Plasma Analysis
Application Note 236

EQP

The energies of positive & negative ions in an RF plasma in nitrous oxide

Summary

The sampling of negative ions from plasmas is known to be more difficult than the sampling of positive ions. One successful technique (Reference 1) is to switch the RF power applied to a capacitively driven plasma on and off using an audio-frequency gating signal. During the period when the RF power is off, the plasma decays and a point is reached where the plasma potential (positive with respect to the grounded electrode through which the EQP is sampling ions) is no longer sufficiently high to prevent the negative ions leaving the plasma and entering the EQP.

This technique is excellent as a means of determining the nature of the negative ions produced in the plasma and has produced useful results, for example for plasmas in silane and silicon tetrachloride.

Under some circumstances, however, negative ions can be sampled from RF plasmas in capacitively-driven reactors without the need to use decaying plasmas. The work presented here describes the measurement of positive and negative ion energies by utilising the 'mixed mode' scanning facility of the Hiden EQP; a facility which enables both positive and negative ions to be sampled within a single scan structure. The energy distributions are discussed in terms of the fixed and derived discharge parameters.

Manufactured in England by:

HIDEN ANALYTICAL LTD
420 Europa Boulevard, Warrington, WA5 7UN, England
t: +44 (0) 1925 445225 f: +44 (0) 1925 416518
e: info@hiden.co.uk w: www.HidenAnalytical.com

Experimental

The experiments were carried out in nitrous oxide at a gas pressure of 6 mTorr. The RF signal to the 5 cm diameter driven electrode was superimposed on a d.c. bias potential set using a 0-100 V d.c. power unit. The driven electrode was 8 cm from the entrance plane of an EQP instrument. A 5 cm diameter, 6 cm long glass tube sitting on the driven electrode partially confined the plasma and shielded it from the influence of the grounded walls of the discharge chamber.

Measurements of the energies of the N_2O^+ and O^- ions arriving at the sampling orifice of the EQP were carried out for a fixed d.c. bias of -70 V applied to the driven electrode, the power of the 13.5 MHz signal superimposed on this bias being varied between 0.5 and 3 W. The only negative ions detected were O^- ions while the most abundant positive ions were those of N_2O^+. From previous work at Hiden, the negative ions detected for the steady-state conditions of the present work are presumed to have been generated by electron impact in the sheath region formed at the driven electrode (see Application Note 230).

Results and Discussions

Figure 1 shows the energy distributions measured for the N_2O^+ ions. The mean energy increases with increasing RF power and is assumed to be following the change in plasma potential. It may be noted that at the higher RF powers the ion energy distribution develops the saddle-shaped structure characteristic of ions which cross the sheath in front of the EQP's entrance plane in a time comparable with the period of the applied RF.

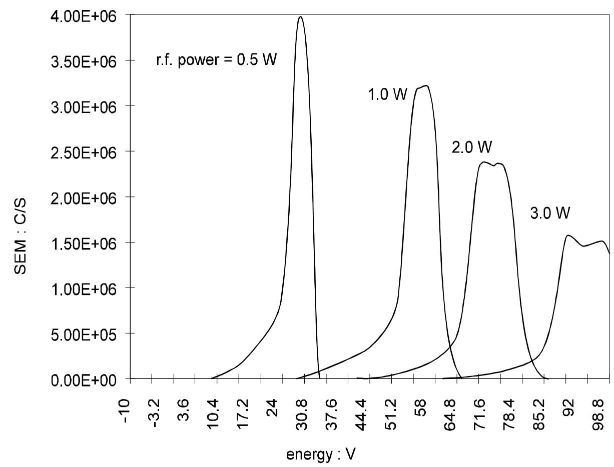

Figure 1

Figures 2 to 4 show the ion energy distributions observed for the O^- ions. Several comments may be made:

1 the O^- signals are, as expected, much lower in intensity than those of the N_2O^+,

2 for the 0.5 W power, figure 2 shows the maximum energy to be 70 eV, which is expected from the d.c. bias of -70 V,

3 as the RF power is increased the maximum ion energy increases above 70 eV. This is to be expected when it is remembered that the RF peak to peak voltage applied to the driven electrode increases with the applied power and that it is the combined effect of the d.c. bias and RF voltage which accelerates the ions through the sheath at the driven electrode,

4 the energy distribution shows structure which is most pronounced in figure 3 for an input power of 1 W. The cause of the structure is not known but may be due to ion-bunching effects related to the ratio between the transit times of the ions across the sheath and main body of the plasma and the period of the RF signal. For the ions in the peak at 74 eV in figure 3 the ions take over 30 cycles of the RF to cross the full width of the discharge gap, travelling about 2 mm in 1 cycle.

