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SEM Examination of a Newly-Machined NLCTA Cell†

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±*Abstract*

An as-received not-SLAC-cleaned cell was examined in the SEM. A number of native and machining defects were visible.

1 Introduction

Single-point diamond machined copper surfaces generally appear featureless when examined after fabrication. The cell discussed in this report, however, had visible marks that are atypical. These were examined by secondary electron microscopy.

2 Experimental Details

The cell was fabricated at KEK where it was finish-machined by single-point diamond. The cell was subsequently used on NLCTA test structure T105VG5.

The SEM instrument is described briefly in the Appendix.

3. Results

Figure 1 shows the cell surface at the iris ID. Residual lubricant is visible in the form of black streaks. However, the machining structure is uniform with no burrs visible at the iris. That was also true when examining the rest of the iris ID. The lubricant would normally be removed by the cleaning process for cells, SLAC Plating Shop Process C01a. Only machining ridges would remain after cleaning, without significantly roughening the surface finish.

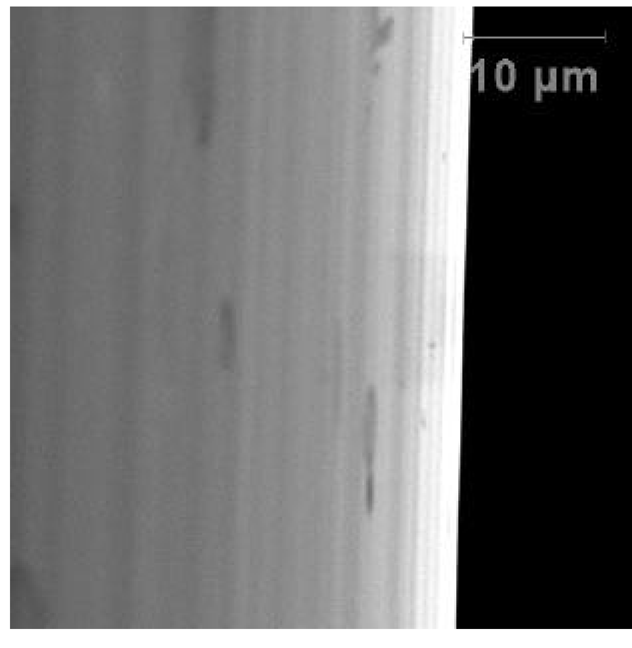

Figure 1. Cell surface near iris ID. Except for machining ridges, all other features should be removed in the C01a cleaning process.

The rest of the iris surface, radially away from the ID, was not physically featureless. It contained a small number of native and machining defects and debris. Figure 2 shows some native defects.

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Figure 2. Missing copper grain and inclusions. Mottling is probably due to traces of cutting fluid on the surface.

The central large feature is a missing copper grain. It is identified as sub-surface by using a special SEM technique, electron backscatter imaging. The view generated by this technique is equivalent to placing light illumination at 10 o'clock. The edge shadow observable identifies the feature as sub-surface. In this case, the grain was improperly consolidated with its neighbors and either fell out or, more likely, was knocked out by passage of the cutting tool.

Also visible in the same image is a string of holes (or carbon inclusions) to the right of the missing grain. This is a native feature found, at very low density, in the best quality copper.

This cell also exhibited the long machining feature which is the focus of this report, shown in Figures 3-5. Figure 3 is an overall low-magnification image. Figures 4 and 5 show detail of the two ends of the feature. Figure 4 is particularly interesting because it shows the fracturing of material at the starting end of the feature. What is not visible, because of the contamination film, is the grain structure of the surface. In earlier work on clean hydrogen-fired cells, we observed that such leading edge tearout begin at a grain edge. Porosity at the grain boundary, or perhaps elsewhere in the grain, coupled with favorable cutting parameters, tool geometry and crystal orientation results in shearing just below the cutting plain. Galling and tearing occur between tool and grain, which eventually clears the tool.

