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Transition Edge Sensor Fabrication

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Improving x-ray spectral energy resolution in conventional scanning electron microscopes (SEM) can be achieved by using microcalorimeters. Although improvements to microcalorimeter design are still being studied, several research groups have developed fabrication techniques that result in consistent devices [1]. Here we discuss the fabrication techniques we use to make microcalorimeters using superconducting transition edge sensors (TES) as thermometers.

We begin by depositing a 1 μm, low stress silicon nitride layer onto a <100> silicon wafer. A molybdenum (Mo)/copper (Cu) bilayer is then deposited via electron beam evaporation. The Mo layer is 40 nm thick and is deposited at a substrate temperature of 700 ^{0}C. The high substrate temperature helps facilitate optimum grain size and structure of the Mo. Without breaking vacuum, a 180 nm thick Cu layer is then deposited at 100^{0}C.

To obtain our goal of producing a 400 μm x 400 μm TES pad with Mo leads (see Figure 1) 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 ~ 300 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 covering the device to keep it protected. The KOH etch will follow the (111) planes and stop on the silicon nitride layer.

Two primary problems are present in our fabrication process. One is contamination of the mo/cu interface, which may lead to an unpredictable transition temperature. Two hours and twenty minutes pass between the deposition of the layers due to necessary cooling time of the substrate. During this time, we believe that there is sufficient oxygen content within our electron beam system to contaminate the surface of the moly film.

The second and biggest challenge we are facing is device repeatability (see Figures 2, 3). To help facilitate consistency between devices, we are investigating improvements to our electron beam system. The installation of an ion gun for surface cleaning and a second mass meter are two of the changes that are being considered.

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

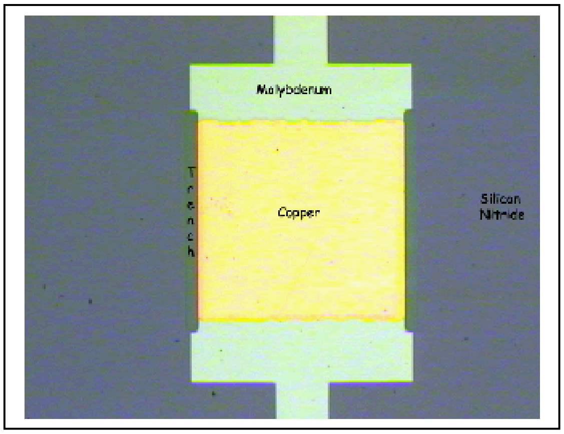

Figure 1: This light microscopy image shows a 400 µm x 400 µm TES device with Mo leads. The trenches described in step one are visible along the vertical sides of the pad.

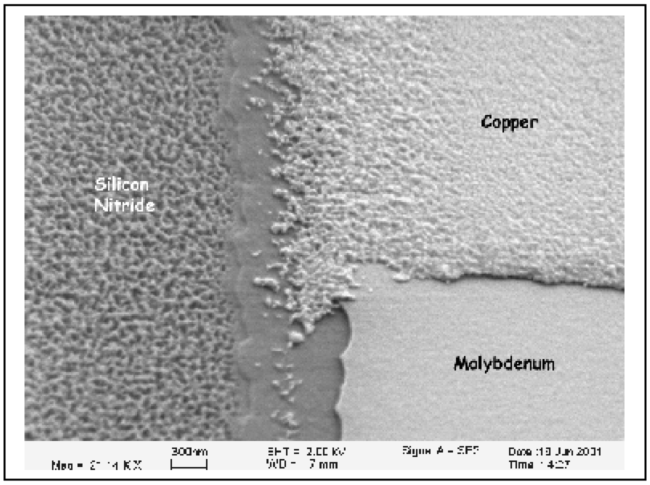

Figure 2: This SEM image shows the lower left corner of a bad TES device. Note the loss of Cu integrity.

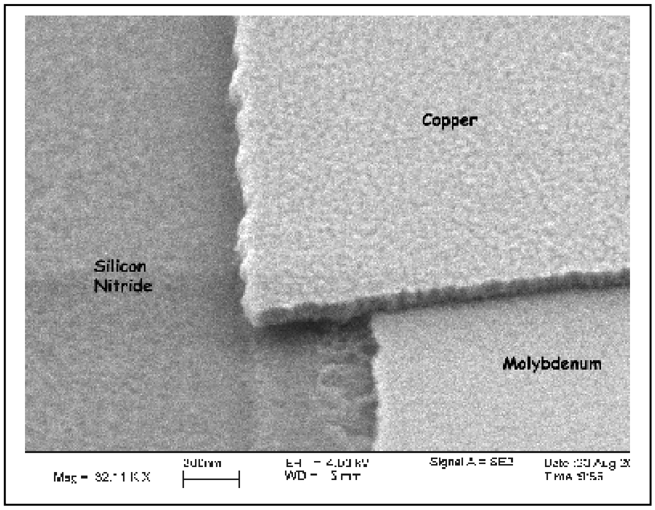

Figure 3: This SEM image shows the lower left corner of a good TES device. Note the straight Cu edge and clean overhang.

**Note: Figures 2 and 3 were devices on the same wafer. This shows the inconsistencies we are observing.