Study of Ar/He mixed plasmas to probe the excitation and ionization processes in Grimm-type glow discharges

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Introduction

The increasing use of mixed gases, including helium mixtures, in glow discharge mass spectrometry has led to a need to understand the resulting signal enhancements due to changes in excitation and ionization processes. To help in understanding these processes in glow discharge, we have carried out complementary OES experiments. The plasma gas plays a vital role in the excitation/ionization processes in discharge. To identify unusual excitation processes affecting particular lines in GD, helium was added up to 60 % v/v in the plasma gas. The additional gas can drastically influence the observed emission line intensities of the main plasma gas and sputter analyte. Selective excitation processes which are mainly dependent on the nature of the plasma gas and analyte material are also observed.

We report results of investigation on the effect of Ar/He mixed plasmas on the emission intensities of sample (copper & iron) and plasma gas, electrical parameters, pressure and sputter rate. The results presented here were obtained by using 'standard' conditions (700 V & 20 mA).

Pressure required to maintain the 'standard' discharge parameters

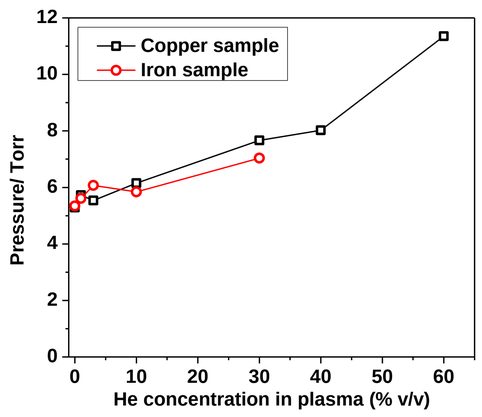

Fig. 1 Pressure measurement in Ar/He plasma using copper and iron samples at 700 V & 20 mA.

Electrical parameters for various Ar/He plasmas

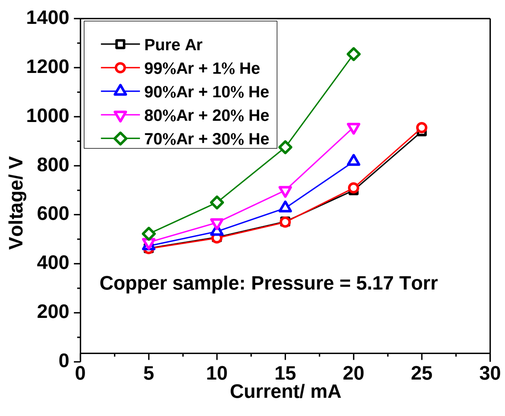

Fig. 2 Effect of addition of (0-30 %v/v) helium in plasma using copper sample, measured at constant pressure of 5.17 Torr.

Effect of Ar/He on normalized line of Ar I 811.531 nm

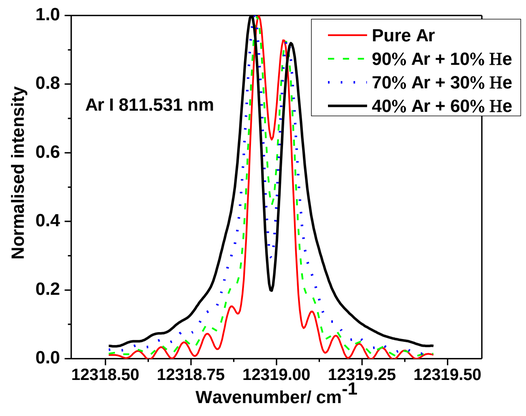

Fig. 3 Normalized line profiles showing self-absorption in pure Ar and self-reversal for various He concentration at 700 V & 20 mA.

Behaviour of He I emission lines in Ar/He plasmas

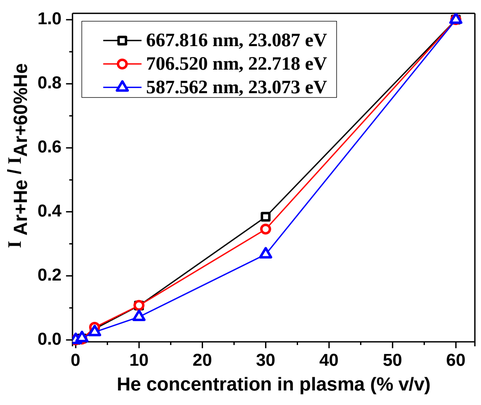

Fig. 4 Plots of the He I lines as a function of helium concentration, normalized to intensities measured at 60 (%v/v) He in plasma.

