EQP

Characterisation of an ICP reactor (II)

Summary

In Part 1 of this Application Note we described measurements, using a Hiden EQP instrument, for experimental conditions in which the coupling of RF power into the reactor was predominantly inductive. To do this, a grounded aluminium foil cylinder was inserted between the 4 turn copper coil, powered by the RF supply via a matching network, and the outside of the reactor's Pyrex wall. For comparison, the present Note describes the data obtained with the grounded cylinder removed so that some proportion of the RF input was capacitively coupled into the plasma. There were significant differences in the ion energy distributions observed.

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 data

Figure 1 shows the energy distributions measured for ArH+ ions (m/e = 41) in an argon plasma at 5 mTorr for input powers of 5 and 15 Watts when the excitation coil was placed around the reactor tube 7 cm from the sampling orifice of the EQP. It can be seen immediately that, in marked contrast to the case of an inductively coupled plasma, the most probable ion energy is strongly dependent on the input power, increasing from around 40 to 60 eV.

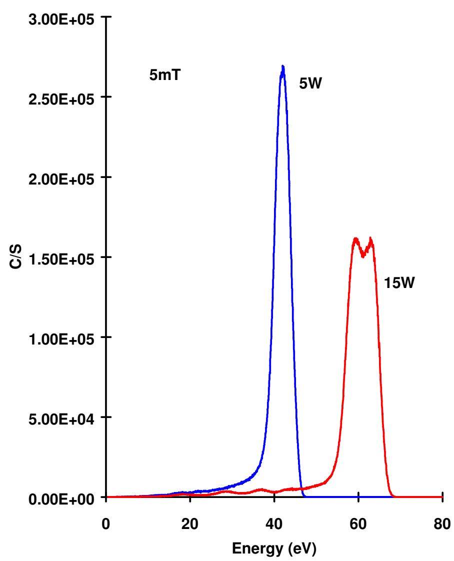

Figure 1 ArH^+ IEDs

Similar changes in the most probable energies for the impurity ions $^m/_e$ = 28 (N_2^+) and $^m/_e$ = 19 (H_3O^+) are shown in figures 2 and 3.

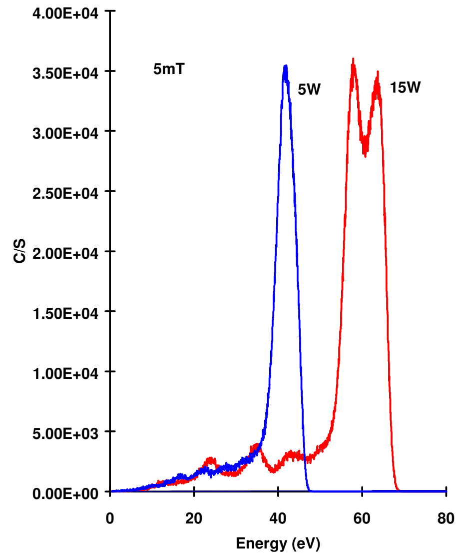

Figure 2 Impurity (N_2^+) IEDs

A second obvious feature of the distributions shown in figures 1, 2 and 3 is the peak splitting that occurs at 15 Watts. This is the familiar structure observed when the ions cross a sheath region between the plasma and the entrance orifice to the EQP in a time comparable to the period of the applied RF and has been seen many times for capacitively coupled plasmas in parallel plate reactors.

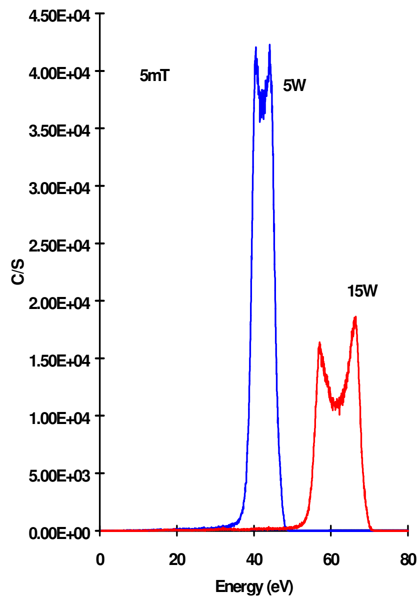

Figure 3   Impurity (H_3O^+) IEDs

The fact that the structure is seen in figures 1, 2 and 3 encourages the view that, with the grounded screen removed, the RF coupling includes a capacitive component. The contrast between the data obtained with and without the grounded screen is emphasised in figure 4 which shows the energy distributions obtained for the same conditions of power and pressure.

