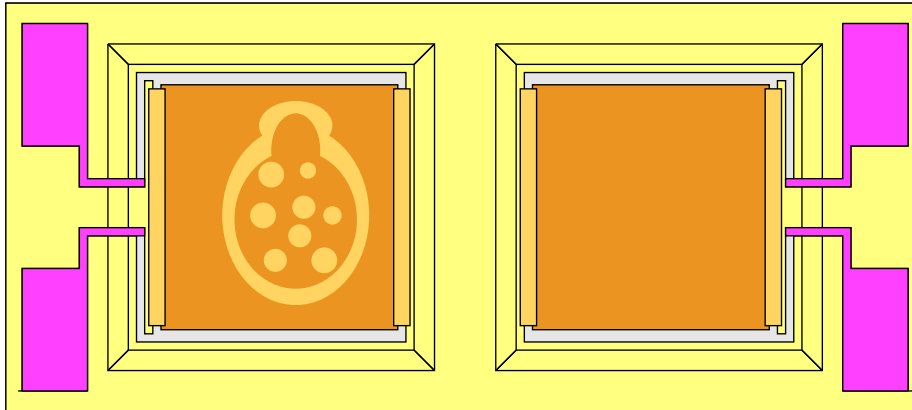
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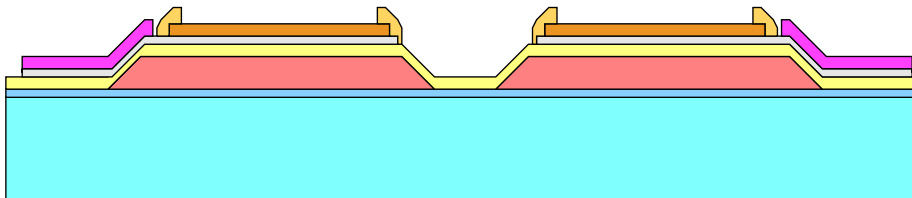
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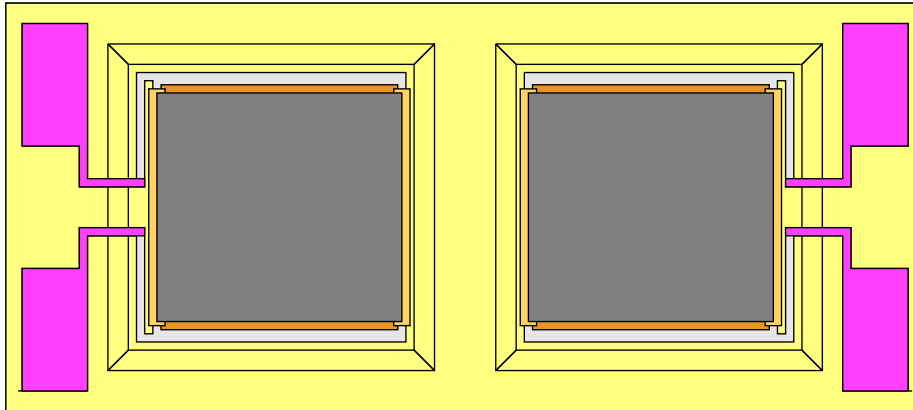
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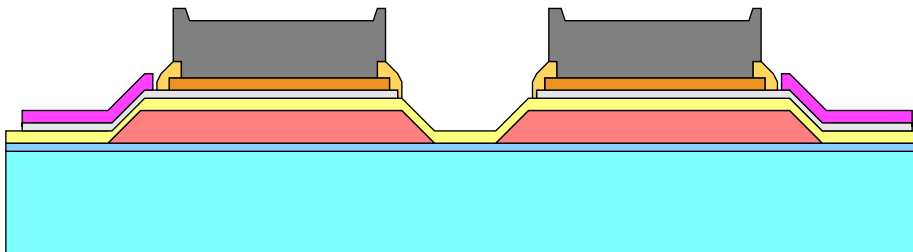
