Optical emission spectroscopy characterization of a novel atmospheric pressure argon/ammonia gliding arc

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Gliding arc plasma reactors find applications in a wide variety of fields, including environmental remediation, waste treatment, and energy conversion [1]. The energetic nature of the plasma discharge facilitates the decomposition of volatile organic compounds (VOCs), pollutants, and other hazardous substances present in gas streams, offering a sustainable approach to air and water purification. Moreover, the highly reactive species generated in gliding arc reactors with low power consumption make them suitable candidates for the synthesis of value-added chemicals and materials from renewable sources, contributing to the advancement of green chemistry and sustainable manufacturing practices.

In this work, we use a novel gliding arc reactor where the active electrode is an ovoid and the grounded electrode consists of a mesh that surrounds the former, both made of stainless steel (this configuration provides a large discharge region). A sinusoidal electrical signal (3kV and 300 Hz) was used to ignite the discharge and different mixtures of Ar and NH_3 were used as inlet gases. The emission of the plasma discharges was registered using a Horiba Ltd., Jobin-Yvon FHR640 spectrometer equipped with a 1201 grooves/mm diffraction grating centered at 330 nm. The emission was transversely collected from the most intense region of the plasma near the central electrode and recorded with a spectral resolution ranging from 0.05 to 0.1 nm.

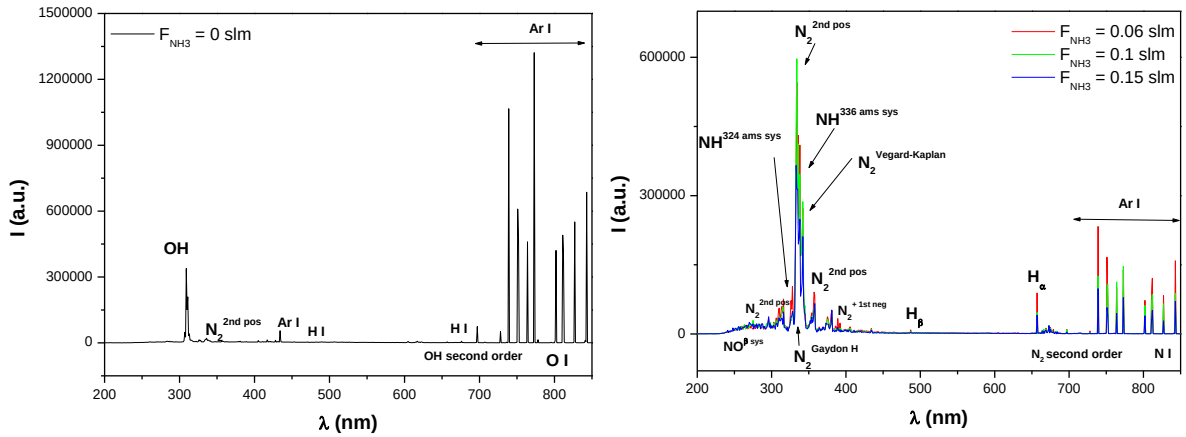

Fig. 1: OES spectrum detected for (left) the pure Ar and (right) Ar/NH_3 discharges.

For the pure argon discharge (Fig. 1(left)), the emission of atomic argon lines dominated. Excited species OH*, O*, and H* were also detected, which proved that some air entered the reactor. The addition of ammonia into the main gas resulted in a significant reduction in the emission of argon lines, while new molecular bands corresponding to species containing nitrogen (N_2, NH, N_2^+) appeared in the spectrum (Fig.1 (right)). Additionally, the emission of atomic hydrogen lines intensifies, and atomic nitrogen lines appear. The intensity evolution with the ammonia flow rate of the different excited species was tracked (Fig. 2).

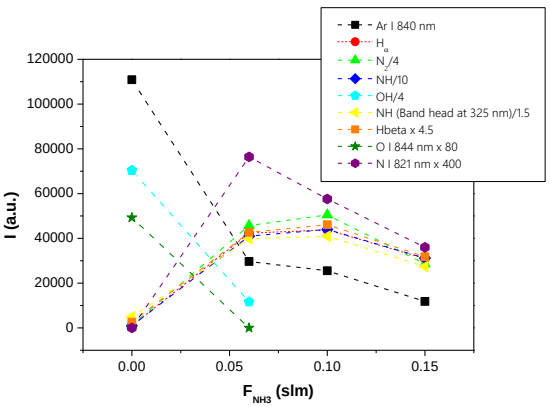

Fig. 2: Excited species in the plasma.

The plasma electron density (n_e) was measured from the Stark broadening of both H_α and H_β lines [2] (Fig. 3 (left)). A maximum was detected when moderate fractions of NH_3 were introduced in the discharge. The gas temperature (T_g) was measured from the collisional broadening of Ar I 840.82 nm emission line following the method proposed in reference [3] (Fig. 3 (right)). The gas temperature exhibited an increase upon NH_3 introduction. It's worth noting that the values of the rotational temperature $T_{rot,N2}$ derived from the simulation of the N_2 ($C^3\Pi \rightarrow B^3\Pi$) rotational band (band head at 353.67 nm) are notably higher than T_g, thus overestimating this plasma parameter.

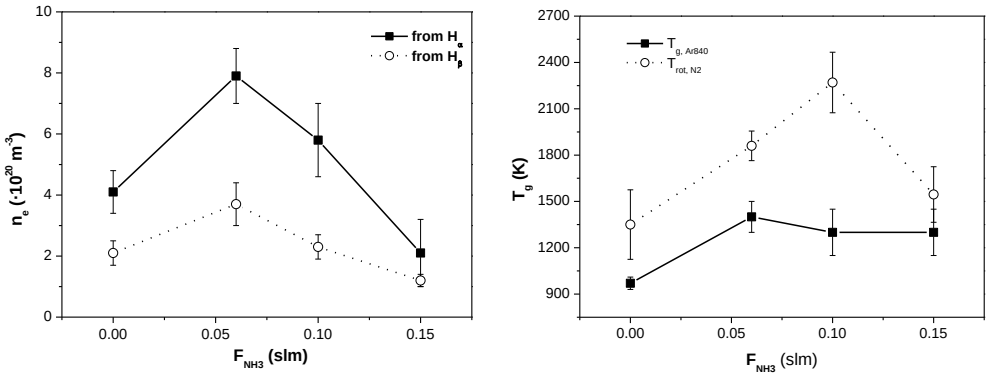

Fig. 3: n_e (left) and T_g (right) evolutions with NH_3 flow rate.

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