O^- from N_2O
Bias = -70 V, Power = 0.5 W

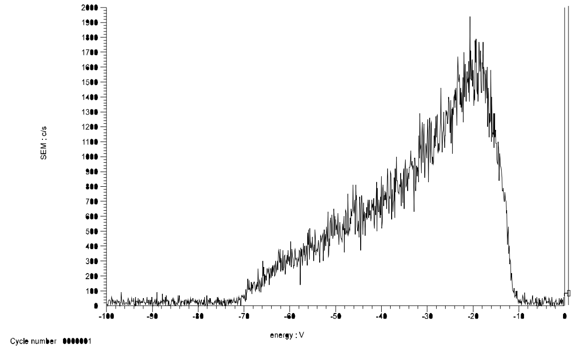

Figure 2

O^- from N_2O
Bias = -70 V, Power = 1.0 W

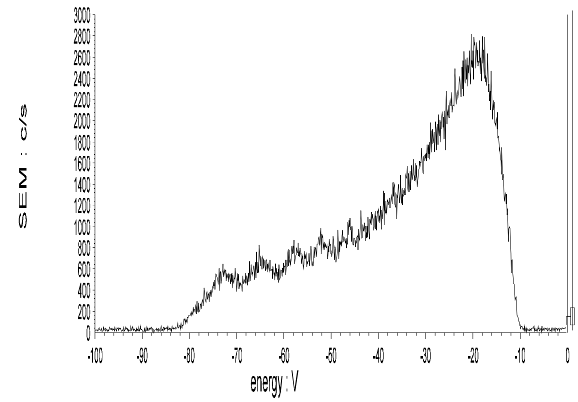

Figure 3

O^- from N_2O
Bias = -70 V, Power = 3.0 W

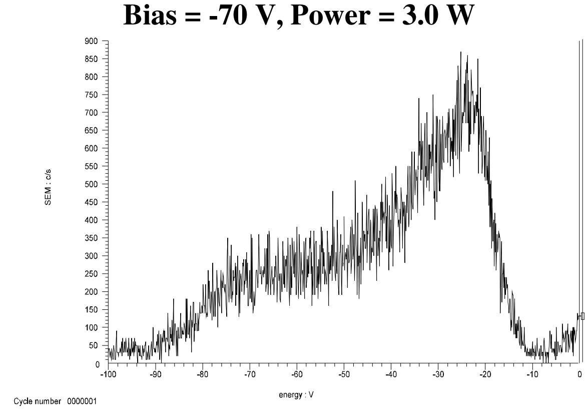

Figure 4

Conclusions

It has been demonstrated that energy distributions can be determined for both positive and negative ions arriving at the grounded electrode of a capacitively-fed parallel plate RF discharge. The data are consistent with the view that the negative ions are produced in the sheath formed in front of the driven electrode. For systems in which the d.c. bias of the driven electrode can be set independently of the magnitude of the applied RF the energy distribution of the positive ions arriving at the grounded electrode is strongly affected by the plasma potential which is in turn strongly influenced by the magnitude of the RF signal voltage. The energy distribution of the negative ions is, on the other hand, much less dependent on the plasma potential, the maximum energy being closely related instead to the applied d.c. bias. These results are of interest in plasma applications such as the oxidation of silicon in which negative oxygen ions have an important role. They suggest that the energies of the positive and negative ions arriving at a substrate placed on the grounded electrode of a parallel plate reactor may be independently controlled by a suitable choice of the plasma potential and the d.c. bias of the driven electrode.

Reference

1. A. A. Howling et. al., J. Phys. D. 26, 1003, 1993.