Abstract

Among the techniques in common use for mass spectrometric studies of processing plasmas, the so-called "threshold ionisation" (TI) method for examining the neutral species generated in a plasma has been particularly useful. In the past, the technique has been applied using source pressures in the mass spectrometer of about 10⁻⁴ Torr. With the current availability of particle detectors which can be operated at much higher pressures, it is of interest to examine possible extensions of the TI technique. The present data for mass spectrometer pressures of up to 4.10⁻⁴ Torr, using gas mixtures which include two gases, show clearly the generation of long-lived metastable atoms of the inert gases in both the source of the mass spectrometer and in the plasma. For gases such as oxygen, generation of metastable species in the mass spectrometer source is also observed. The interpretation of the experimental threshold ionisation data is discussed. The measurements suggest new avenues of research for both gas analysis and plasma diagnostics for gases having long-lived, metastable states.

Introduction

With the availability of particle detectors that can be used at pressures up to 4x10⁻⁴ Torr, it has become possible to operate mass spectrometers at pressures that are much closer to those used in many plasma processing systems. This enables the improved sampling of both neutral and ionised species from plasma reactors. Additionally, the Hiden Analytical quadrupole mass spectrometer (QMS) can operate in a mode where the energy of the electrons emitted within the ionisation source is variable. This mode is called TIMS (Threshold ionisation Mass Spectrometry). Different elements have defined ionisation energies required to release stable-electron ejected electrons. This energy is dependent on the electron orifice, i.e. lower mass neutrals generally have lower ionisation energies due to their greater distance and lower electrostatic forces from the nucleus. This gives rise to the electron impact ionisation efficiency curves shown in Figure 1.

Results

The ionisation potential of helium is 24.6 eV. The section AB of the curve is utilised for the formation of metastable He⁺, atoms, which have a very lifetime against spontaneous decay. They have sufficient energy to generate peak counts when impacting on the detector. For electron energies above 24.6 eV the section BC of the curve includes both metastable and excited helium contributions. Similar data were obtained in other experiments for neon, krypton and argon. Data for krypton are included in figure 3. The form of the curves shown in figure 3 may be understood by reference to figure 4.

Conclusions

Reducing the pressure difference between a plasma reactor and an attached mass spectrometer enables direct detection of metastable species produced in the plasma if these have long lifetimes and sufficient internal energy. Detectors of lower energy, but still long-lived, metastable species and other plasma products is also simplified, such measurements may be used in considering the role of energetic neutral species in the plasma processing of surfaces.

References


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