

SPECTROSCOPY STUDIE OF ATMOSPHERIC PRESSURE MICROWAVE INDUCED PLASMA

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1. INTRODUCTION

The determination of electron number density (N_e) is important in diagnostic studies of plasmas used in analytical atomic emission (AAES) spectrometry. In these plasmas, gaseous species are partially ionized and the N_e values can be used to deduce the degree of ionization and the analytical characteristics of the plasmas. Several laboratory techniques have been applied for the determination of N_e : (a) Stark broadening; (b) Saha-Eggert ionization equilibrium; (c) absolute continuum intensity; (d) Langmuir probes. Among these techniques, Stark broadening is used most frequently in plasma spectrometry because the procedure is relatively simple, theoretical spectral line intensity profile is available for the emission line from H, He, and Ar, and most laboratories are equipped with optical instruments suitable for such kind of measurements. Additionally, the Stark broadening technique is applicable to plasmas where local thermal equilibrium (LTE) may not prevail.

In the present paper for characterization of plasma for spectrometric analyses, spatial distribution of atomic hydrogen line H_{β} at 486.13 nm for determination of electron number density, and the dependence of this parameter on operating condition have been investigated for the tangential flow MIP.

2. EXPERIMENT

The instrumental components and procedure in the present experiment, which were described elsewhere (Jovićević et al, 1996) are summarized in Table 1.

Table 1. Instrumental apparatus and components

Component	Specification
Microwave generator	2.45 GHz (AHF model: GMW 24 - 302 DR)
Microwave cavity	TEM ₀₁₀ Beenakker type (Beenakker, 1976) Van Dalen's modification (Van Dalen's et. all, 1978)
Discharge tube	tangential flow Al oxide (6 / 4 mm)
Nebulizer	right-angle pneumatic nebulizer (Meinhard TR30-C3)
Monochromator	0.5 m Ebert type (Jarrell Ash 82-025)
Photomultiplier	EMI 9659QB
Picoammeter	Keithley 414 S
Data acquisition	Boxcar averager (Stanford Research Systems SR 250)

In order to obtain the discharge which is temporally and spatially stable we exchange the single capillary discharge tube with so called "tangential flow torch" reported by Bollo-Kamara et. all (1981). Instead of quartz concentric tubes and thread insert, which are fused all together, we used alumina tubes separated by cooper wire. Windings of the wire are the same as coils of their threaded insert. Analyte sample gas goes through the inner tube, while the plasma support gas is introduced through the outer sleeve and exit from the cooper wire windings with a spiral trajectory. In such a manner, temporally and spatially stable discharge, separated from the walls, was obtained. Also the discharge wall etching and consequence memory effects are decreased and tube lifetime was prolonged. The wet and dry gases are obtained by system, which is similar to the one described by Veillon *et all* (1968). It consists of right angle pneumatic nebulizer, spray chamber in case of wet gases and additional evaporating chamber and modified Liebig-Graham condenser for obtaining dry gases. Other experimental conditions are presented in Table 2.

Table 2. Experimental conditions

	Sample gas	Support gas	Gas condition
1	Ar + H ₂ O	Ar	wet
2	(Ar + 1.6% H ₂) + H ₂ O	Ar	wet
3	(Ar + 1.3% H ₂) + H ₂ O	Ar + 1.3% H ₂	wet
4	Ar + 1.6% H ₂	Ar + 1.6% H ₂	pure
5	Ar + 2.9% H ₂	Ar	pure
6	(Ar + 1.6% H ₂) + H ₂ O	Ar	dry
7	(Ar + 1.6% H ₂) + H ₂ O	Ar + 1.6% H ₂	dry

For all presented side-on experiments, sample and support gas flow 20 ml/min and 200 ml/min respectively and forward microwave power of 80W are used. The two-axis movement of MIP for obtaining spatial distributions of various spectral lines shapes was enabled by the means of PC controlled x-y table.

3. RESULTS

The results of the electron number density obtained from spatial distribution of atomic hydrogen line H_β are presented. For the separation of contribution for different plasma layers and for obtaining the true radial plasma intensity distribution we used Abel inversion procedure as developed by Djurović *et all* (1996). Electron number density is determined from combinations of the approximate formulas i.e. application of Kelleher's (1981) formula for determination of Stark half-half widths and Wiese's (Wiese *et all*, 1972) dependence for Ne = f(W_s):

$$W_s = (W_m^{1.4} - W_{D,i}^{1.4})^{1/1.4} \quad W_{D,i} = (W_D^2 + W_i^2)^{0.5} \quad W_D = 3.58 * 10^{-7} \lambda (T_g / M)^{0.5}$$

where W_s - Stark halfwidths, W_D - Doppler halfwidths and W_i - instrumental halfwidths

$$Ne \text{ (cm}^{-3}\text{)} = 10^{16} * (W_s / 4.74)^{1.49}$$

Typical obtained electron density spatial distribution is presented in Figure 1.

