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RADIO-FREQUENCY ONE-ELECTRODE SOURCE OF PLASMA WITH AUTOMODULATION FOR GAS ANALYSIS

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INTRODUCTION

At present the spectrum exciting source (SES) of radiation caused by inductively-coupled plasma (ICP) is widely used to analyse the element composition of gas mixtures, liquids, and solids [1,2]. This source has a set of undoubted advantages in comparison with the arc, spark and laser SES. However, there is one large demerit: it is necessary to use a very complicated radio-frequency (RF) generator at high power (of the order of several kilowatts). Accordingly, it has a big size and costs very much. Due to these reasons it has limited possibilities for utilisation in applied physics and industry.

The SES on the basis of one-electrode flare discharge is relatively wide known [3]. But it also works with high RF-power and high voltage (~ 6 kV). The modulation of the discharge current is created by a special generator. This work offers to use a new type of one-electrode RF-discharge with automodulation (RFDA) [4] for emission spectroscopy of gas mixtures.

EXPERIMENTAL PROCEDURE AND RESULTS

The principal scheme of RFDA-generator is presented in fig.1. This generator creates RFDA with self-exciting. The discharge generation is produced by itself when the high voltage is switched to the anode of RF-lamp. The amplitude modulation of the discharge current is produced by passive circuits of the autogenerator but not by the active modulator. The frequency modulation is produced by the cathode-grid RC-sercets. The parameters of the generator are: RF-power — 100 W, high voltage — 3 kV, sizes — 20x25x20 cm.

The discharge formation is produced under stationary conditions in air or noble gases and in the flow of these gases. The discharge photo in air is presented in fig.2. It is necessary to note that the discharge is focused in Ar to the size of 0.1 mm in diameter and it stretches in the longitudinal direction to the size of 50 mm.

The gas is given into the discharge through the quartz tube with diameter 4 mm (Fig.3). This tube is placed on the stainless steel electrode with diameter 3 mm and a sharp end. The discharge is formed in the stainless steel chamber to protect the registering apparatus against RF-power.

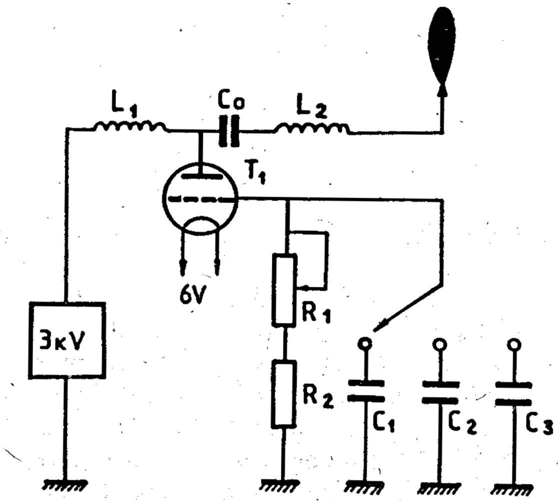


Fig.1. The principle scheme of RFDA-generator, where: T_1, the RF-lamp; L_i, the limiting inductances; R_i, C_i, the grid resistances and capacitances; C_0, the decoupling capacitance

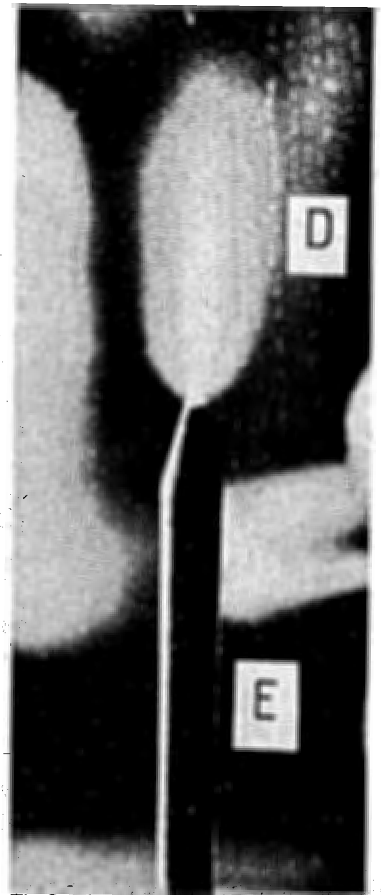


Fig.2. The photo of RFDA in air where: *E*, electrode with diameter 3 mm; *D*, discharge

The optic radiation is focused by quartz lens with focus length $f = 112$ mm on the entrance slit of the diffraction monochromator with the wave length range $\Delta\lambda = 200$—2000 nm and dispersion factor 2—8 nm/mm. The registration of the radiation was carried out by photomultiplier PEM-100 in wave length range of 200—860 nm. The photosignal was registered by the graphic recording voltmeter with relaxation time 20 ms or oscilloscope. The photosignal and RF-signal are shown in fig.4. The impulse repetition frequency ν_i was changed from 1 hz to 30 khz and the impulse duration τ_i was changed from 6 μs to 100 μs. The spectra of Ar and air radiation are presented ($\nu_i = 10$ kHz, $\tau_i = 10\,\mu$s) in figs.5 (a,b,c) and 6. The volume flow rate of the gas is 0,2 l/min. The Ar spectrum of RFDA is analogous to the Ar spectrum ICP. There are the vibration-rotational zones of the molecular nitrogen N_2 and oxygen O_2 in the air spectrum. There are also the lines of

