Plasma Analysis
Application Note 243

EQP

Characterisation of an ICP reactor (I)

Summary

A small, cylindrical reactor typical of a design used by various investigators for the deposition of thin films has been built and characterised using a Hiden ESPION Langmuir probe and EQP Mass/Energy Analyser. The measurements reported here are those obtained using the EQP system for plasmas generated in argon using a 13.56 MHz generator to supply power via a 4 turn coil of copper wire. The reactor was a Pyrex cylinder of 10 cm diameter attached to the EQP as shown in figure 1.

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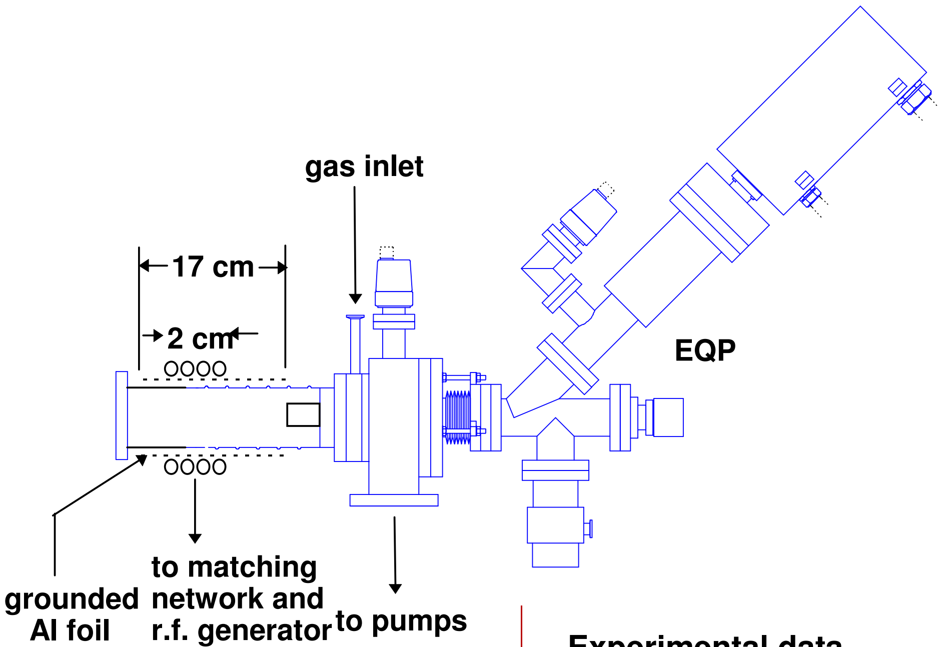

Figure 1 Experimental Arrangement

Experimental set up

In the first series of experiments with the system shown in figure 1 the excitation coil was positioned 15 cm from the entrance to the EQP and the matching network adjusted to give negligible reflected power for the range of input powers and gas pressures employed. Initially the coupling of power into the plasma was found to be partly capacitive and partly inductive, as is often the case. To simplify interpretation of the data, a grounded shield of aluminium foil was therefore introduced between the RF coil and the glass cylinder, as indicated in figure 1. The power coupling was expected to be then very largely inductive. The data to be described below support this view.

Experimental data

Figure 2 is typical of the data obtained for an argon plasma at a gas pressure of 5 mTorr. The energy distributions of the Ar^+ ions have a pronounced 'tail' extending down to low energies, as the result of inelastic collisions with the background gas in travelling through the plasma to the sampling orifice of the EQP. The most probable ion energies for the three input powers of 5, 15 and 25 Watts are approximately 21, 20 and 18 eV respectively, suggesting that the plasma potentials were around 21, 20 and 18 volts, decreasing slightly as the input power was increased. The decrease in plasma potential is accompanied by an increase in the number density of the Ar^+ ions.

Similar energy distributions to those of figure 2 were also obtained for various impurity ions generated in the plasma but there were other interesting features.

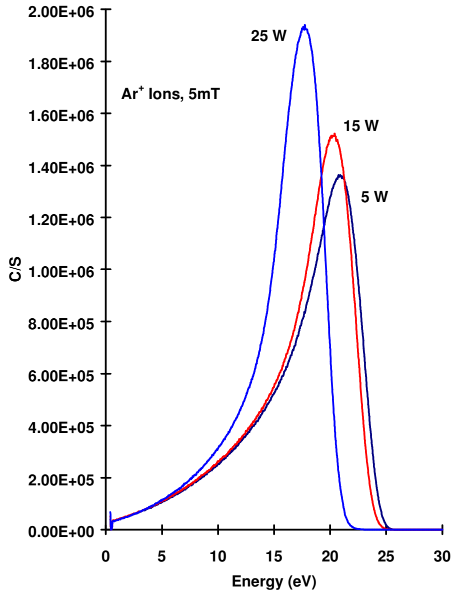

Figure 2 Ar^+ IEDs

For example, figure 3 shows the energy distributions measured for a 10 mTorr, 30 Watt plasma for ions with $^m/_e$ = 32 and 44 (presumed to be O_2^+ and N_2O^+ since the system had been used earlier for experiments in nitrous oxide) for the same plasma.

