Characterization of Focused Ion Beam Milled Line

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Abstract

As the nanotechnology is becoming an important aspect of science research and development, the application of the focused ion beam (FIB) technique is getting more attention. The focused ion beam is a tool for milling tiny objects. This research explored the characterization of FIB by relating milled line widths with their milling time. The scanning electron microscope (SEM) is used to image the milled lines and ImageJ to analyze the images. We found that the through-lens-detector (TLD) provides the best SEM image by reducing the shadowing effect which interfered with the data analysis. A logarithmic relation between the milled line width and milling time was determined. These presented results can help scientists design a FIB milling experiment in the future.

Introduction of FIB (Focused Ion Beam)

- FIB can be applied for imaging in low beam current, and for milling in high beam current
- Compare to electron, ion is heavier and larger, which has larger momentum to damage the object and lower penetrate depth of the same energy.
- Compare to the particles without charge, ions can be controlled by polarity field to adjust the acceleration rate and beam shape.
- FIB is widely used in cross-section cutting to observe inside of mircrobe, investigation of integrated circuit board and other scientific research.

LMIS (Liquid Metal Ion Source)

LMIS (Liquid metal ion source) is the essential of FIB. It works as the electron gun (SEM) in the scanning electron microscope .

- the sockets are connecting with high voltage power supply,.
- The current go through sockets to filaments and heat up the reservoir
- Metals or alloys which has low melting point, and solid at room temperature are set in the reservoir, after the heating, they will change phase to liquid and drop to cover the tip.
- The tip is sharp, so that large curvature will cause the huge electric field to generate the ions out.

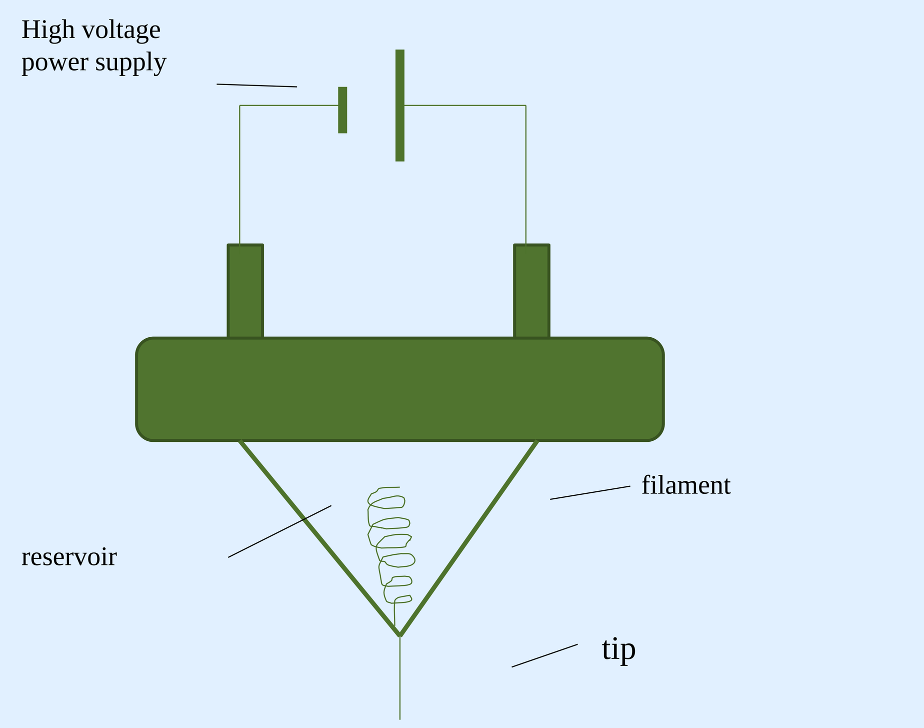

Figure 1. schematic cross-section of a typical liquid metal ion source, showing its components

Experiment

The experiment is going to explore the characterization of FIB by the milled line burn width vs. the milling time. Lineburns is the most common and useful utilization to apply FIB in milling. To mill lineburns with certain aperture current and time will provide a reliable data of width and depth to scientists, so that they could know the performance of this FIB set-up.

