Neutral Energy Studies for Etching Plasmas

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1 Introduction

The continued advance of semiconductor technologies requires a downscaling of the critical dimensions of devices into the single nm range. This calls for new approaches to lithography and etching. In particular neutral beam etching (NBE) has been proposed [1] as a means of mitigating distortions associated with localised charging during plasma etching. The work presented here concerns investigation of neutral beam production in inductively coupled plasmas (ICP). It focuses on methods to monitor energetic neutral species extracted from the plasma boundary.

The source of neutral particles is charge exchange (CX) in the sheath where fast ions transfer charge to slow neutrals to create fast neutrals and slow ions. Alternative schemes use surface neutralization. It is possible to tailor the plasma environment to encourage a large depletion of neutrals [2] which could be used to interact with a substrate, with a significant fraction of power deposited in the neutrals.

2 Energy Studies of Neutral Species

The detection of fast neutrals can be done reionizing them with an electron beam impact after they have passed through a sampling orifice. Here an ion sampling mass/energy analyzer (Hiden EQP) has been used in conjunction with a switchable thermionic ionizer. In the event that fast neutrals enter the analyzer along with fast ions a differential signal can be obtained showing the contribution from neutrals by switching the ionozing filament on and off. Current work has been influenced by studies on magnetron plasmas (Matsui et. al and Hiden Analytical [3, 4].

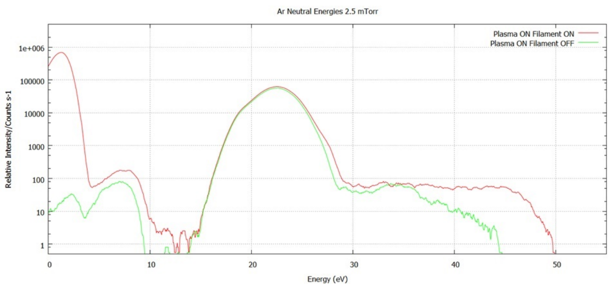

Fig. 2: *Ar Energies taken by the EQP with ionization filaments On and Off*

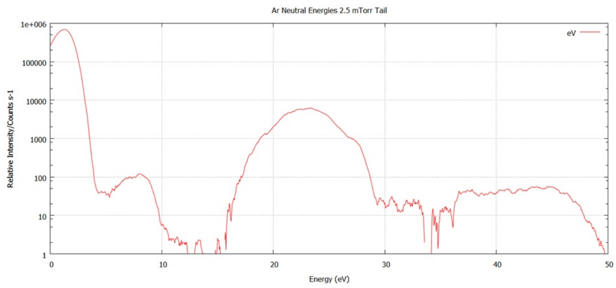

Fig. 3: *The energies of the neutral species as calculated from the difference*

Experiments were done in argon plasmas at 2.5 mTorr, in a cylindrical ICP (60 mm diameter, 260 mm length), excited by 150 W of 13.56 MHz powerU under which conditions axial sampling of energetic argon species is expected to include a signifcant CX fraction. Figure 2 shows the energy distributions of Ar^+ detected in the EQP with filaments on and off in RGA mode. With the filament off the Ar^+ ions reaching the detector come directly from the plasma. With the filament on an additional contribution can be seen that corresponds with ionized neutrals, some of which have energies slightly exceeding those of the detected ions. The difference between these ion traces with and without the filament is shown in Figure 3 and this corresponds with the energy distribuion of neutral argon that crosses the plasma boundary. It is seen that CX neutral energies slightly exceed the ion energies but atof a much lower intensity. The present arrangement offers mass discrimination. It has been establishesd that neutralization occurs only in a pressure regime where sheath scale $\sim$ mean free path for CX and that speies such as ArH^+ do not survive neutralisation.

The aim is to compare this direct method of quantifying neutral species with simpler techniques such as bolometry and momentum transfer. The technique will also be applied to surface neutralisation schemes.

References

[1] S. Samukawa *Journal of Vacuum Science & Technology A* **20** pp 1566

[2] A. Fruchtman 2008 *Plasma Sources Sci. Technol.* **17** pp 10

[3] H. Matsui H. Toyoda H. Sugai 2005 *Journal of Vacuum Science & Technology A* **23** pp 671

[4] Hiden Analytical *APlasma Analysis - Application Note* **271** pp 1