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DIAGNOSTICS OF AN LOW PRESSURE MICROWAVE INDUCED Ar PLASMA

S.Jovićević, M.Ivković, Z.Pavlović, N.Konjević
Institute of physics, Pregrevica 118, 11080 Zemun, Yugoslavia

1. INTRODUCTION

Microwave induced plasma (MIP) discharges have long be used as sources for exciting atomic and polyatomic species. The high degree of excitation afforded by such sources, coupled with their relatively low cost, have made the MIP attractive in many situations where intense, monochromatic sources are needed or where elemental emission spectra must be obtained. The nature of of MIP discharges varies considerably with the nature of their applications. For example, the kind of MIP used as a source for atomic fluorescence spectroscopy differs considerably from that used for element analysis of aqueous samples. The former sort of MIP is ordinarily operated in closed vessel and at a pressure of a few Torr, whereas the latter usually uses a flowing gas system at atmospheric pressure. The MIP is seen as an attractive alternative to other discharges (ICP for instance) for other reason as well. The observed emission spectra from the MIP are rarely complex, consisting mostly of resonance transitions of neutral species. The continuum background is also low, so that high-resolution is not necessary to minimize background contribution at the analytical wavelength. This kind of the discharge can be also operated in different gasses, such as He, Ar, N_2 and air. Besides the fact, that understanding of fundamental processes and exact characteristics of this discharge would allow researchers to improve reproducibility, accuracy and detection limits of various elements traces only a limited number of papers deal with precise plasma parameters' determinations. In this paper plasma parameters of the low pressure argon MIP discharge was determinated.

2. EXPERIMENTAL SETUP

Schematic diagram of the experimental setup is presented in Fig.1 As a power supply commercial 2450 MHz generator connected by the waveguide to the TEM_{010} type Van Dalen's modification of Beenakker microwave cavity is used. An 18 cm long quartz tube with ID 3 mm was installed in the center of the microwave cavity. All measurements are performed with microwave power among 30 and 60 W, with reflected powers minimized to less than 5%. Gas mixture (Ar + 1.5% H) pressure was adjusted by needle valve between 1 and 7 Torrs. A 1:1 image of the plasma source is projected on the (15 μm wide and 2 mm high) entrance slit of 0.5 m Ebert type spectrometer (Jarrell Ash 82-025) with inverse dispersion 1.6 nm/mm. Spectra recordings were performed by the use of photomultiplier EMI 9659 QB mounted on the exit slit of the spectrometer. The wavelength scanning was performed by the step motor and step motor drive (Isert ID 3304) controlled with PC AT computer. The spectral line shapes are recorded by the help of boxcar averager (Stanford Research Systems SR 250) and the same computer. For enhancement of the signal to noise ratio, averaging of 10 signals at each step of the motor was also performed. For self-absorption checks spectral lines are recorded with open diaphragm D placed between the end of the discharge tube and mirror M_3 with a focal length of 20 cm.

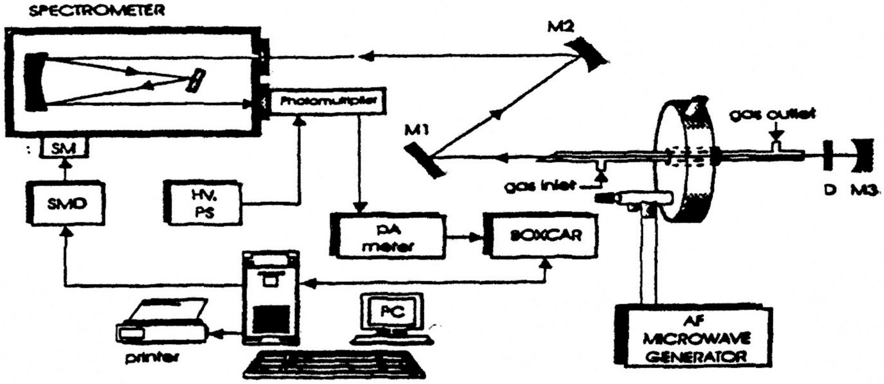

Figure 1. Schematic diagram of the experimental setup

2. RESULTS AND DISCUSSION

In this paper we present results of rotational temperature, excitation temperature and electron density determinations of low pressure Ar MIP discharge.

Rotational temperatures were determined from relative radiance's of a series of the R_2 branch of the $^2\Sigma$ - $^2\Pi$ (0,0) electronic band of OH. Typical obtained OH spectrum is presented in Figure 2.

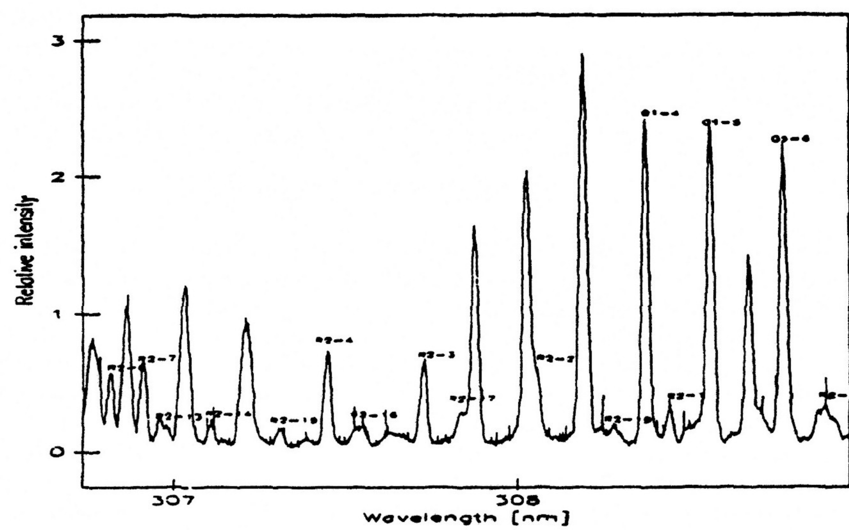

Figure 2. Observed OH band at microwave power 50 W and argon pressure 2 Torrs

In further calculations we obtain results similar to the one obtained at elevated (almost atmospheric) Ar pressures from OH and N_2^+ bands by (Pak *et al.* 1994) and (Brown *et al.* 1986) as can be seen in Figure 3.