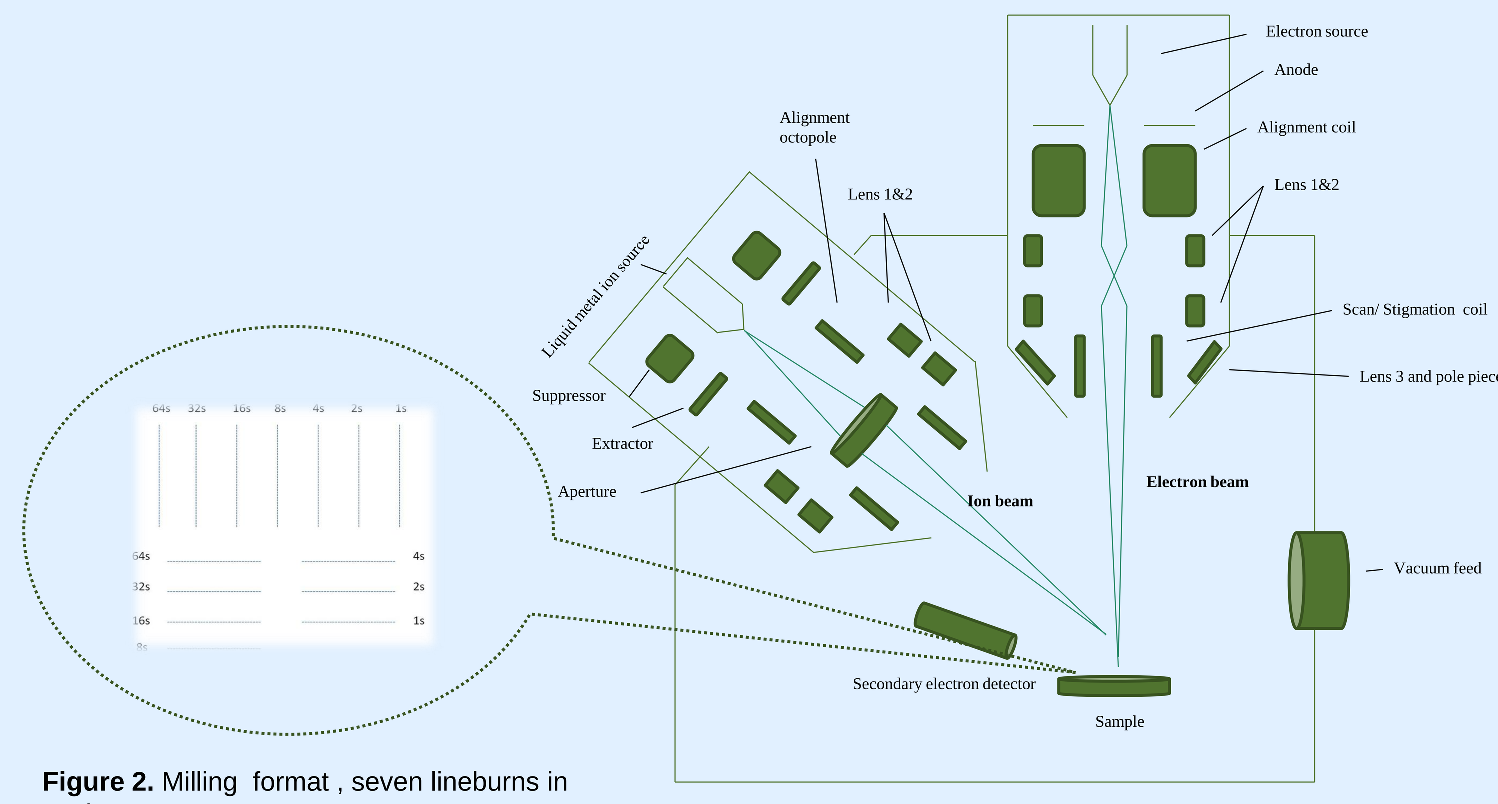

Figure 2. Milling format , seven lineburns in each set.

Figure 3. Schematic of Dual beam (FIB and SEM) system, showing its components.

- In dual beam system, they are two columns, the vertical column is SEM, in this experiment, SEM is use to imaging; the tilted column is FIB, it is used for milling there.
- When to mill lineburns, the sample mount could tilt to perpendicular to the ion beam.

Analyzing SEM image

- To use software ImageJ to analyze the SEM image of lineburn width vs. milling time. The rectangular box shows the area that ImageJ could help to read the grey level.
- Assuming grey level as the standard to determine the edge of lineburns. Then, to find out the width by determine the two edges.
- To help determine the edges easier, it is necessary to take the differential value of grey level, and make a plot again. The maximum and minimum point can be regard as edges to determine the relative edges.