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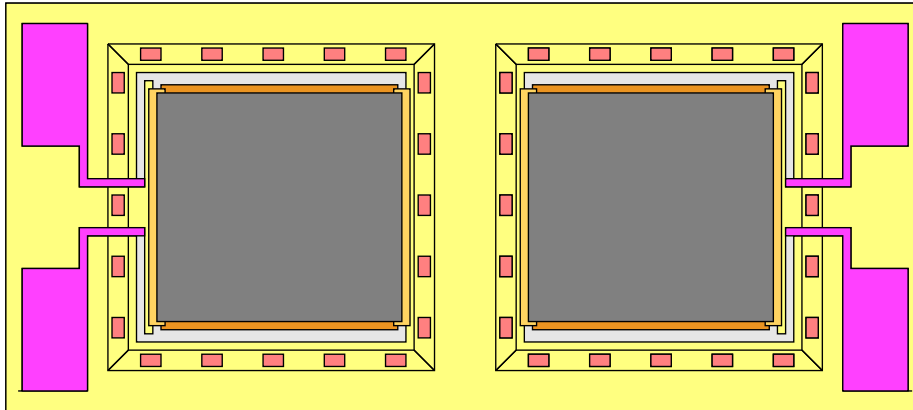
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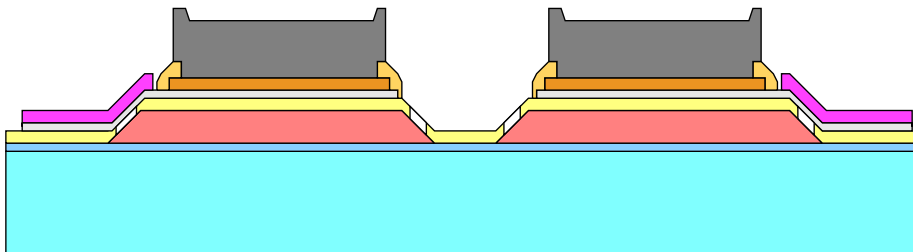
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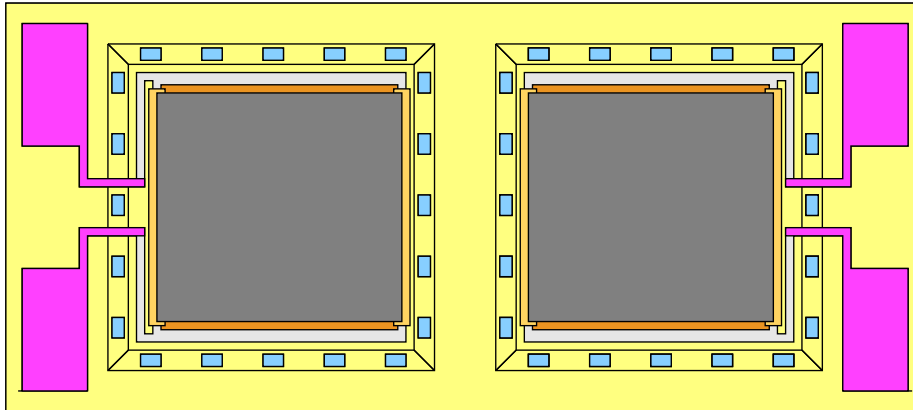
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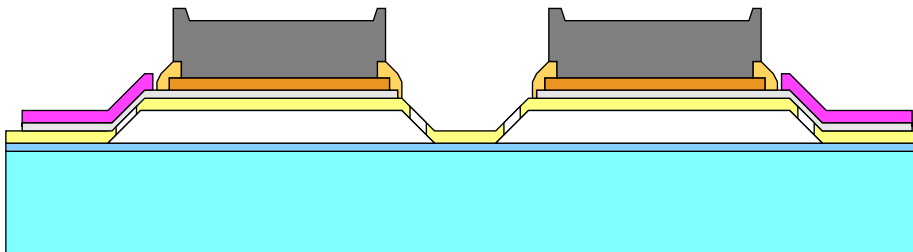