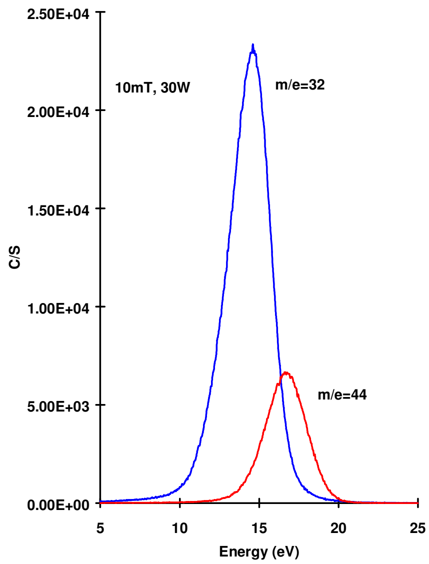

Figure 3 Impurity IEDs

There is a clear difference in the most probable ion energies for the two species.

Even more interesting is the distribution shown in figure 4, again for the same plasma conditions as figure 3, for $^m/_e$ = 28 (N_2^+ ions). The peak splitting is not thought to be that often seen for ions crossing a sheath region in a time comparable with the period of the RF input power, since otherwise the $^m/_e$ = 32 distribution would be expected to show a similar effect, given that the ion masses only differ by about 12%.

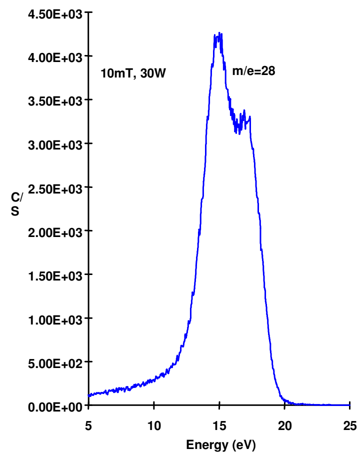

Figure 4 N_2^+ IED

For ions with $^m/_e$ = 19 (H_3O^+), the energy distributions for 5 and 25 Watts at 5 mTorr are shown in figure 5 using a logarithmic scale to emphasise the development at 25 Watts of a high energy 'tail' in addition to the more usual low energy component.

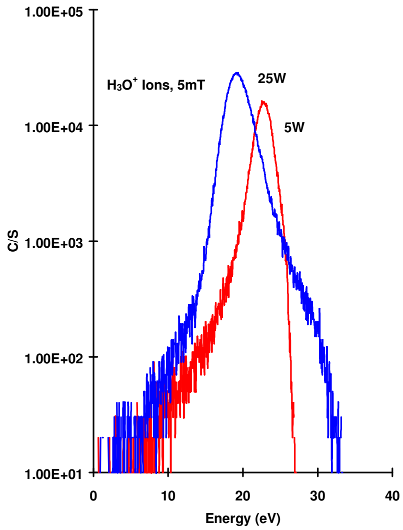

Figure 5 H_3O^+ IEDs

The most probable energies are again rather different to those shown in figure 2 for the dominant Ar^+ ions for the same plasmas.

We offer no explanation for the differences noted above for the most probable energies of the various ions for identical plasma conditions but note that they were repeatable, as was the peak splitting for the $^m/_e$ = 28 data and the high energy tail for the $^m/_e$ = 19 data.

Figure 6 shows the energy distributions measured for the Ar^+ ions for an input power of 30 Watts at pressures of 7.5 and 10 mTorr.

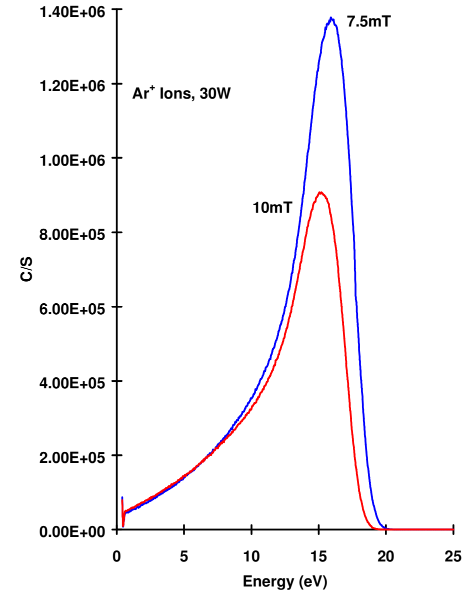

Figure 6 Ar^+ IEDs

The data show the most probable energy to decrease slightly with increasing pressure while the ion number density decreases significantly. The decrease of most probable energy with increasing plasma density is as noted earlier for the variation of these parameters with input power at a given gas pressure. The decrease in ion number density was probably the result of increases in the conversion rates of reactions of Ar^+ ions with trace impurities and of an increase in the population of Ar_2^+ ions.

Conclusions

The ion energy distributions measured for an argon plasma generated by inductively coupling RF power from a 13.56 MHz supply via a small coil and a matching network show the energies of ions reaching a grounded surface (in this case the sampling orifice plate of the EQP) to be relatively insensitive to the input power. The most probably energy for a given ion decreased by about 15% for an increase in power of a factor of 5 (5 to 25 Watts). The plasma density, however, increased significantly with the input power.

There were interesting, and as yet unexplained, differences in the energy distributions observed for the various ion species. The data should be compared with that in the accompanying Application Note describing experiments for the same system in which the coupling included a strong capacitive component.