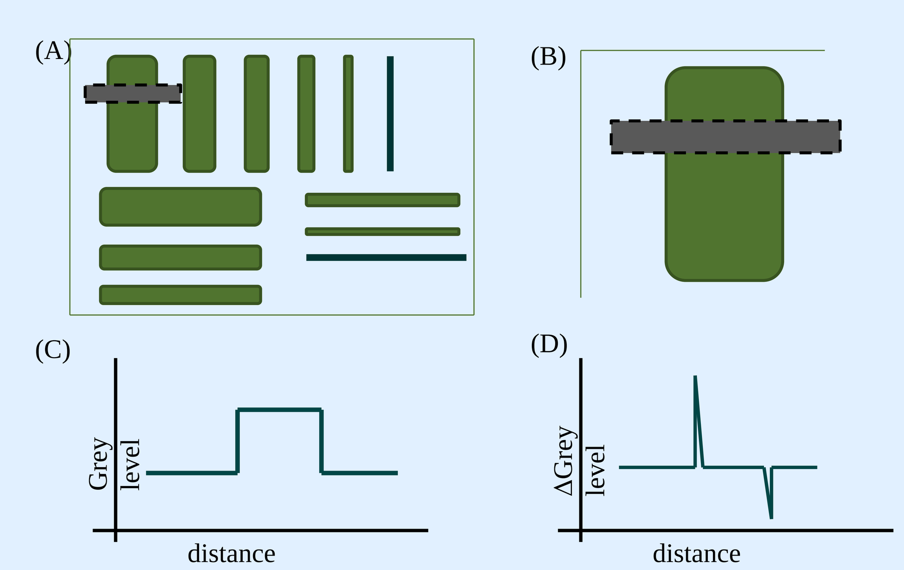

Figure 4. (A) (B) schematic of SEM images and the cross-section of imaging analyze; (C) distance vs. grey level of the choosing cross-section; (D) the differential value of grey level vs. distance.

Result

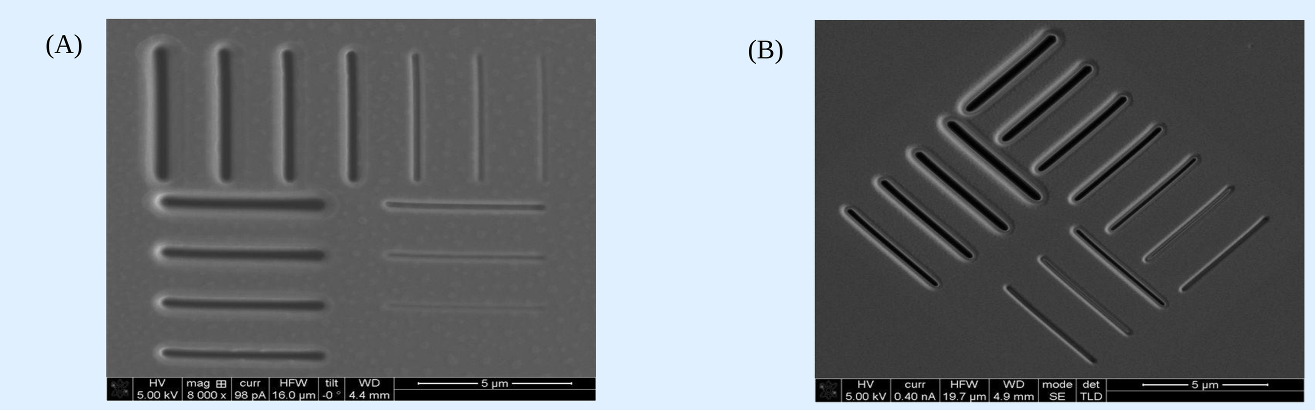

Figure 5. (A) Milled lineburns. Sample use: silicon. Voltage setting is 5KV, current through aperture is 1010pA, and Work distance is 4.4mm; (B) Milled lineburns. Sample use: Cr-glass. Voltage setting is 5KV, current through aperture is 1010pA, and Work distance is 4.9mm.

In Figure 5 (A) the edge of lineburns are not straight, and shadowing distribution is unequal on edges. To improve the quality of SEM image for analyzing, I rotated sample mount 45° to avoid strong shadowing effect, and in the mean while change the sample from silicon to Cr-glass, which the lineburns are look straighter. Image (B) is suitable to use for the image analyzing work.