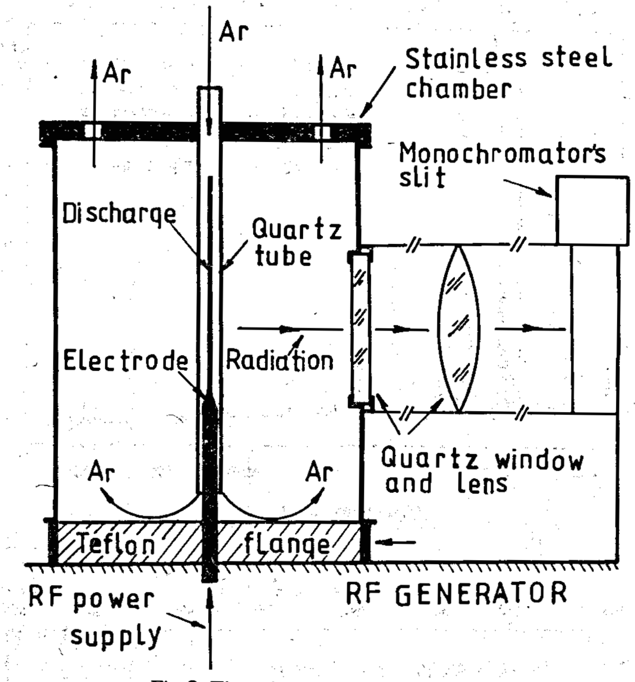


Fig.3. The scheme of RFDA formation

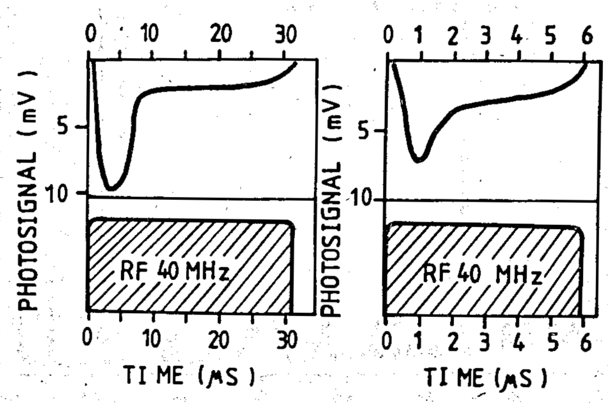
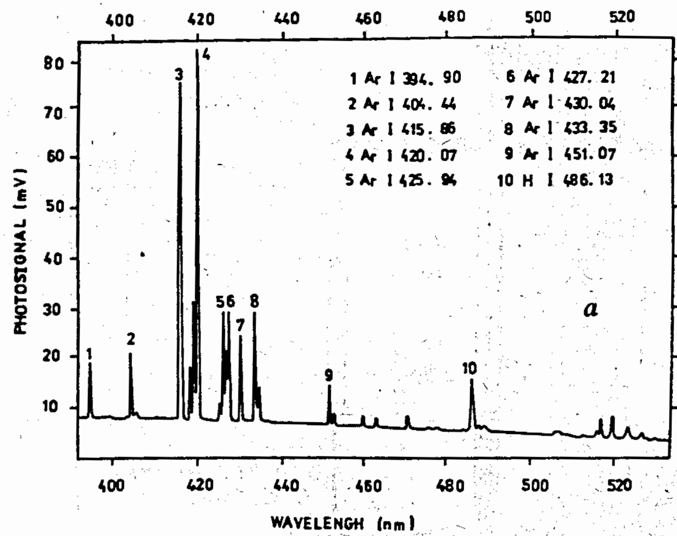
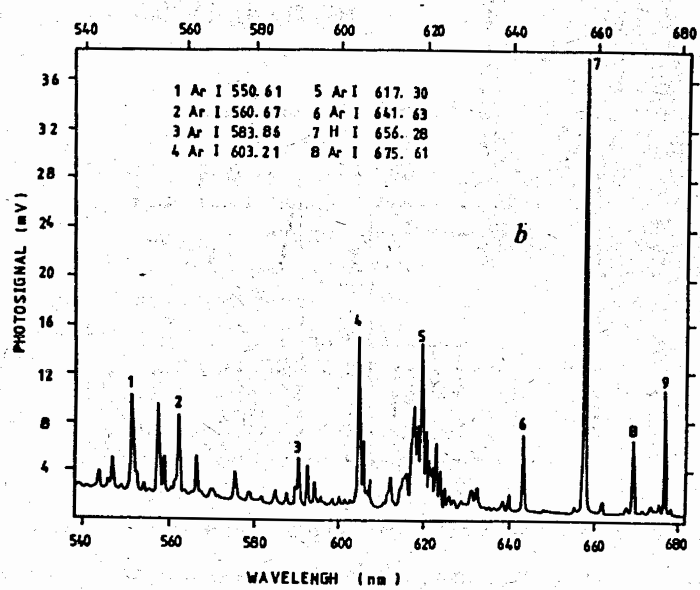


