Developing fully integrated TES Microcalorimeters using Ir TES and Sn Absorbers

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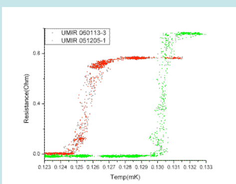
Abstract:

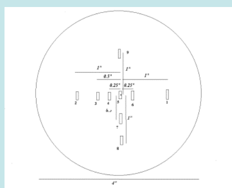
Cryogenic Microcalorimeters are the future detectors for X-ray astrophysics. Our group is focusing on developing transition edge sensors (TES) using single layer Ir films as detector and deposited Sn as absorber. We obtained good unsuspended devices with reproducible transition temperature around 120mK and transition width of 1-2 mK. Ir films are deposited using RF magnetron sputtering and photolithography lift-off techniques. Al is used for electrical traces and is deposited via RF magnetron sputtering and wet etching. We also successfully deposited Sn mushroom like structures with high filling factor using photolithography techniques on a Si substrate. The devices are suspended on silicon nitride membrane. We are in the process of combining all the processes together to build fully functional X-ray devices.

Ir as detector:

Iridium is a superconductor with a bulk transition temperature at 112 mK. In thin films the transition temperature is about 125 mK. Using a single material superconductor should improve the detector array's uniformity and reproducibility. We obtained high purity and uniformity films via RF magnetron sputtering. To improve adhesion a thin layer of aluminum (a few Å thick) is deposited underneath the Ir. Both reproducibility and uniformity tests have been performed. We tested devices deposited a few months apart and the transition temperature does not vary by more than a couple of mK. We deposited Ir over a 4 inch wafer and compared the transition temperature from different regions of the wafer, the differences were in the range of 2 mK which is within the uncertainty range due to changes in the magnetic field between measurements (the measurements where done using an ADR system). We deposited Ir/Al devices successfully using a lift-off photolithography technique. Al was used for the electrical traces.

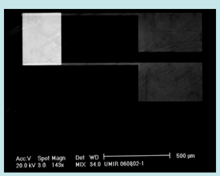


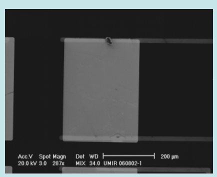
RF sputtered Ir film transitions.

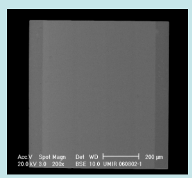


Sample	ΔT (mK)
4	-1.5
5	0
6	1.5
7	-0.4
8	-2
9	-1.8

Differences in the transition temperature for samples coming from different parts of an Ir film deposited on a 4" wafer.



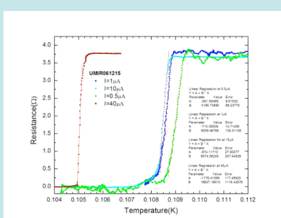


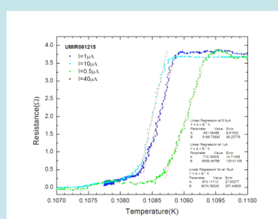


SEM images of Ir/Al single pixels using mixed backscattering and secondary electron beam scan. The devices are obtained via RF magnetron sputtering and photolithography. The Ir pixel is RF sputtered using a lift-off technique. Al is RF sputtered and wet etched.

We tested our devices using different bias current ranging from 0.5 μA to 40 μA. In this range the transition temperature changes by about 4 mK and the sensitivity α at ¼ of the transition ranges from about 500 for the lower bias current to about 1,700.

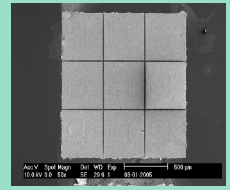
$$\alpha = \frac{T}{R}\frac{dR}{dT} = 500 - 17{,}000$$

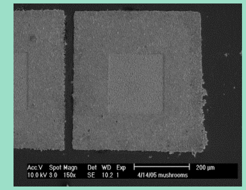




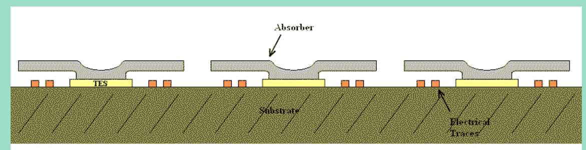
Sn as absorber:

We use tin as our absorber material. To obtain a high filling factor we are working on "mushroom" shaped absorbers. The Sn overhangs the TES covering the area used for electrical connections. As a superconductor, Sn is a good choice of material since it has low heat capacity. We deposited the Sn via thermal evaporation using photolithography techniques. Good mechanical tests with thicknesses of 1.5-2 μm were achieved. In the future, absorbers up to 5 μm thick will be fabricated.





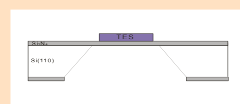
SEM images of a 3×3 mushroom array, mechanical test (top view). The squares at the center of each mushroom are the mushroom stem.



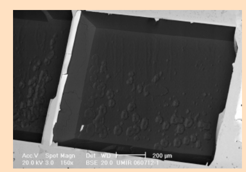
Schematic view of a TES with mushroom absorbers.

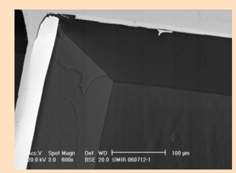
Etching processes:

The TES will be suspended on a silicon nitride (Si_3N_4) membrane. The devices are deposited on a Si substrate coated on both sides with Si3N4. The Si3N4 on the back side of the wafer is etched in correspondence of the TES devices using 85% hot phosphoric acid (H3PO4) at 165°C. The silicon is then etched with 35% potassium hydroxide (KOH) at 80°C, using the Si3N4 as a mask. KOH is a directional etchant for Si. We use Si (100), obtaining walls with an angle of 54.6° with respect to the horizontal plane.



Schematic view of our suspended devices





Scanning electron microscope (SEM) images of etched Si(100).

References:

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2. C.A. Kilbourne; Nuclear Instr. And Methods In Physics Research A 520 (2004) 402
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Acknowledgment:

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