Characterization of an Argon-Sulfur Microwave Plasma Column at Reduced Pressure by Optical Imaging and Emission Spectroscopy

C. Moderie [1], A. Durocher-Jean[1], R. Martel [2], L. Stafford [1]
[1]*Département de Physique, Université de Montréal, Montréal, Canada*
[2]*Département de Chimie, Université de Montréal, Montréal, Canada*

Abstract: A reduced pressure argon microwave plasma column sustained in the presence of solid sulfur is investigated. This study reveals two distinct regimes: (i) a contracted bi-coloured plasma (pink and blue) and (ii) a diffusive (blue) plasma. Optical diagnostics are done to analyse the physiochemistry along the plasma axis. The results show that a high sulfur density induced the transition between the contracted and diffusive regimes.

1. Introduction

Sulfur-based materials have attracted considerable interest in a wide range of applications due to their exceptional chemical and physical properties. Non-equilibrium plasma offers a versatile and efficient pathway to incorporate sulfur atoms into materials at low temperatures. Despite its potential, plasma-based sulfurization poses several challenges, including the toxicity and hazardous nature of sulfur-containing precursors, the need for complex heating systems to maintain precursor delivery, and the concerns about reactor contamination. In this work, we characterize a simple and efficient method for generating an argon-sulfur microwave plasma column at reduced pressure.

2. Methods

Argon surface-wave plasma columns were sustained at reduced pressure (5-10 Torr) by a 915 MHz microwave generator. This plasma is placed in contact with solid sulfur S_8 to produce an argon-sulfur atmosphere. The reactive plasma is investigated over a range of pressures and powers by optical imaging to characterize the contraction phenomenon and by optical emission spectroscopy (OES) to gather fundamental plasma properties. In particular, the argon line broadening technique was used to determine the neutral gas temperature T_g in the argon and argon-sulfur plasma column using a ultra-high spectral resolution spectrometer. Also, OES was done to probe the nature and concentration of chemical species along the plasma column. In particular, actinometry analysis were developed and used to probe the atomic sulfur density using either Ar or Xe as the actinometer gas.

3. Results and Discussion

In the presence of sulfur and for low power conditions, discharge contraction is seen, which is indicated by the filament radius being smaller than the tube dimension (see Figure 1). At higher powers, a diffusive regime is observed. Over the range of experimental conditions investigated, T_g values obtained from high-resolution OES analysis reveal a significant increase with increasing pressure and with rising gas phase sulfur concentration. For example, T_g is 460 K and 485 K for the agon and the argon-sulfur column, respectively. On the other hand, sulfur density obtained from actinometry measurements indicate a prominent increase between the low- and the high-power conditions, going from from 10^{19} at 24 W to 10^{21} m^{-3} at 76 W. Based on this set of data, it can be assumed that the transition between the contracted and the diffusive regime is linked to the increase of the sulfur density in the gas phase.

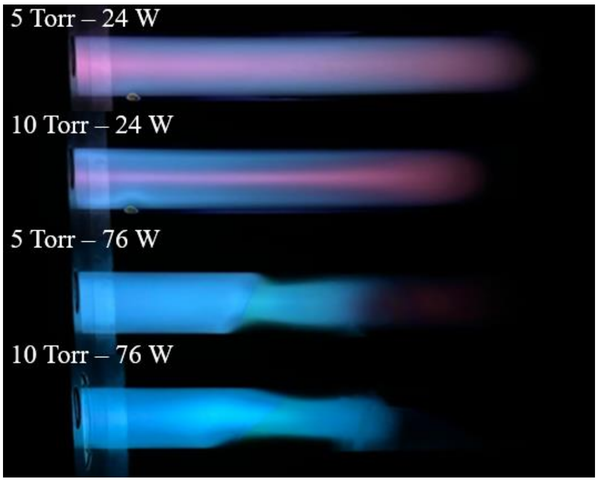

Fig. 1. Plasma pictures for four experimental conditions with the bi-colored and diffusive regime.

4. Conclusion

This contribution presents an easy way to produce an argon-sulfur microwave plasma column. Investigations iof the physics and chemistry of this highly reactive plasma by optical imaging and optical emission spectroscopy revealed that the presence of sulfur can either enhance or inhibit the contraction phenomenon.

Acknowledgement

This work was financially supported by the National Science and Engineering Research Council (NSERC), Photon etc., the Fonds de Recherche du Québec—Nature et Technologies (FRQNT) and the Canada Research Chair programme (L. Stafford and R. Martel).