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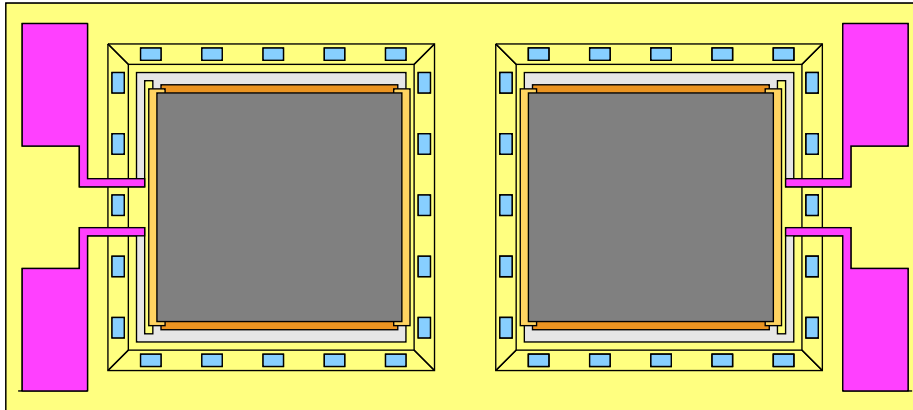
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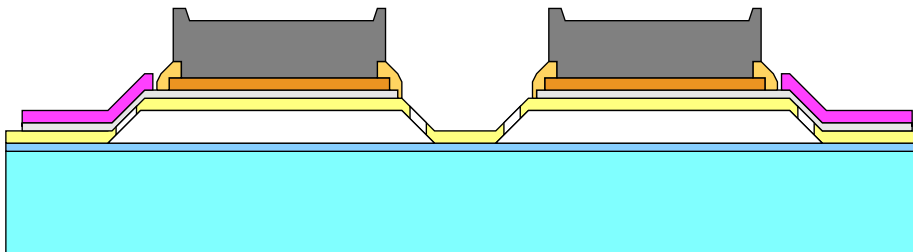
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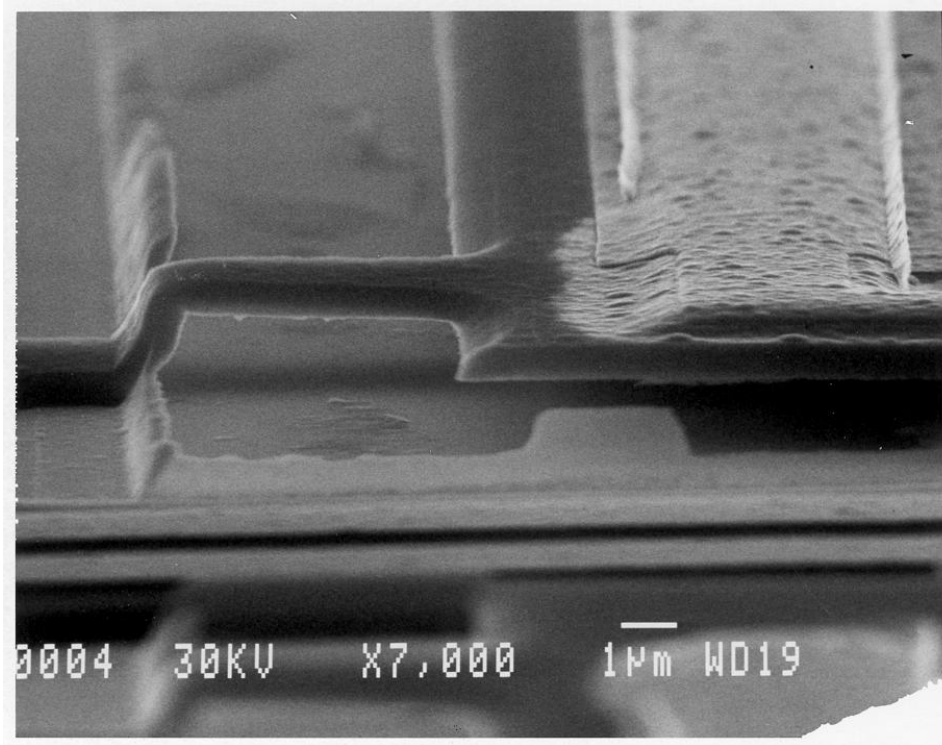
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Surface Micromachining