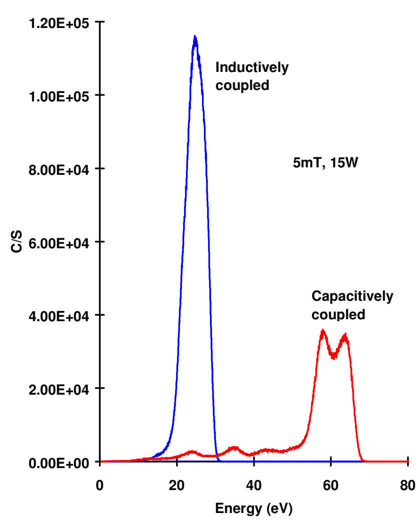

Figure 4 N_2^+ IEDs
(Inductive & Capacitive coupling)

When the coupling is largely capacitive the ion energies are markedly higher than for the inductive case.

Figure 5 emphasises that the degree of peak splitting is a function of the ion mass, increasing as the mass decreases. The peak separation, ΔE, in figure 5 is not, however, as strong as that predicted by the usual expression $\Delta E = f(m^{-1/2})$.

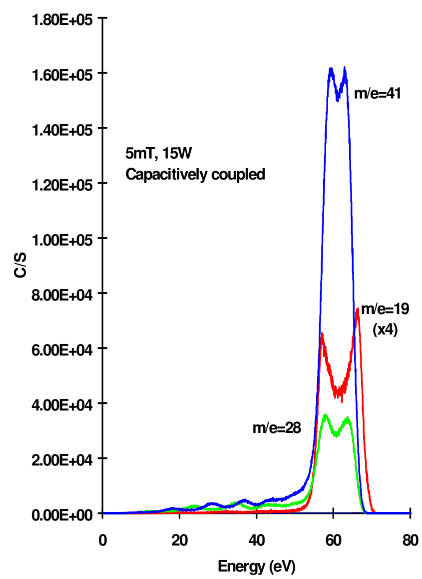

Figure 5   mass dependence of IEDs

The third feature of the distributions obtained with the grounded shield removed is the marked structure at energies below the most probable energy. The structure is seen clearly in figure 6 which is an enlargement of part of figure 5 for the N2+ and ArH+ ions.

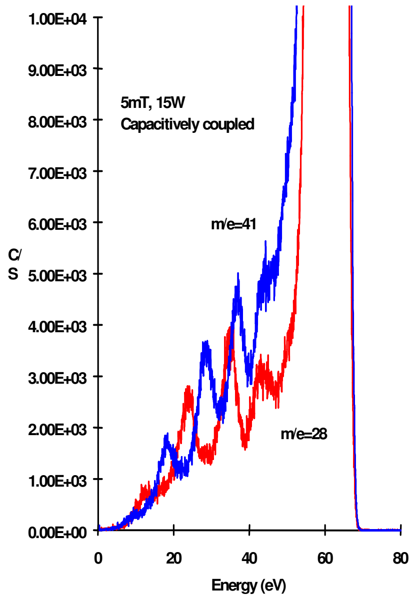

Figure 6 enlarged view of fig 5

The structure is attributed to the effects of ion-molecule collisions in the sheath region between the main body of the plasma and the EQP's sampling plate. No such structure was observed when the grounded shield was in position.

Conclusion

There are clear differences between the energy distributions obtained for given conditions of gas pressure and input power, for the cases where the RF coupling is purely inductive or strongly capacitive. The distributions obtained in the latter case are very similar in form to those obtained in studies of parallel plate, capacitively coupled plasmas, showing both low energy structure, attributable to ion-molecule collisional effects, and peak splitting associated with phase angle effects. A very significant effect is the contrast between the strong dependence of the ion energies on the input power for capacitive coupling and the very much weaker dependence described in Part 1 for inductive coupling.