Plasma Analysis
Application Note 232

EQP

Mass Spectrometry of Processing Plasmas with the Hiden EQP Mass/Energy Analyser

Summary

The Hiden EQP system provides for the mass analysis of neutrals and neutral radical species, and the mass and energy analysis of positive ions and negative ions direct from plasma. This application note describes measurements made on processing plasmas using the Hiden EQP system to analyse the relative abundances of various neutral molecules and positive ions. The two sets of data illustrate the performance of the EQP as a highly sensitive RGA system and highlight the additional information about process conditions provided from the positive ion spectra available from the EQP. Other application notes which describe the information available from energy analysis, neutral radical analysis and negative ion analysis are referenced within this application note.

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Mass analysis of neutral species

The EQP instrument includes a twin filament electron impact ioniser for Residual Gas Analysis (RGA) of a processing chamber. The ioniser is situated close to the sampling orifice for high sensitivity to neutral and neutral radical species sampled from the plasma. The close proximity of the ioniser to the sampling orifice combined with the high degree of control of ioniser parameters afforded by the EQP operating system ensure high sensitivity RGA operation. The mass analyser included in the EQP system is a triple filter molybdenum rod quadrupole with a high gain, pulse ion counting channeltron detector.

For a typical processing chamber which has been cleaned and pumped, but not baked to reduce the outgassing of water vapour and other gases trapped on the chamber walls, the mass spectrum obtained may be of the form shown in figure 1. Clearly such spectra are useful in determining whether there are undesirable impurities present as background gases in the chamber which may have an effect on subsequent processing programmes.

If the processing chamber is now filled with a sample of processing gas to a gas pressure typical of that used whilst carrying out a processing procedure, new RGA-type measurements can be made. The mass spectra obtained will now be dominated by peaks representing the processing gas (or gas mixture) but there may still be significant signals from background impurities. Figure 2 shows a typical spectrum obtained by sampling gas from a processing chamber filled to a pressure of 30 mtorr with argon. For the majority of processing systems, there is a steady flow of gas though the chamber and it is possible to monitor changes in the composition of the gas in the chamber by re-measuring the data of figure 2 at suitable time intervals, or by following the intensities of gas species plotted against time in a trend analysis.

For both the above types of measurement, the ions which are mass analysed are produced in the EQP's own ion source. With the EQP selected in its positive ion mode the EQP mass analyses ions from the processing plasma itself. In this application, positive ions from the plasma are sampled through the sampling orifice of the EQP. The EQP's own ionisation source is switched off during these measurements, and therefore there is no neutral background signal as occurs with RGA measurements.

In the positive ion mode the user selects an energy or a range of ion energies for which mass analysis is required. The ions transmitted by the energy analyser are subsequently mass analysed and give spectra such as that of figure 3 which is for an RF plasma operated in argon.

Comparison of figures 2 and 3, which were obtained from the same plasma chamber under identical conditions except for the fact that the plasma discharge was 'off' and 'on', respectively, show that there are significant differences. For example, with the plasma on, significant numbers of M = 20, M = 41 and M = 80 AMU ions are observed. These correspond to Ar^{2+}, ArH^{+} and Ar_2^{+} ions. There are also differences in the abundances of impurity ions.

Clearly, in a processing plasma, used either for etching or deposition purposes, it is important to know both what ions impact on target surfaces and what neutral species are present in the plasma. Data such as that of figures 2 and 3 are of equal importance therefore , and illustrate how the RGA and positive ion modes of the EQP combine to give a more complete picture of plasma conditions than RGA of neutrals alone.

It is implicit in the above discussion of figure 3 that the relative abundance of the ions shown is that corresponding to a given ion energy. In a processing plasma not all the ions striking a target surface will do so with the same energy. Even for ions of a given mass, because of collisions between the ions and neutral particles, there may well be a spread of energies. It is therefore of considerable value to be able to plot data such as that of figure 3 for a range of ion energies.

It is of course possible to use the EQP to measure for a given ion species the distribution of energies at the entrance to the EQP. Figure 4 shows a typical Argon ion energy distribution (IED). Use of the EQP in this way is described in Application Note 228. The study of negative ions produced in processing plasmas can, for some classes of plasmas (such as capacitively coupled RF plasmas), require special techniques. Examples of the use of the EQP for measuring the energy distributions of negative ions are discussed in Application Note 230.