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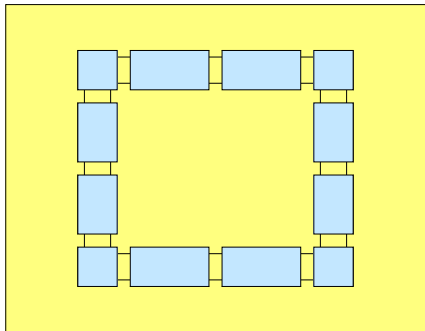
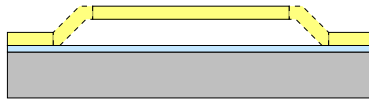
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Surface Micromachining Problems

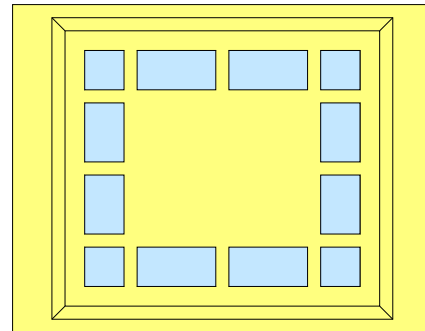
- Low yield obtained for first arrays
- Failure mode - broken supports on cooling from RT to 4K
- Worse with Bi absorber



Differential thermal contraction forces pulling on weak "table legs"

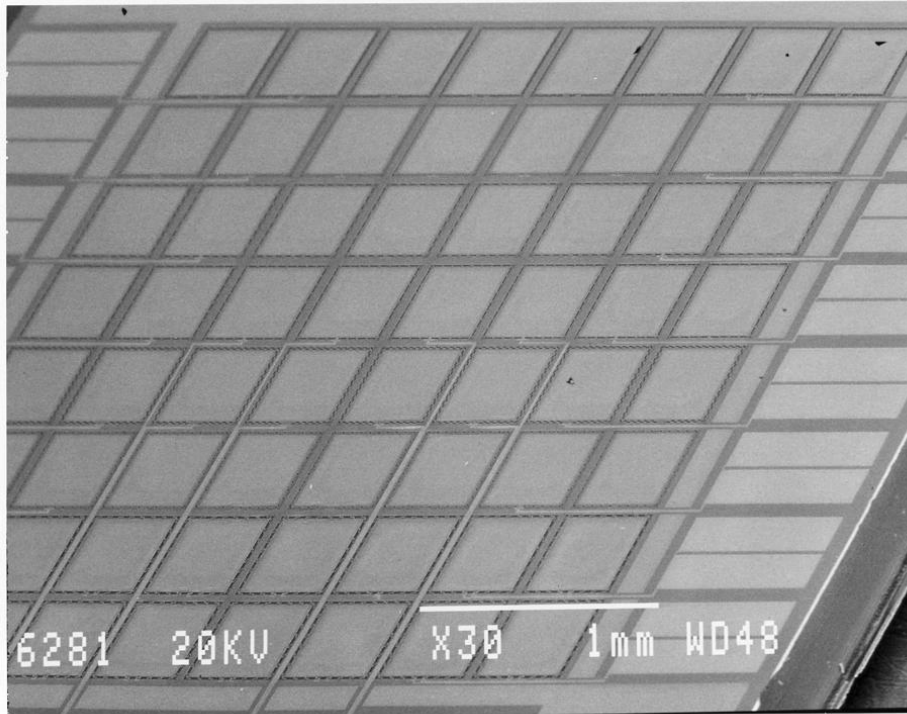


Old Design (table legs)



New Design (platform)