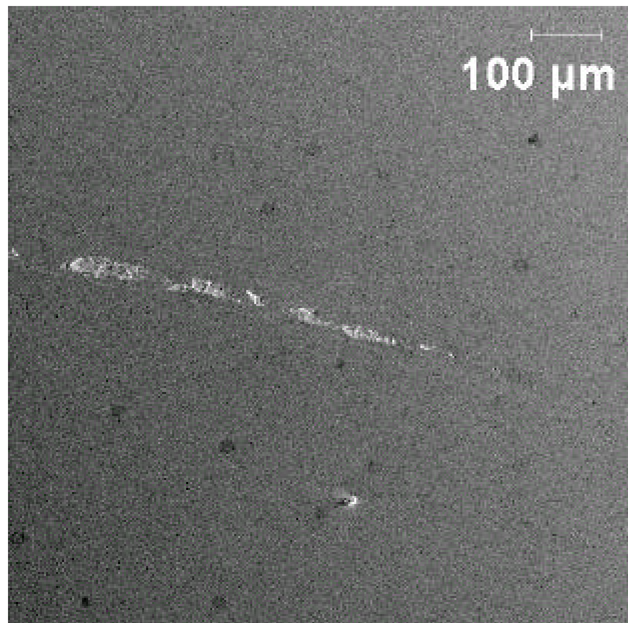

Figure 3. Machining tearout. Black spots are likely cutting fluid droplets.

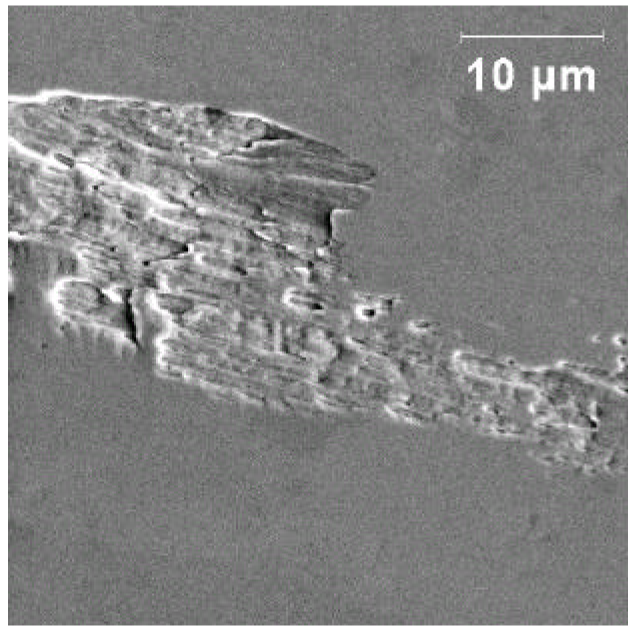

Figure 4. Enlarged image of clockwise (believed to be leading edge) of tearout. Note the fracture of material at the upper center of the image.

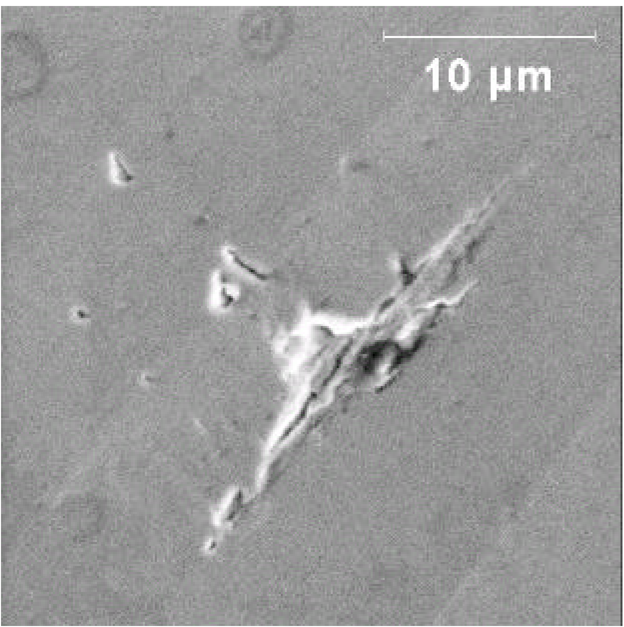

Figure 5. Counter-clockwise end of the tearout. Note the wide (relatively!) diagonal machining ridge.

4. Discussion

The tearout imaged in Figures 3-5 cannot be removed by mild etching. Heavy etching, on the other hand, will roughen the surface. Features of this type may possibly be minimized by changing cutting tool parameters or feed rates.

5. Appendix

Scanning Electron Microscopy (SEM)