SPECTROSCOPY OF ELECTRIC DISCHARGE PLASMA IN METAL VAPOURS

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The radial profiles of the temperature and electron density in the plasma of the electric arc between composition electrodes based on cooper (Cu-Mo, Cu-W) are studied by optical spectroscopy techniques. The electron density and the temperature in plasma as initial parameters were used in the calculation of the plasma composition in local thermodynamical equilibrium (LTE) assumption. We used the Saha's equation for copper, nitrogen, oxygen and W (or Mo) atoms, dissociation equation for nitrogen and oxygen atoms, the equation of plasma electrical neutrality and Dalton's law as well. So, it would be possible to determine the amounts of metal vapours in plasma.
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INTRODUCTION

As well known, parameters of electric arc plasma which appear between contacts surfaces of switching devices depend on the electrodes materials. The copper based composition materials (for example, Cu-W and Cu-Mo) are often used in the electrical engineering as electrode materials.

In our previous investigations of free burning in air electric arc between consumable electrodes we determined the electron density and the temperature in plasma by the optical spectroscopy [1, 2]. In a case of LTE the plasma composition can be calculated. So, obtained in such manner plasma parameters can be used for developing of the physical model of this multicomponent plasma source.

1. EXPERIMENTAL SETUP

The experimental setup was described in our previous paper [1]. The electric arc is ignited between two non-cooled electrodes E1, E2 (see Fig.1). No stabilization of arc column is used. The discharge column is focused on entrance split of the monochromator MDR-12 by the lens O. The image of the arc was rotated on 90є by Dovet prism to realize the measurements of radial profiles of spectral intensities. The CCD linear image sensor SONY ILX526A provided a registration of spectral lines on exit split of monochromator. The ISA slot of IBM PC in control and data transferring was used.

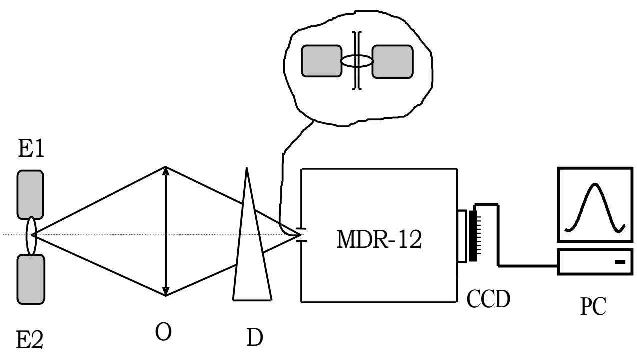


Fig.1

In such manner experimental setup allows to determine the radial distribution of radiation from any cross section of plasma object on specific spectral line. The hardware and software was especially designed for laboratory and industry plasma research.

The investigation was carried out at the arc current 30A and discharge gaps l_{ak} = 2, 4, 6 and 8 mm between Cu, Cu-W, Cu-Mo and Cu-Mo-LaB_6 electrodes. In discharge gap of 8 mm the measurements were performed for the various distances from cathode (FC): 1 mm, 2 mm, 4 mm (center), 6 mm and 7 mm. The temperature radial profiles were calculated from relative intensities of two CuI spectral lines 521.8 and 510.5 nm.

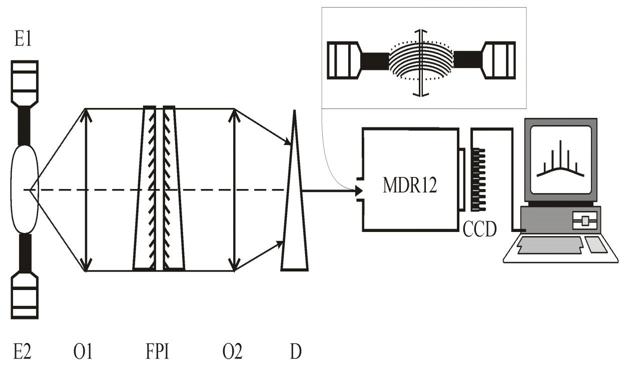


Fig.2

In a combination with a Fabry-Perot interferometer the spectrometer provides simultaneous registration of spatial and spectral distribution of radiation intensities (see Fig.2)[2].

Thus, the spectrometer allows measuring contours of spectral lines in different spatial points of plasma volume.

