Plasma Analysis
Application Note 238

EQP

Energies of ions sampled through a DC biased, RF driven electrode

Summary

The following measurements were taken using an EQP instrument sampling through a 50mm orifice in the surface of a 24.5mm diameter driven electrode to which either rf, dc or a mixture of rf and dc signals, could be applied to generate a plasma. The counter electrode was mounted 12mm in front of the EQP's driven electrode and grounded.

The measurements were carried out using argon as the plasma gas at pressures of 2, 5, and 10 mbar. At the lowest pressure the dominant ions were Ar^+ but as the pressure was increased the Ar^+ ions became replaced by first of all ArH^+ and then by H_3O^+, NO^+ and O_2^+ presumably as the result of ion-molecule reactions between the Ar^+ and impurities present in the plasma chamber. The gas inlet system was not the usual distributed inlet system which would have kept the impurity effects to a lower level.

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Results

Figure 1 shows the energy selected mass spectrum for a pressure of 2 mbar with the dc bias of the driven electrode set to 25 volts. The dominant ions are seen to be Ar^+, ArH^+, Ar_2^+ and m = 30. The latter are assumed to be NO^+ ions.

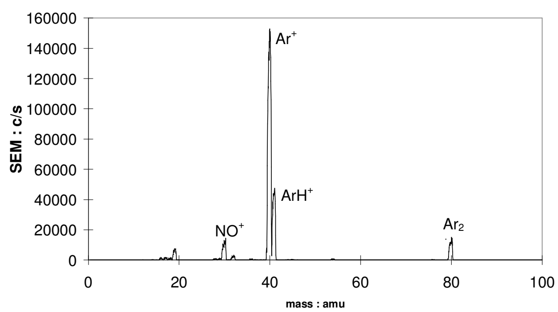

Figure 1

Figure 2 shows the corresponding IED for the Ar^+ ions together with the IEDs for applied dc biases of 20, 15, 10, 5 and 0 V respectively. For the higher bias values, the IEDs show the twin peak structure which is characteristic of situations in which the ions cross the sheath in front of the sampling orifice in a time which is of the order of the period of the 13.56 MHz rf signal. At the lower bias settings (≤15 V) the twin peaks merge. The IEDs of figure 2 are consistent with a plasma potential of 3 volts with respect to the applied dc bias. For example, for a bias of 10 V the peak ion energy occurs at 13 eV falling to 8 eV as the bias is decreased to 5 V.

It should be noted, however, that for an applied bias of 0 V the peak of the IED occurs at around 6 eV and not at around 3 eV as might have been expected from the IEDs obtained at higher bias voltages.

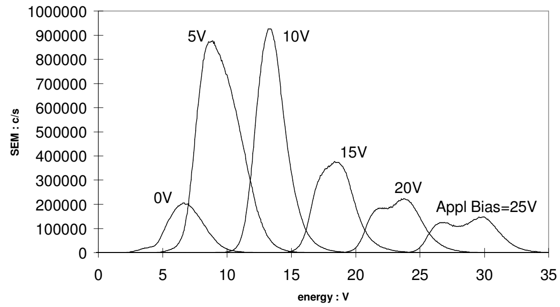

Figure 2

For the same plasma conditions, figure 3 shows the corresponding ion energies for Ar_2^+ (m = 80) ions. It is noticeable that the peaks are in all cases single peaks which is as expected given the factor of 2 difference in the Ar_2^+ and Ar^+ masses. The broadening of the IED for a dc bias of 5 V may be noted.

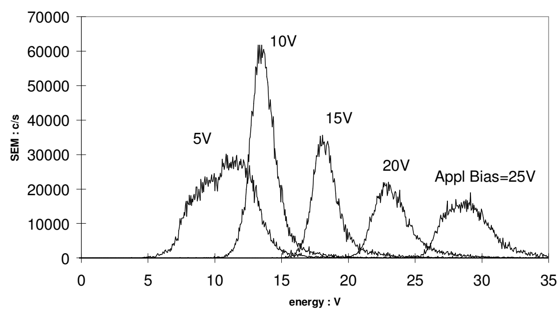

Figure 3

Figure 4 shows the energy selected mass spectrum obtained at a pressure of 5 mbar in the plasma chamber. As mentioned above, the dominant ion is now m = 30 (NO^+).