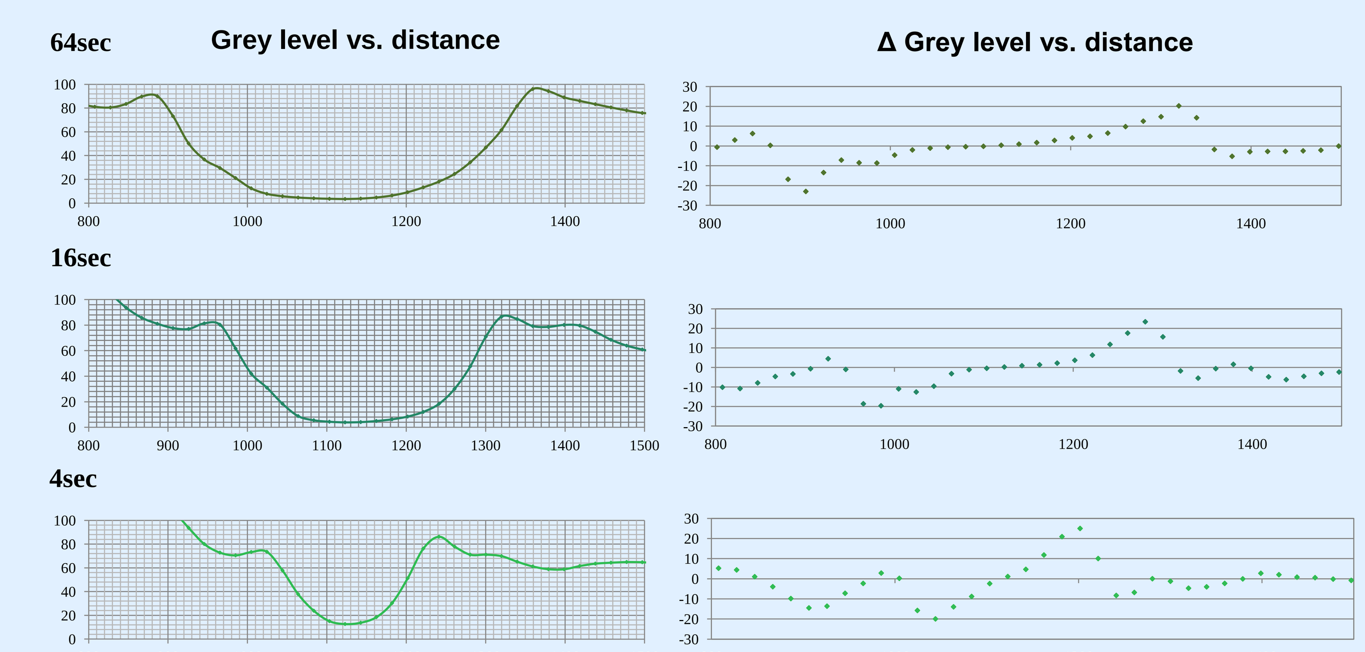

Figure 6. these three group of data plots are pulled out from vertical line sets of figure 5. (B). As milling time drops, the width is getting smaller.

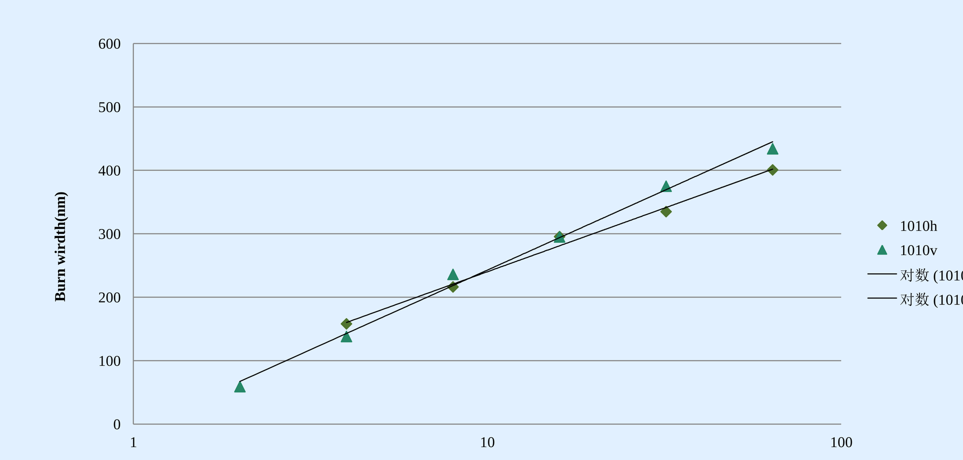

Figure 7. Milling time in logarithm vs. width

Conclusion

- Provides an approach to the application of Dual-Beam system, and relative measure of lineburn.
- The logarithm relationship between milling time and lineburn width is determined.

Reference

References and copy of abstract are available from author upon request.

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