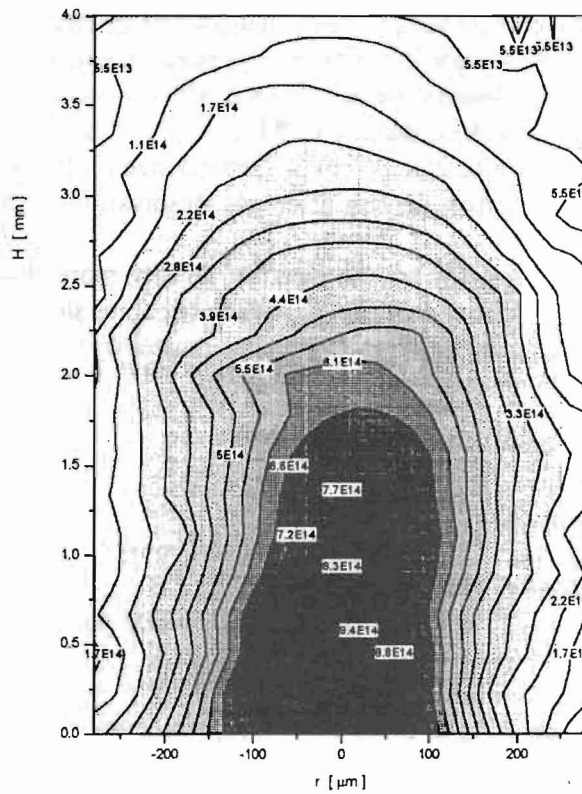


Figure 1. Electron density spatial distribution in case 1 (see Table 2.)

Electron density dependence on height in the middle of the discharge ($x=0$) in different cases is presented in Figure 2.

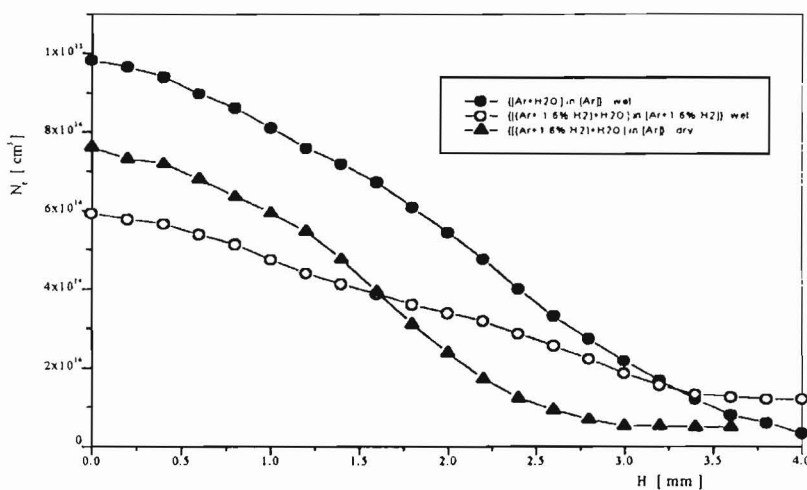


Figure 2. Electron density dependances on height in different cases

4. CONCLUSION

From performed measurements we conclude that maximum electron density ($1 \times 10^{15} \text{ cm}^{-3}$) is obtained in wet Ar + H₂O sample gas with Ar as a support gas. If a 1.6% H₂ is added to sample gas, changes in electron density distribution are within experimental errors. Drying of sample gas lowers maximum electron density ($0.8 \times 10^{15} \text{ cm}^{-3}$), that becomes closer to the values obtained in pure gas mixture ($0.25 \times 10^{15} \text{ cm}^{-3}$). Dependence on height in all four cases is preserved. Lowering of the electron density after gas desolvation is observed by other authors (Pak et. all, 1994) too.

Adding of H₂ to support gas lowers the electron density more than desolvation (to $0.6 \times 10^{15} \text{ cm}^{-3}$), but also exchange spatial dependence, which becomes slower and broader (see Fig.2). This effect may be explained by large thermal conductivity of hydrogen plasma at elevated temperatures, caused by dissociation of molecules.

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