Application Note 229 is concerned with the use of the EQP to monitor neutral species created in a processing plasma, including long-lived radicals, by examining the threshold region of the ionisation efficiency curve observed by using the EQP's internal source to generate positive ions from the sampled neutral fragments. For electronegative neutral fragments, a potentially more powerful technique, which involves the generation of negative ions from the neutral fragments in the EQP's source, is described in Application Note 231.

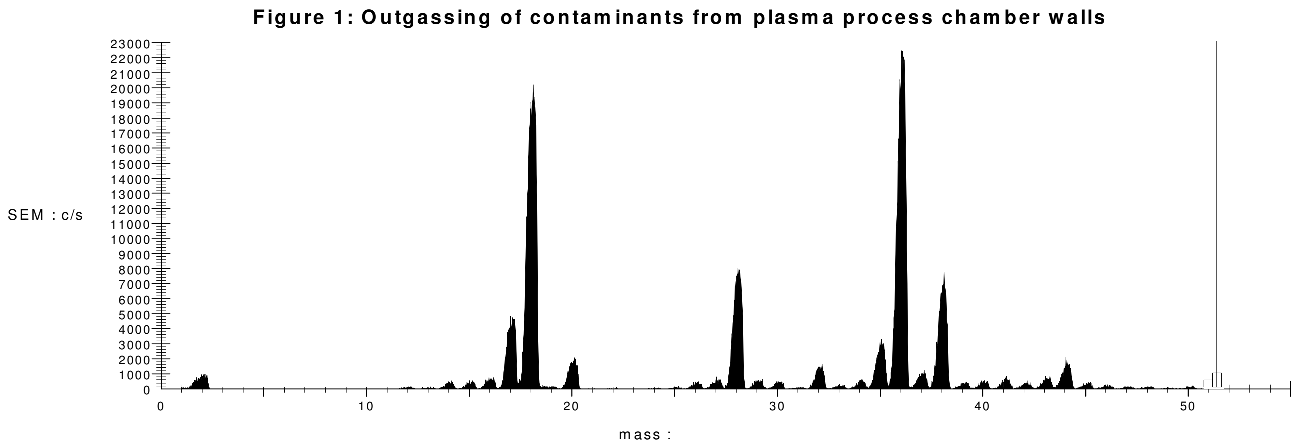

Figure 1 Background RGA

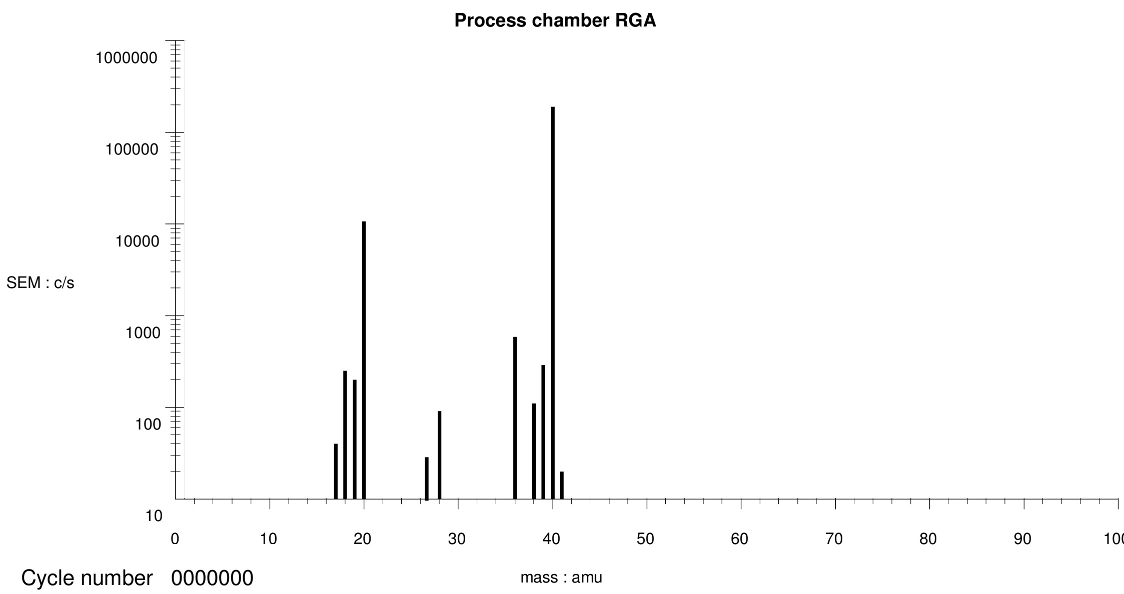

Figure 2 Process gas RGA spectrum

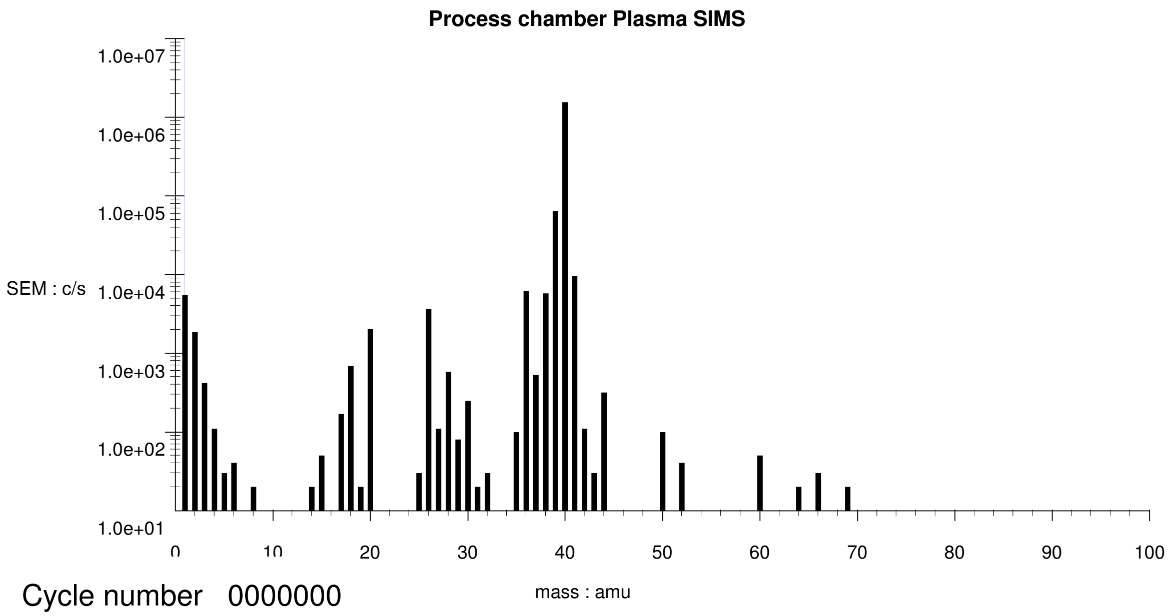

Figure 3 Process chamber plasma SIMS spectrum

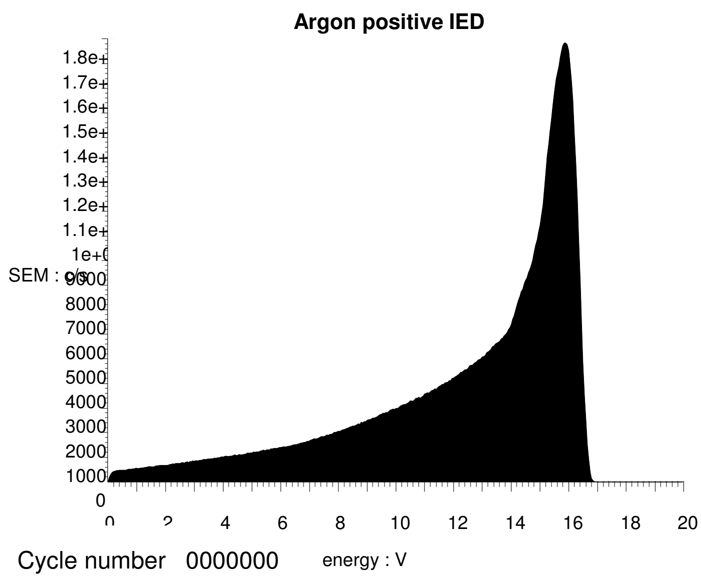

Figure 4 Argon IED