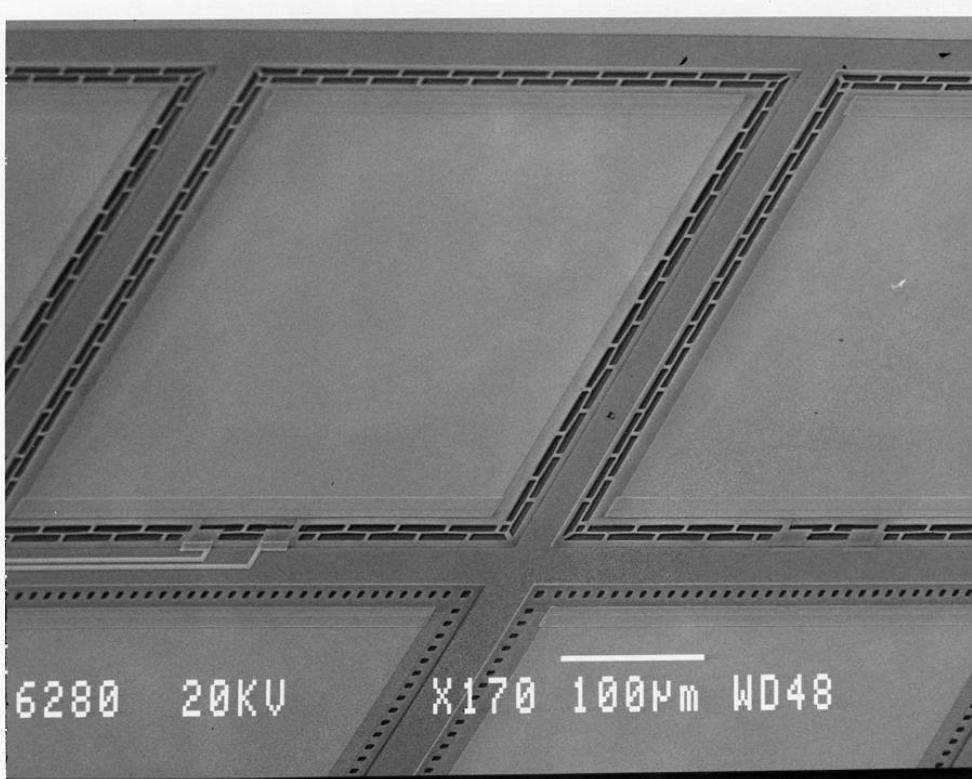
Surface Micromachining - Chip Overview



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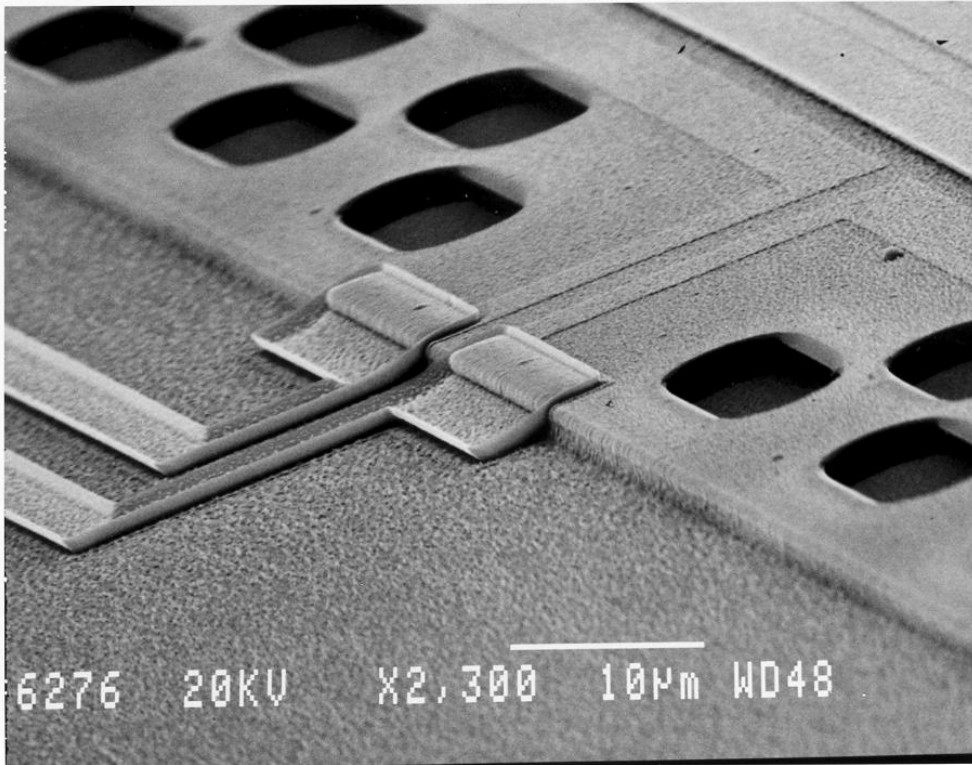
Surface Micromachining - Perforation structures