Behaviour of Ar I emission lines in GD with Ar/He plasmas

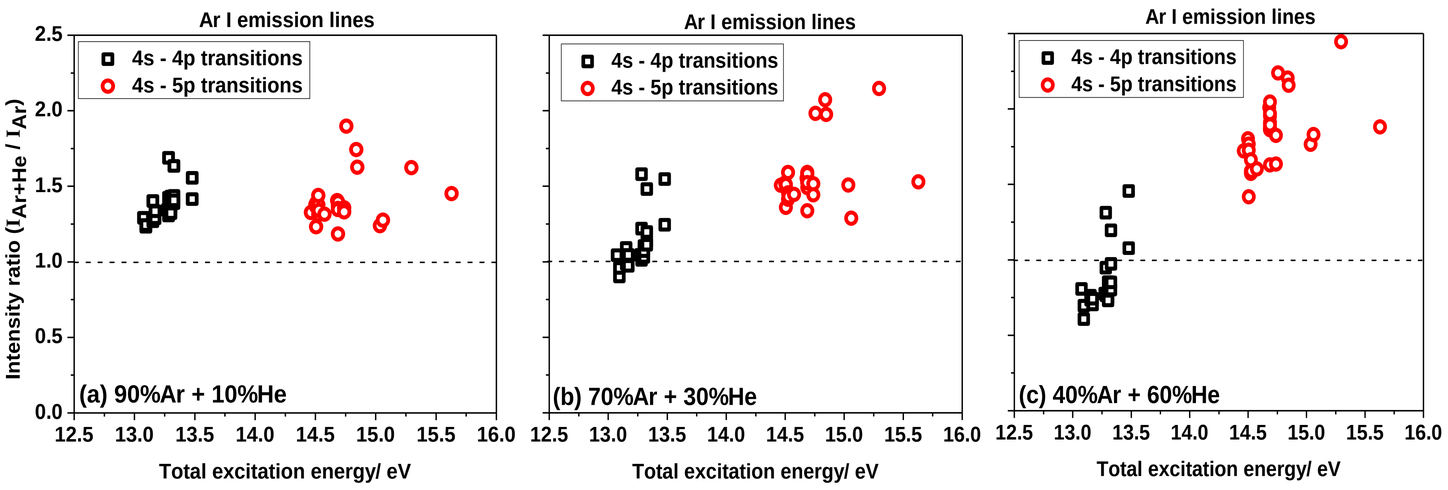

Fig. 5 Intensity ratios for argon atomic lines measured in (a) 90%Ar + 10%He (b) 70%Ar + 30%He and (c) 40%Ar + 60%He as a function of total excitation energy using Cu sample.