Fig.4. The phortosignal and RF-signal from RFDA

atomic oxygen O and hydrogen H in the air spectrum appearing from dissociation of molecular O_2 and H_2O. It is necessary to stress that there are no lines of the electrode material in the spectrum and the stability of the photosignal is not worse than 2%.





- Measuring of the main plasma parameters: the time average electron temperature T_e and the time average electron density n_e of RFDA, has been made in the experiments. The T_e has been determined by measuring of the ratio

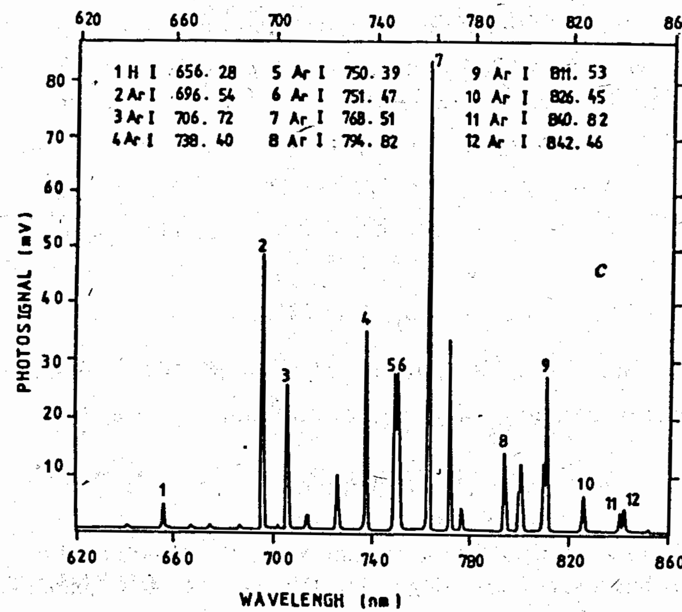


Fig.5 (a,b,c). The blank emission spectrum of an Ar RFDA showing the principle features of the Ar-spectrum. Numbers locate Ar marker wavelengths

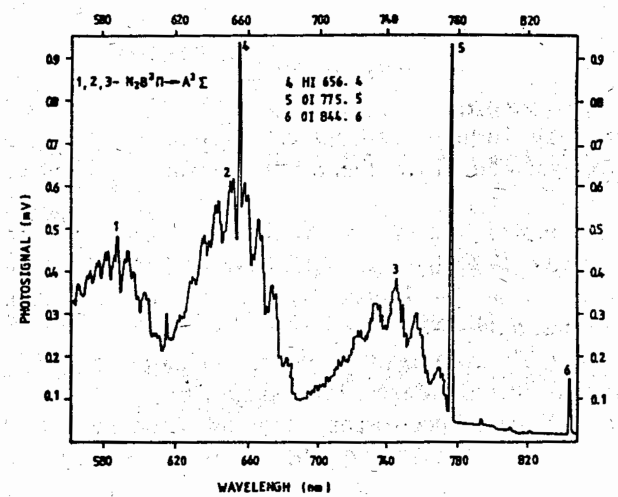


Fig.6. The blank emission spectrum of an air RFDA showing the principle features of the air spectrum. Numbers locate N_2, H, O marker wavelengths

intensities of helium (He) and H lines [5]. In the experiments the T_e maximum has been obtained equal to 0.7 eV when the gas flow rate is $V = 0.2$ l/min. When the gas flow rate increases to value $V = 0.6$ l/min the T_e reduces to value $T_e = 0.4$ eV. T_e is independent of the impulse repetition frequency and impulse duration of RF impulse power. The accuracy of the T_e measuring is equal to 30%. The electron density n_e has been obtained from the line width of hydrogen H_β [6]:

$$n_e = C(n_e, T_e) \cdot \Delta \lambda_s^{3/2},$$

where $\Delta \lambda_s$ is Stark width of line and $C(n_e, T)$ is coefficient, weakly dependent on n_e. It was measured that $n_e = (1.7 \pm 0.2) \cdot 10^{15}$ cm^{-3}.

CONCLUSIONS

The spectrum-analytical characteristics of the RFDA are analogous to the ICP sources. It has a set of advantages: low RF-power (100 W), small size and simple construction of the generator, small size and simple construction of the generator, small flow rate of Ar (0.2 l/min).

It is necessary to mention that discharge generation mechanism has not been found out yet. Special investigations will be devoted to studying this mechanism.

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