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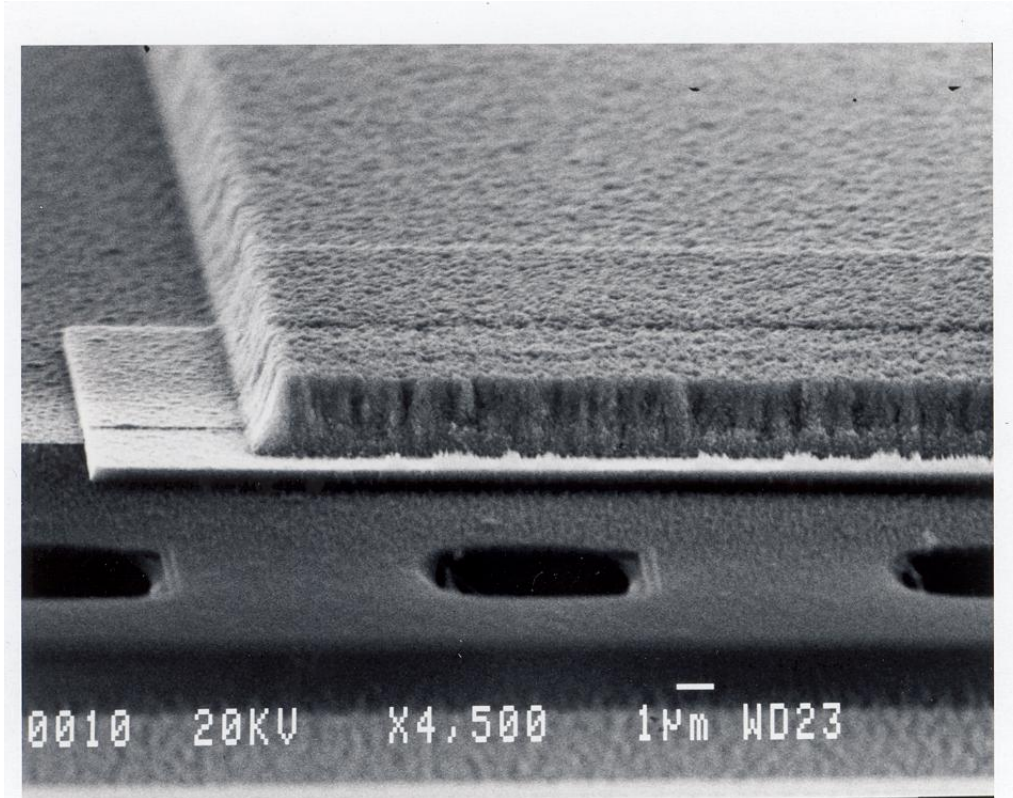
Surface Micromachining - Wiring detail



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Surface Micromachining - Absorber on membrane