Behaviour of Ar II emission lines in GD with Ar/He plasma

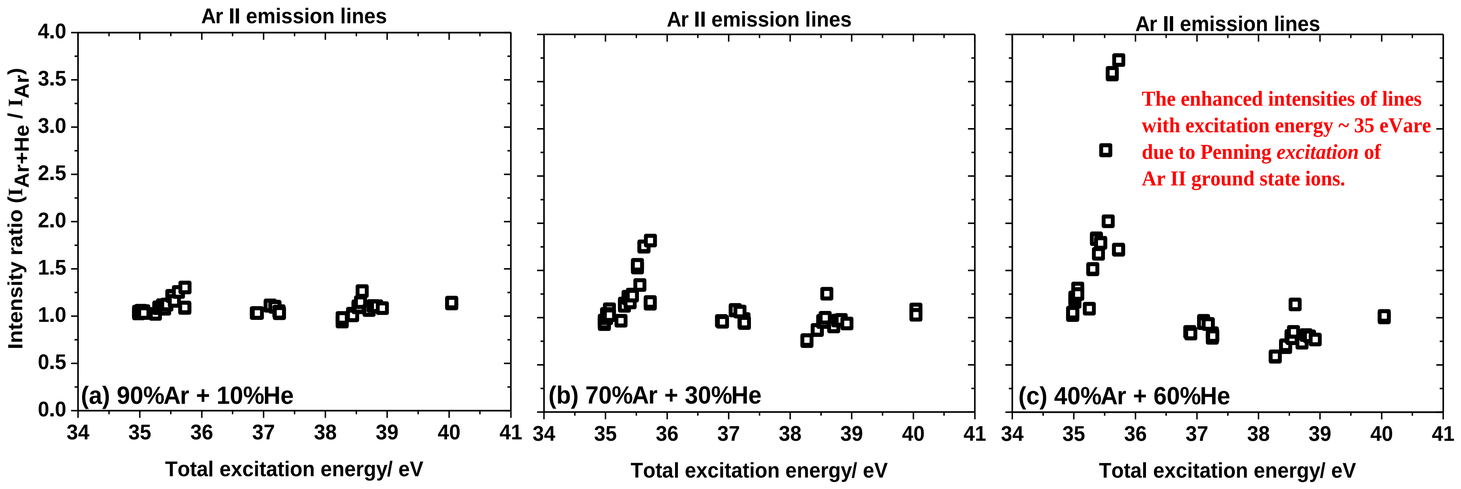

Fig. 6 Intensity ratios for argon ionic lines measured in (a) 90%Ar + 10%He (b) 70%Ar + 30%He and (c) 40%Ar + 60%He as a function of total excitation energy using Cu sample.

Behaviour of analyte emission lines in Ar/He plasma

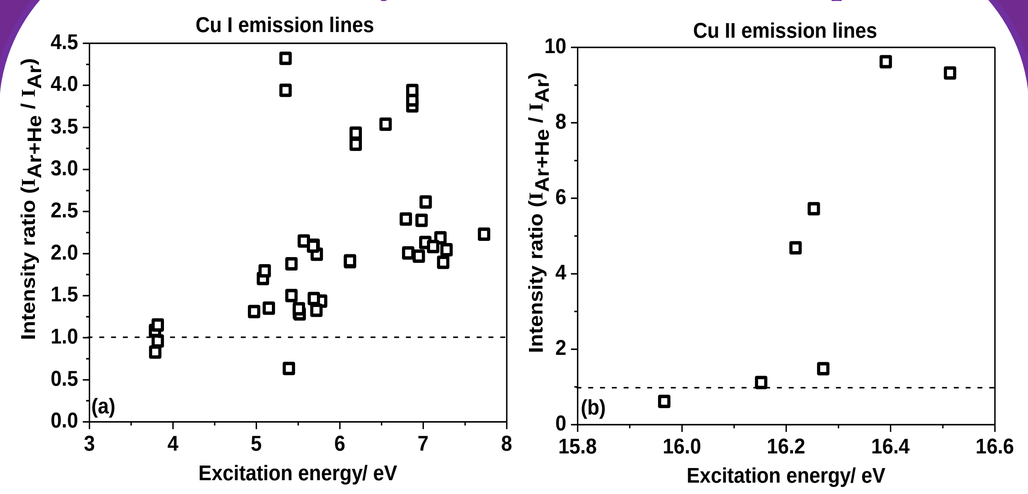

Fig. 7 Intensity ratios for (a) Cu I and (b) Cu II emission lines measured in 40%Ar + 60% He for 700 V and 20 mA.

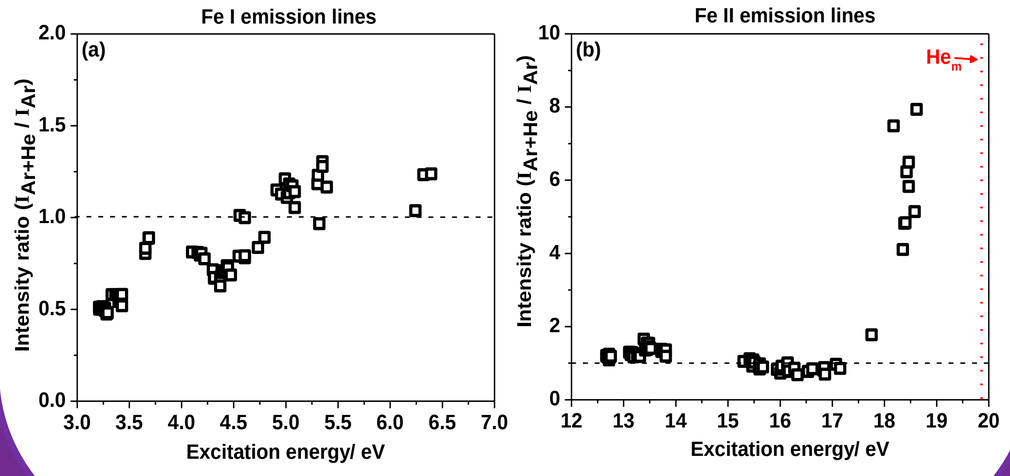

Fig. 8 Intensity ratios for (a) Fe I and (b) Fe II emission lines measured in 40%Ar + 60%He for 700 V and 20 mA.

