Use of ion source to etch thin foil targets for ion acceleration

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Introduction

In laser driven ion acceleration experiments, there is currently much interest in investigating target thickness as the mass of a target can have a large effect on the resulting total energy and flux of the accelerated beam [1]. The use of high contrast, $>10^8$ systems enable interactions with targets with a thickness approaching the skin depth. Consequently, there has been a great deal of interest into methods of thinning foil targets in situ within the vacuum interaction chamber, prior to the shot. This would eliminate the problems thin targets can suffer from in atmosphere such as changes in humidity, air currents and oxidization.

Here we report a preliminary study into the use of an ion source to etch targets in situ and detail the present issues with this method that need to be overcome.

Ion Source Operation

The device used for this experiment was a Veeco Gridded DC 3cm ion source, a schematic of which is shown below.

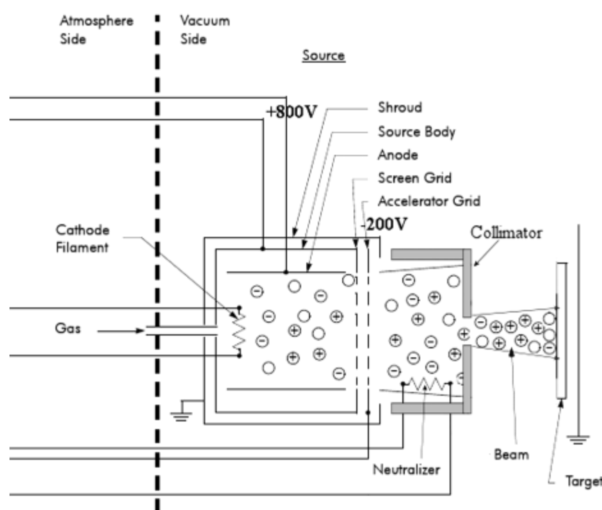

Figure 1. Schematic of the Ion Source used.

A flow of argon gas is ionized with the electrons being removed from the flow by a transverse electric field. The ions are then accelerated forwards out the device by a negatively charged grid. The neutralizer filament injects electrons into the ion beam to reduce the space charge density and to prevent the target and surrounding surfaces becoming charged. When the neutralizer current is too low, or if the filament fails there can be a resultant sparking between components in the chamber.

In previous tests the ion source has been seen to etch over an f/2 cone and there is also deposition over a wider cone still of material which is etched away from within the device. Therefore, a collimator was made to reduce the area over which the device etches and deposits. This reduced the deposition area significantly and also narrowed the etching cone to approximately f/5. The end cap of the collimator was made out of tantalum as this is known to be very resistant to etching. It was found that with the collimator fitted to the ion source the gas flow had to be set lower that normal, presumably due to constriction of the exiting gas flow, down from 2sccm to 0.5sccm. This in turn affected the power supply parameters required for optimum usage as described in the next section.

Calibration

To calculate the etch rate of the ion source the thicknesses of aluminum and carbon coatings were monitored by measuring the transmission of a green diode laser (empirically related to coating material and thickness) as each target was etched.

The target was etched at an angle of around 45° as this was the desired main experimental geometry. This was repeated many times for carbon and aluminum targets and figure 2 shows the etch rates with the distance between the collimator and the target being set to 9cm.

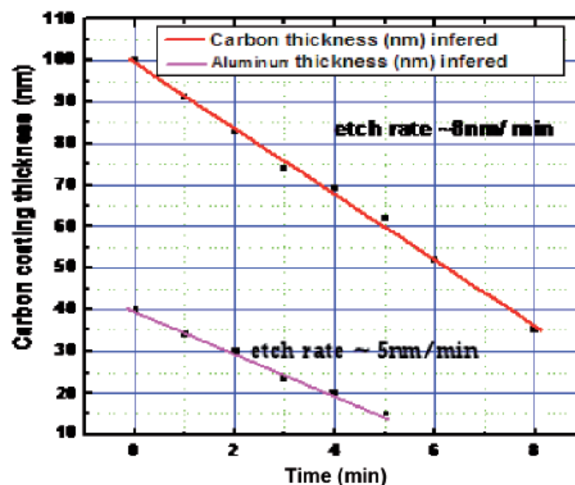

Figure 2. The relative etch rates of carbon and aluminum coatings with a collimator to target distance of 9cm.

The distance between the collimator and target was also varied to see the effect this had on the etch rate.

These results show that in principle that the ion gun is usable to etch aluminum and plastic targets at a relatively fast but controllable rate and that the thickness can be monitored.

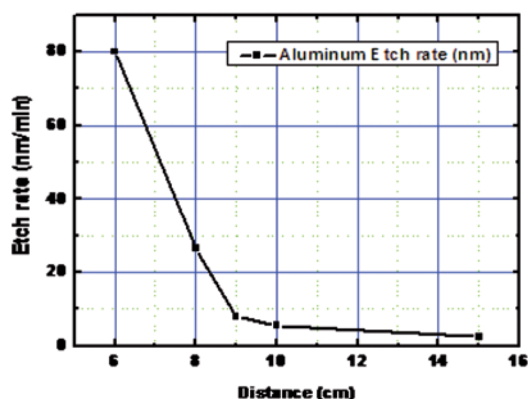

Figure 3. The effect of collimator to target distance on aluminum etching rate.

As the etch rate is also dependant on the operating settings for the ion source it was desirable to deduce the optimum settings and then keep them constant during use. However, this was not possible as the ion source heats up considerably during use, affecting the various parameters considerably. This in turn forces the power settings to be altered in order to keep the device from tripping out the safety interlocks. Table 1 shows an example of the power supply settings used both when the device was cold and when it was hot.

Parameter	Cold	Hot
Argon Flow Rate	0.3-0.5 sccm	0.3-0.5 sccm
Cathode Filament Current	2.1 A	2.1 A
Discharge Voltage	55 V	55 V
Discharge Current	0.25 A	0.54 A
Beam Voltage	800 V	800 V
Beam Current	27 mA	45 mA
Accelerator Voltage	200 V	200V
Accelerator Current	12 mA	19 mA
Neutralizer Filament Current	2.35 A	2.35 A
Neutralizer Emission Current	24 mA	179 mA

Table 1. Power supply parameters used for the ion source. As the device heats up from use the values drift towards those in the right hand column.

Current Issues and Limitations

For the reduction of targets thicknesses down to less than 20nm, as required for skin depth targets, our configuration was unsuccessful. It was found that with a collimator to target distance of around 10cm a target would break when etched to 15-20nm. Also, the target surface quality (which was found to have a big effect on ion beam quality and flux) decreased rapidly during the process.

They way in which the targets broke also raised some questions about whether the targets were being etch uniformly across their surface. It was common to see half of a target disappear while etching, leaving the other half intact. Assuming that the targets were originally of a uniform thickness, this suggests that either one half of the target was being etched more quickly or that there was a flaw or defect in the target.

Summary

This work has shown that, even though the method explored here did not yield the production of sub 20nm target thicknesses, the ion source has proven that it is a practical tool for etching target without causing collateral damage to the experimental set-up.

Further study on this technique is required to determine if this method can be adapted to allow further target thinning. This may be achieved by reducing ion beam intensity or a change in the angle of incidence. Monitoring of the target surface to give a map of how the thickness varies across it would be a very valuable tool in developing this technique further.

References

1. D. Neely, P. Foster *et al.*, *Appl. Phys. Lett.* **89**, 021502 (2006).