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SPUTTERING MEASUREMENTS USING A SCANNING MICROTOPOGRAPHER*

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ABSTRACT

A quantitative method is described for measuring the sputtered depth profile of an ion beam and calculating the corresponding current density profile and sputtering coefficient. Two examples are given for a 5 keV Ar beam on stainless steel.

NOTES
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I. Introduction

A method used to measure the sputtering rate and current density profile of a low-energy ion beam is described in this report. The measurement involves sputtering a very flat surface and measuring the depth profile of the sputtered crater with a scanning microtopographer. The data presented here are important for DMFE related H/He implantation studies.

II. Experimental Method

A stainless steel target was milled to dimensions of approximately 13mm x 13mm x 3mm and mechanically polished on a wheel using 600-grit emery paper as the final step. A circular scribe of 7.2mm diameter with a vertical scribe across the diameter was made on the surface to serve as a reference in later measurements. A depth profile was then made using a Gould Model 200 Microtopographer, scanning the target at $\sim 200 \mu\text{m}$ intervals with a depth sensitivity of $0.2 \mu\text{m/mm}$.

Next, the target was placed in a vacuum system and sputtered with a modified Physical Electronics Model 04-191 ion gun using an unanalyzed 5 keV argon beam of $4 \mu\text{A}$ current at 45° incidence. An electron suppressor with a bias of -300 V was used to ensure accurate measurement of the current on a current integrator. Total sputtering time was 3-1/2 hours and the total Ar integrated charge was 0.5 c.

After the sputter run, a second depth profile was taken on the microtopographer using the same orientation, scan width, magnification, and depth sensitivity as the first profile.

III. Results and Discussion

The two profiles (before and after) are shown in Figure 1. One notes a portion of the circular scribe and the sputtered portion of the sample. The sputtered depth was measured at regular intervals along each scan line

and the results were compiled and plotted as shown in Figure 2 to show the depth profile more clearly. The distances and changes in depth along the scan lines were scaled directly from Figure 1 using the magnification settings of the microtopographer. However, the distance between scan lines cannot be scaled from the drawing and instead was found by dividing the diameter of the scribed circle by the number of scan lines across the diameter. Depth resolution is limited to about .1 μm using this technique.

Figure 3 shows the results of a second experiment where a specimen was sputtered with a rastered beam and an integrated charge of .2 c. Notice the relatively flat area, about 2mm wide at the bottom of the crater.

Once the depth at every grid point on the sputtered area Z_i is known, the total volume of material removed (V) can be calculated numerically from $V = A \sum Z_i$; where A is the area of each grid element. With this information we can calculate the distribution of the beam fluence $\left(\frac{dQ}{dA}\right)_i$ at any point.

$$\left(\frac{dQ}{dA}\right)_i = Z_i \frac{Q}{V}$$

Finally, the sputtering yield (S) can be calculated from:

$$S = \frac{\rho N_A e V}{M Q},$$

where

- ρ = density of material
- M = average mass per atom in AMU's
- N_A = Avagadro's number
- e = charge per incident particle, and
- Q = total integrated current.

The sputtering coefficient was determined to be 3.1 for the unswept beam and 3.9 for the swept beam. Multiplying by $\cos 45^\circ$ as an approximate correction for oblique incidence gives values of 2.2 and 2.8. Von Seefeld, et al⁽¹⁾ have published a sputtering coefficient of 2.5 at normal incidence using an analyzed beam. This agreement may be fortuitously good since the unanalyzed beam may have a significant fraction of neutral Ar.

IV. Conclusion

Microtopography has been shown to be a quantitative method of calibrating sputtering profiles and beam current density profiles. It can also be used to measure sputtering yields, although it is not as sensitive as some other methods, such as weight loss.

Figure 1. Overlay of before and after profiles at 20X magnification and .2 $\mu\text{m}/\text{mm}$ depth sensitivity.

Figure 2. Sputtered depth profile of unrastered Ar beam.

Figure 3. Sputtered depth profile of rastered Ar beam.

References

1. H. Von Seefeld, H. Schmidt, R. Bohrisch, and B. M. U. Scherzer,
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