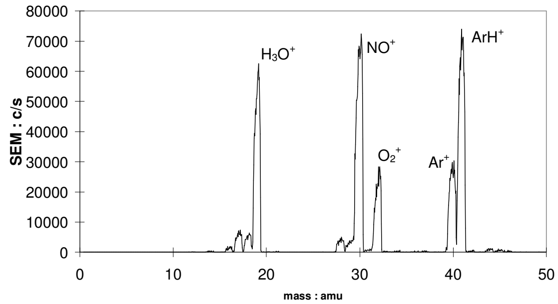

Figure 4

Figure 5 shows the IEDs for Ar+ for applied dc biases of 25, 20, 15, 10, 5 and 0 V respectively. The main features are consistent with those of figure 2 and again suggest a plasma potential of around 3 V; except for an applied bias of 0 V for which the plasma potential appears to be about 6V.

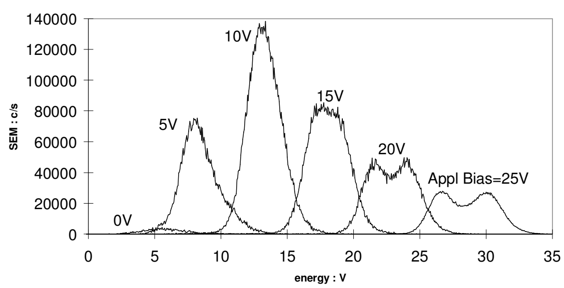

Figure 5

Figure 6 shows the IEDs for the NO^+ ions. The IEDs are consistent with those of figure 5 for Ar^+ except that the twin-peaked structure for bias settings of 25, 20 and 15 is more pronounced (as is expected from the mass difference) and that the IEDs for bias settings of 5 V and 0 V show structure similar to that found for Ar_2^+ at 2 mbar. The structure is presumably related to the mechanisms controlling the formation of NO^+ and Ar_2^+ ions in the plasma sheath in front of the driven electrode.

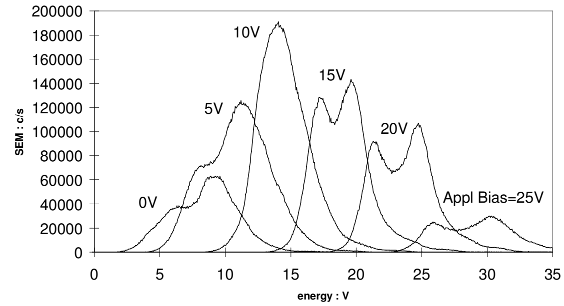

Figure 6

Finally, figure 7 shows the IEDs for NO^+ ions at a pressure of 10 mbar. The main features are of the same form as those for the lower pressures. There is no low-energy structure for the 5 V and 0 V cases, however.

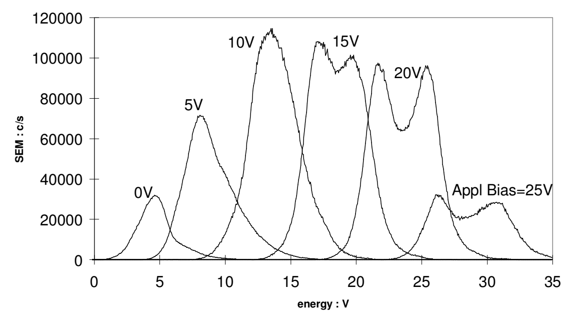

Figure 7

Comments and Conclusion

The observed IEDs show interesting variations with pressure and applied dc bias, and suggest variations in the sheath width as those conditions are changed.

It should be noted that the plasma potential appears to be referenced to the (positive) dc bias applied to the driven electrode which is as expected from the fact that plasmas normally reference themselves to the potential of the most positive surface with which they are in contact. The energies of the ions incident on the surface of the driven electrode are as those shown in figures 2 , 3, 5, 6 and 7 with the dc bias value subtracted and are shown to be dependent only on the plasma potential for the conditions used in these studies.