Results and discussion

- Argon atomic lines in the 600 – 900 nm region (transitions to the 4s levels) show increasing amount of self-absorption and self reversal, with increase in He concentration, suggesting an increase in the population of these levels.
- Argon ionic lines with total excitation energy 35-36 eV are excited by 'selective' Penning *excitation* of ground state argon *ions* by helium metastable atoms.
- Cu I and Fe I lines other than resonance lines, show an increase in intensity ratios with the addition of helium to the plasma gas.
- It appears that Fe II lines, upper energy near to 19 eV, are excited by non-selective Penning *ionization* by He_m atoms of ground state iron atoms. Lines emitted from levels closer to the He_m level are in the VUV region below the lower wavelength limit of the Imperial College VUV FTS.
- Several intense Cu II lines (16.2 – 16.5 eV) appeared in Ar-He, it is suggested that these intense Cu II lines may be the results of a cascade effect.

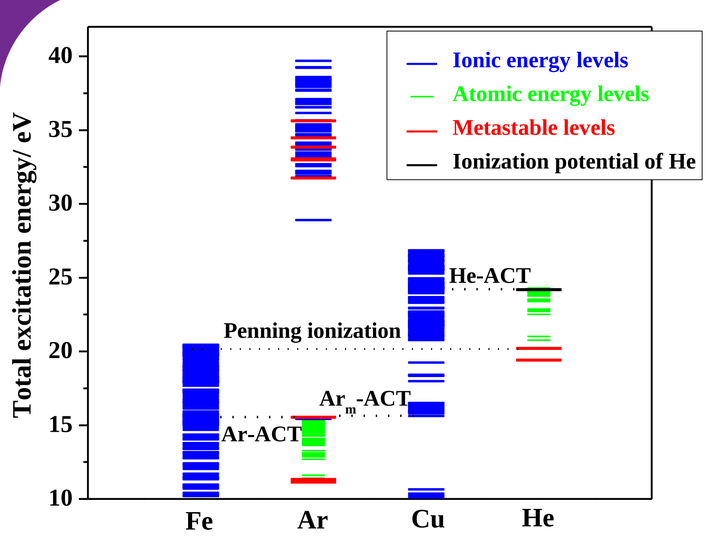

Fig. 9 Schematic representation of some energy levels of relevant elements (atomic in green, ionic in blue).

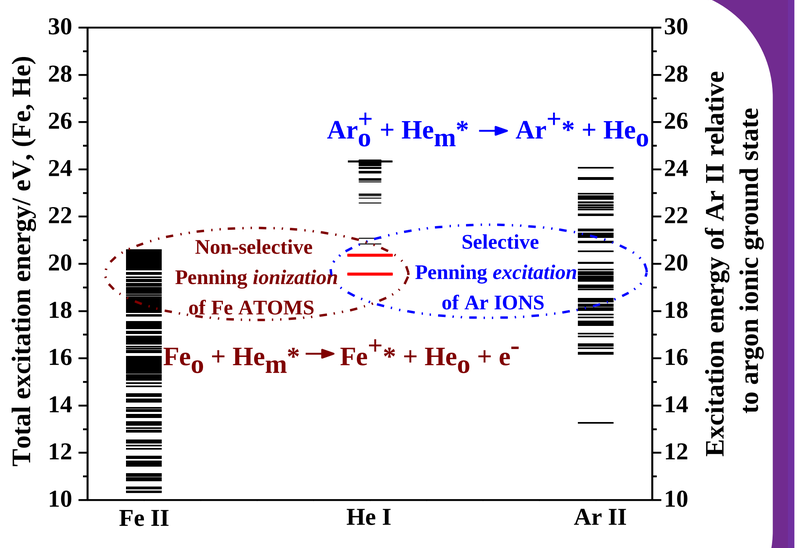

Fig. 10 Schematic representation of non-selective Penning *ionization* & selective Penning *excitation* of relevant elements.