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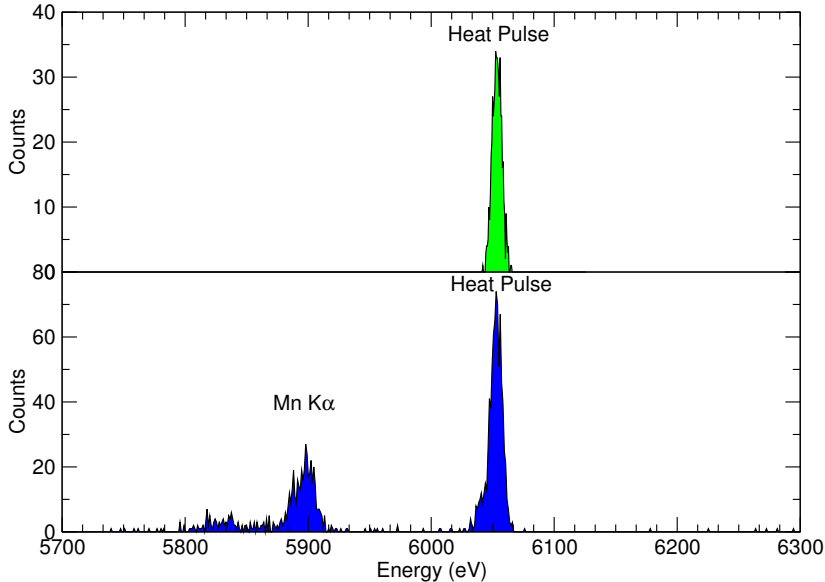
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Measurements

- 8×8 array, 8 perforation varieties, 24 pixels wired
- Measured chip without Bi absorbers
- Pixel size $400 \mu\text{m} \times 400 \mu\text{m}$
- T_c 95 - 102 mK (several chips -2different fridges)
- R_n 17 m Ω
- Long time constants (1 - 2 ms), all perforation styles not yet measured
- Multiplexed readout x-ray and dark: See Randy Doriese E-05 Friday
- Single channel readout: (measurements from last week)
 - Baseline noise/pulse height: 6 eV
 - Heat pulses (equivalent to 6 keV): 10 eV
 - Collimated ^{55}Fe x-rays 22 eV



X-ray and Heat Pulse Spectra



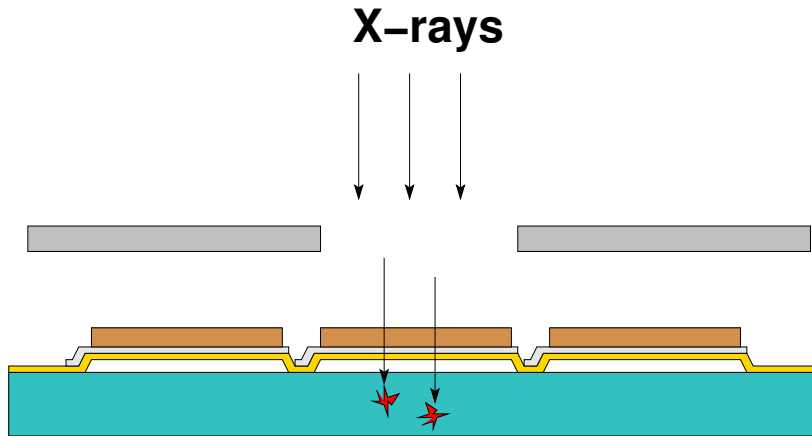
Heat pulses degraded by x-ray flux (10 eV \rightarrow 13 eV + low energy tail)

X-ray also shows tail (along with other problems)

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Heat Pulses and Substrate Hits



X-ray measurement without an absorber is a bad idea for surface micromachined detectors.

Conclusions

Are surface-micromachined a good approach to TES arrays?

- Fabrication process(es) are successfully yielding small (8×8) arrays
- Demonstrated potential for under pixel wiring, working toward under-pixel mux
- Need to measure devices with absorbers - prevent substrate hits
- Verify absorber improves positional dependence
- Complete study of G vs. perforation - may need to work on increasing G
- Need uniformity and crosstalk study



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