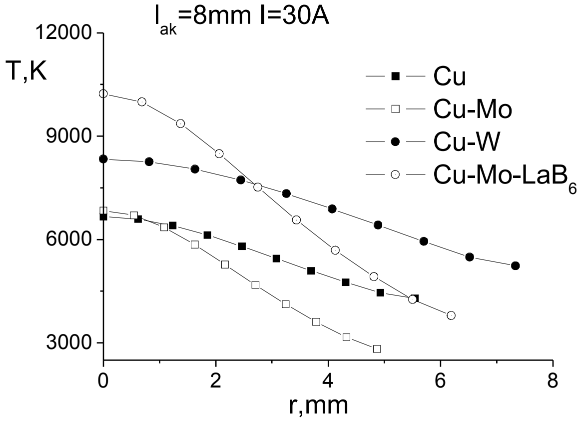
As the plasma source is not uniform there is a problem to obtain the local values of plasma parameters in a discharge (electron density in our case of dominating Stark broadening of spectral line CuI 515.3 nm) using this interferogramm.

In a previous paper the method based on the simulation of such experiment was suggested [2].

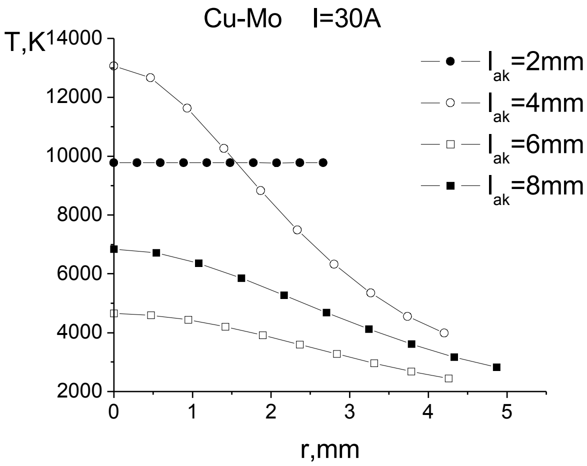
2. RESULTS AND DISCUSSIONS

2.1 RADIAL DISTRIBUTIONS OF THE TEMPERATURE AND ELECTRON DENSITY IN THE PLASMA OF THE ELECTRIC ARC

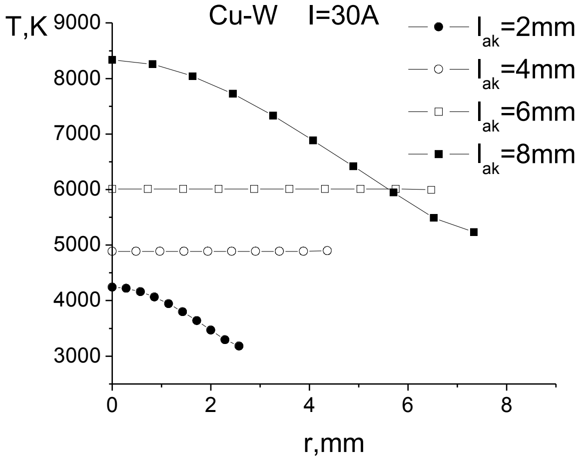
In Fig. 3 the obtained radial distributions of the temperature (a, b, c, d, e) and electron density (f) in plasma of electric arc discharge between cooper and composition electrodes on the cooper base are shown.



a



b



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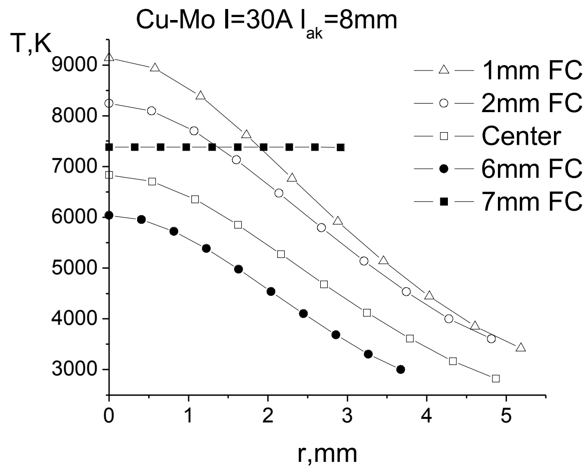
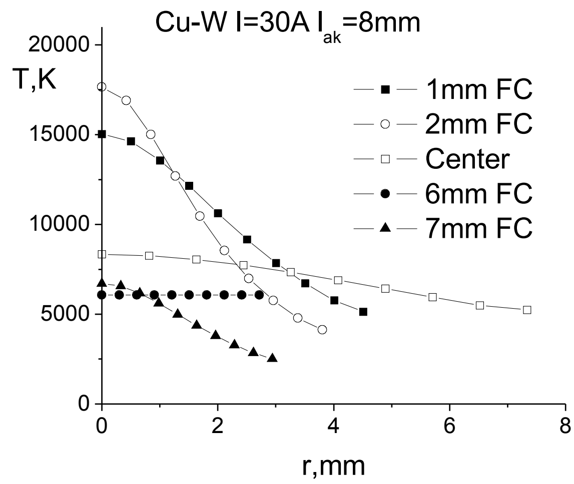
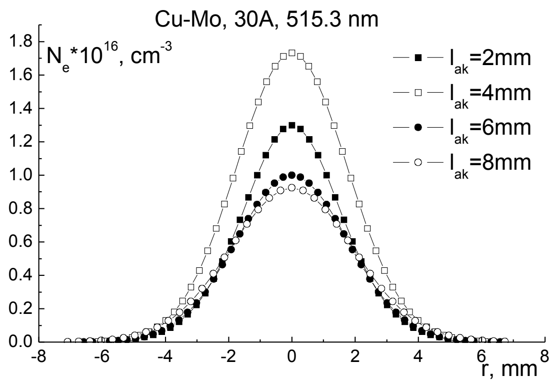


