

## Microelectronic Fabrication of Transition Edge Sensors

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Achieving optimum spectral energy resolution in conventional scanning electron microscopes (SEM) can be accomplished by using microcalorimeters. Improvements in device design are being studied, although many research groups have developed fabrication techniques that produce consistent results [1]. Here, we discuss the fabrication method that we are using to produce microcalorimeters using superconducting transition edge sensors (TES) as thermometers, and some of the roadblocks we are observing.

Many materials have been employed to engineer TES devices. We begin by depositing a 1  $\mu\text{m}$  low stress silicon nitride layer onto a <100> silicon wafer. A molybdenum (Mo)/copper (Cu) bilayer is then deposited via ebeam evaporation without breaking vacuum between depositing the layers. The Mo,  $\sim 400 \text{ \AA}$  in thickness, is evaporated at an elevated substrate temperature of  $\sim 565 \text{ }^\circ\text{C}$  to facilitate optimum grain size and shape. The Cu layer,  $\sim 1740 \text{ \AA}$  in thickness, is then evaporated at a much cooler substrate temperature of  $\sim 100 \text{ }^\circ\text{C}$ .

To obtain our goal of producing a  $400 \mu\text{m} \times 400 \mu\text{m}$  TES pad with Mo leads, the bilayer is fabricated via various masking steps involving both wet and dry etches. The general micro-processing consists of the following steps:

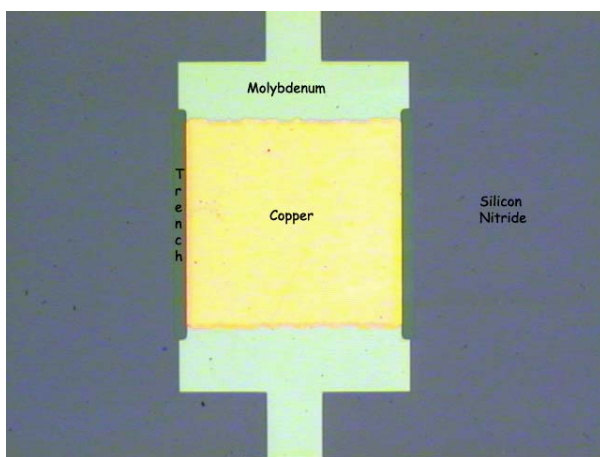
1. Wet etch two trenches in the Cu to gain access to the Mo layer. These trenches define the sides of the TES pad.
2. Using the remaining Cu as a mask, the exposed Mo is etched via dry plasma. This process laterally etches the Mo resulting in the Cu overhanging the Mo layer by  $\sim 300 \text{ nm}$ . The Cu overhang is fabricated to eliminate superconducting shorts along the edges of the device.
3. Wet etch the Cu to define the ends of the TES pad.
4. Wet etch the Mo to define the leads.
5. The device, to be a good thermometer, must be thermally isolated. We achieve this by etching a window in the silicon substrate. KOH is used to etch the silicon from the back of the wafer while the device is covered for protection. The KOH etch will follow the (111) planes in the silicon and stop on the silicon nitride layer.

The primary problem present in our fabrication method revolves around Cu technology. To process the Cu, we have chosen ammonium persulfate as a wet etchant. After the Cu is etched away from the underlying Mo, we have consistently measured a Cu undercut of  $\sim 3 \mu\text{m}$ . However, when etching a Cu layer that is not part of a Mo/Cu bilayer, there is no visible undercut.

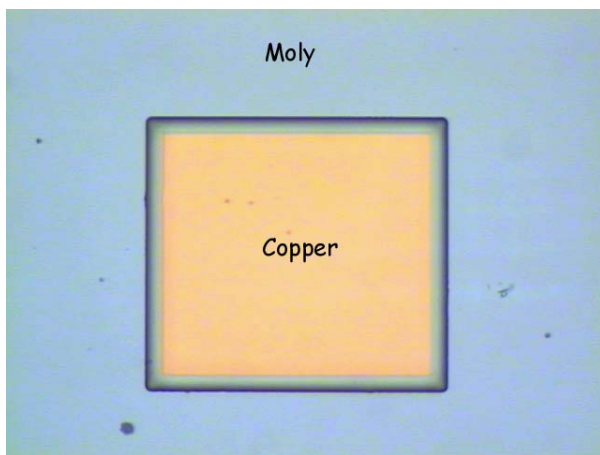
To treat the Cu layer and attempt to eliminate undercutting, the bilayer was placed in a 1% Benzotriazole (BTAH) solution immediately after the evaporation process. BTAH, a known Cu corrosion inhibitor, showed no proof of stopping the undercutting problem. However, we are currently testing whether the chemical shows proof of hindering Cu oxidation.

To further assess the undercutting concern, we are investigating the root cause. One possibility is that the percentage of exposed Mo presents an accelerated Cu undercut. Tests such as using a highly diluted etchant, cooling the etchant and etching small areas of copper are being conducted. Once the origin of the undercutting is determined, a new mask set will be designed to compensate for the problem.

[1] P.Tan et al., *Low Temperature detectors*, (2002) AIP Conference Proceedings No. 605, and references therein.



**Figure 1:** This light microscopy image shows a 400 x 400  $\mu\text{m}$  TES device with Mo leads. The trenches described in step one are visible along the vertical sides of the pad.



**Figure 2:** This light microscopy image shows a 200 x 200  $\mu\text{m}$  Cu pad with the photo-resist (PR) still covering the Cu layer. The dark line surrounding the Cu layer defines the edge of the transparent PR layer. The undercutting of the Cu layer is represented by the space between the Cu edge and the edge of the photo-resist.