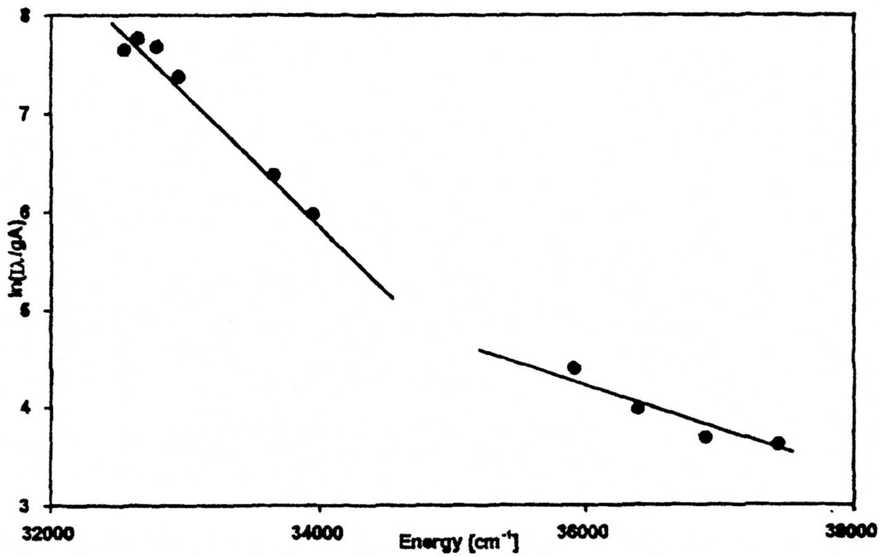

Figure 3. Rotational temperature determination from OH band gas pressure 2 Torr, microwave power 50W

In Figure 3, two groups of points are obtained. One has an energy distribution from 32 000 to 34 000 cm^{-1} and the other from 35 000 to 38 000 cm^{-1}. The temperatures from the two groups were 1050 K and 2650 K, respectively. When a single fitting of all points was used measured temperature was 1500 K. The existence of two different energy distributions as well as self-absorption can influence the linearity. From our measurements we conclude that these lines are not self-absorbed.

Excitation temperatures were obtained from measurements of relative radiance of ten argon atomic emission lines (415.86, 420.07, 425.18, 425.94, 426.63, 427.21, 430.01, 433.36 434.52 and 451.07 nm with corresponding transition probabilities 0.0145, 0.0103, 0.00113, 0.0415, 0.00333, 0.0084, 0.00394 , 0.006, 0.00313 and 0.0123 [10^8 s^{-1}] (W.L.Wiesse,1969). After applying self-absorption checks and corrections due to the responsivity of optical system we obtain excitation temperatures between 4200 and 4500 K for gas pressures from 2 to 6 Torrs and microwave powers 30 to 60 W.

Electron density is determinate from the fitted Hβ, Hγ and Hδ spectral line profiles in conjunction with the theoretical calculations by Vidal et al (1973). Obtained results shows that electron number density is practically almost constant (within estimated errors) in investigated range of gas pressures and microwave powers (see Figure 4). Values determined from line shapes of different hydrogen lines also agree well within 10%.

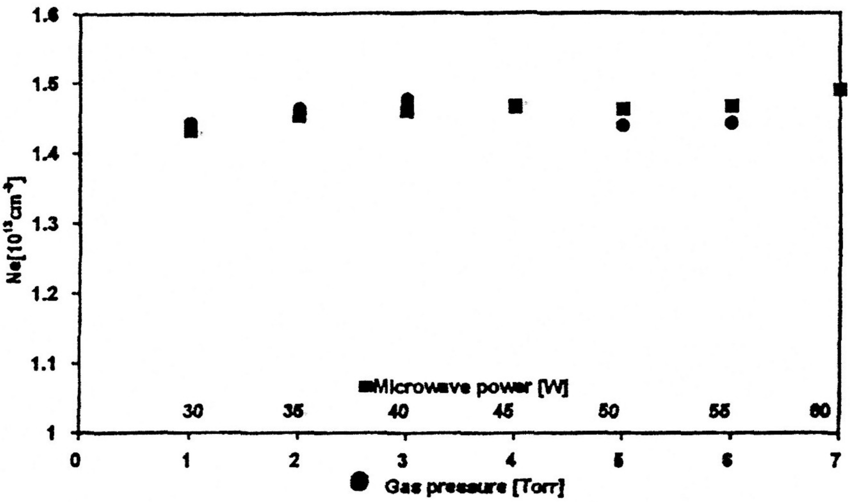

Figure 4. Electron number density dependance upon:
a) gas pressure at microwave power 50 W ●
b) microwave power at gas pressure 2 Torr ■

Further studies of MIP discharges will be directed towards plasma diagnostics at atmospheric pressures. Special attention will be devoted to the study of the OH rotational temperatures.

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