d



e



f

Fig.3

2.2 PLASMA COMPOSITION OF THE ELECTRIC ARC DISCHARGE BETWEEN Cu-W, Cu-Mo ELECTRODES IN AIR

The obtained electron density and the temperature in plasma as initial parameters were used in the calculation of the plasma composition in LTE assumption. We used the Saha's equation for copper, nitrogen, oxygen and metal Me (W or Mo) atoms, dissociation equation for nitrogen and oxygen atoms, the equation of plasma electrical neutrality and Dalton's law as well.

$$n_{N+} + n_{NO+} + n_{O+} + n_{Cu+} + n_{Me+} = n_e \quad (1)$$

$$2\mathrm{n}_e + n_{Cu} + n_{Me} + n_N + n_O + n_{NO} + n_{N_2} + n_{O_2} = \frac{P}{KT} \quad (2)$$

$$n_{N_2} + n_N + n_{N+} + n_{NO} + n_{NO+} = = 3\ .72\left(n_{O_2} + n_O + n_{O+} + n_{NO} + n_{NO+}\right) \quad (3)$$

$$\frac{n_e \cdot n_{NO+}}{n_{NO}} = S_{NO+}(T) \quad (4)$$

$$\frac{n_e \cdot n_{N+}}{n_N} = S_{N+}(T) \quad (5)$$

$$\frac{n_e \cdot n_{O+}}{n_O} = S_{O+}(T) \quad (6)$$

$$\frac{n_e \cdot n_{Cu+}}{n_{Cu}} = S_{Cu+}(T) \quad (7)$$

$$\frac{n_e \cdot n_{Me+}}{n_{Me}} = S_{Me+}(T) \quad (8)$$

$$\frac{n_O \cdot n_N}{n_{NO}} = K_{NO}(T) \quad (9)$$

$$\frac{n_{O^2}}{n_{O_2}} = K_{O_2}(T) \quad (10)$$

$$\frac{n_{N^2}}{n_{N_2}} = K_{N_2}(T) \quad (11)$$

So, it would be possible to determine the amounts of metal vapours in plasma.

CONCLUSIONS

The investigations of temperature and electron density radial distributions in plasma of arc discharge between composition electrodes are carried out. The technique of the determining of amounts of metal vapours in plasma is suggested.

REFERENCES

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СПЕКТРОСКОПИЯ ЭЛЕКТРОРАЗРЯДНОЙ ПЛАЗМЫ В ПАРАХ МЕТАЛЛОВ

А.Н. Веклич, В.Е. Осидач

Методами оптической спектроскопии получены радиальные профили температуры и электронной концентрации в плазме электрической дуги между композиционными электродами на основе меди (Cu-Mo, Cu-W). В предположении наличия локального термодинамического равновесия для расчета равновесного состава плазмы в качестве базовых параметров использованы электронная концентрация и температура плазмы. Решалась система, состоящая из уравнений Саха для атомов меди, азота, кислорода и вольфрама (или молибдена), уравнений диссоциации для молекул азота и кислорода, уравнения электронейтральности и уравнения, описывающего закон Дальтона. Реализованная таким образом методика позволит определить содержание паров металлов в плазме.

СПЕКТРОСКОПІЯ ЕЛЕКТРОРОЗРЯДНОЇ ПЛАЗМИ У ПАРАХ МЕТАЛІВ

А.М. Веклич, В.Е. Осідач

Методами оптичної спектроскопії визначені радіальні профілі температури та електронної концентрації в плазмі електричної дуги між композиційними електродами на основі міді (Cu-Mo, Cu-W). У припущенні наявності локальної термодинамічної рівноваги для обчислення рівноважного складу плазми в якості базових параметрів використані електронна концентрація та температура плазми. Розв'язувалась система, що складається з рівнянь Саха для атомів міді, азоту, кисню та вольфраму (або молібдену), рівнянь дисоціації для молекул азоту та кисню, рівняння електронейтральності і рівняння, що описує закон Дальтона. Реалізована таким чином методика дозволить визначити вміст парів металів у плазмі.