Micromachining for X-ray Microcalorimeter Arrays

Gene Hilton

Jim Beall, Steve Deiker, Leila Vale, Randy Doriese, Jörn Beyer†, Joel Ullom, 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
Micromachining for Arrays

Single detector method
KOH anisotropic wet etch on 100 Si
Micromachining for Arrays

Single detector method
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Bulk micromachining
(Deep Reactive Ion Etching)
Micromachining for Arrays

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Bulk micromachining (Deep Reactive Ion Etching)  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
**Bulk vs. Surface Micromachining**

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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 XeF$_2$ 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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Let’s do both! (But only talk about surface micromachining)
Bulk Micromachining - Deep Reactive Ion Etch
Surface Micromachining Fabrication

- Poly-Si sacrificial islands
- Si₃N₄ Membranes
- Mo/Cu TES bilayers
- Cu normal metal "banks"
- Nb wiring
- Bi absorber
- Membrane perforation
- Membrane release (XeF₂ etch)
Surface Micromachining Fabrication

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Poly-Si sacrificial islands

$\text{Si}_3\text{N}_4$ Membranes

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National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce
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Surface Micromachining
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) vs New Design (platform)
Surface Micromachining - Perforation structures
Surface Micromachining - Absorber on membrane
Measurements

- 8 × 8 array, 8 perforation varieties, 24 pixels wired
- Measured chip without Bi absorbers
- Pixel size 400 μm × 400 μm
- T_c 95 - 102 mK (several chips -2 different fridges)
- R_n 17 mΩ
- Long time constants (1 - 2 ms), all perforation styles not yet measured
- Multiplexed readout x-ray and dark: See Randy Dorise 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}\text{Fe} x-rays 22 eV
Heat pulses degraded by x-ray flux (10 eV → 13 eV + low energy tail)

X-ray also shows tail (along with other problems)
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 \((8 \times 8)\) 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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