THE ELECTRIC ARC PLASMA TEMPERATURE: THE ROLE OF THE SECONDARY STRUCTURE OF THE COMPOSITION ELECTRODE'S WORKING LAYER

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The radial profiles of the plasma temperature of the electric arc between electrodes from composition materials on the base of cooper (Cu, Cu-Mo, Cu-Mo-LaB_6) and silver (Ag-Ni, Ag-CdO) are studied by optical spectroscopy techniques. The occurrence of the secondary structure in electrodes' working layers under effect of the electric discharge was found by metallography technique. The influence of the investigated electrode composition and its secondary structure nature on the plasma axial temperature and its radial distribution is shown.
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INTRODUCTION

A problem of developing of reliable interrupting devices, where ignition of electric arc often is realized, can not be resolved without careful analysis of processes which take place in the arc and its electrodes. Furthermore, an electric arc, being generated at contact disconnection, results in considerable material erosion of contacts. This causes the decrease of device efficiency and limits reliability of its activity.

The composition materials on the copper base Cu-BN, Cu-Cr_2O_5-B, Cu-W (Mo) as electrode materials are used in the technology of the dimensional electro-erosion treatment of the mechanically intractable substances (hard alloys, alloys on the titanium base, tool steels etc.). It was found the efficiency of the electro-erosion treatment essentially increases if we use the boron-containing compound as the addition to the Cu-W (Mo) composition.

Composition materials Ag-CdO with 5-20 % (mass) of oxide contents more often of other systems Ag-MeO (Sn, Zr, Cu) are used for electrical contacts of low-voltage switchgear. These contacts are characterized by small wearing and high stability against welding together.

1. EXPERIMENTAL TECHNIQUE

The arc was ignited between the end surfaces of the non-cooled electrodes. The discharge gap l_{ak} was of 2, 4, 6 or 8 mm. The diameter of the rod electrodes was of 6 mm. To avoid the metal droplet appearing a pulsing mode was used: the current pulse up to 30 A was put on the "duty" weak-current (3.5 A) discharge. The pulse duration ranged up to 30 ms. A quasi-steady mode was investigated.

Because of the discharge spatial and temporal instability the method of the single tomographic recording of the spectral line emission was used. A CCD linear image sensor accomplished fast scanning of spatial distributions of radiation intensity. It allows the recording of the radial distributions of unsteady-state arc radiation intensity in arbitrary spatial sections simultaneously. The synchronization of operation of the CCD linear image sensor with the external electrical circuit is stipulated. The ISA interface slot of IBM PC in a control and data exchange is used. The hardware and software was especially designed for laboratory and industry plasma investigations.

2. RESULTS AND DISCUSSIONS

2.1 PLASMA OF THE ELECTRIC ARC BETWEEN COMPOSITION ELECTRODES ON THE COPPER BASE

In the plasma investigation of the electric arc between composition electrodes on the copper base the temperature profiles are obtained from relative intensities of copper spectral lines 510.5 and 521.8 nm. Because of the discharge spatial and temporal instability the statistical treatment of obtained data was carried out. The spectral sensitivity of the experimental set-up was taken into account.

The radial profiles of temperature are determined in the average cross section of the discharge gap l_{ak} = 2, 4, 6 and 8 mm in air at arc currents 30 A.

As recently was found some secondary structure on a surface of composition electrodes can be realized during the discharge operation [1]. Therefore we studied our plasma in a two different modes.

As an example in Fig.1 radial temperature profiles of the arc between Cu-Mo-LaB_6 electrodes in a two different modes are shown. Curve 1 corresponds to the case of the arc operation between smoothed surfaces of electrodes. The next curve 2 corresponds to the case of electrode surfaces with a secondary structure.

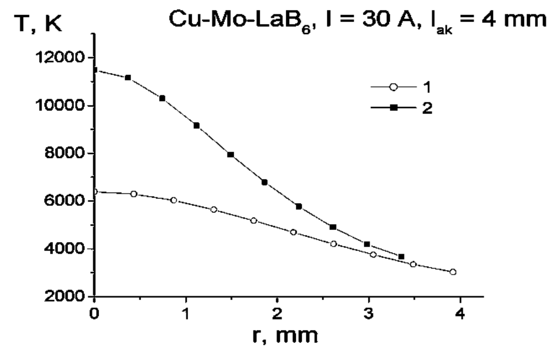


Fig.1

From the comparison of these curves the key role of the condition of the surface electrode follows. Really the presence of the secondary structure must decrease the erosion of the electrode material. As a result the amount of lightly ionized metal vapor in a discharge gap must be decreased. Therefore at the same arc currents the temperature in plasma column must be higher in case of secondary structure on a surface of electrodes.

2.2. PLASMA OF THE ELECTRIC ARC BETWEEN COMPOSITION ELECTRODES ON THE SILVER BASE

We also measured the radial profiles of temperature in plasma of the arc between Ag, Ag-CdO or Ag-Ni electrodes.

There are irreversible structural changes in a working layer of contacts from composition materials Ag-CdO during a current commutation. Naturally it determines the parameters of arc plasma in a discharge gap.

The structural changes in a working layer were studied metallographicly. A surface of a working layer and its perpendicular section were investigated.

It was found, that under effect of electric discharge the relief of a surface changes first of all because of melting away of a contact material. The cracks initiation is observed in a working layer on cooling caused by the arc extinction. Some of cracks on the surface «are healed» by a melt on the basis of silver. There is upbuilding of these defects observed metallographicly in a volume of a contacts working layer as the switching cycles number increases. The temperature increasing of a working layer results in a segregation of a composition. The oxide of cadmium is stored in a near-surface layer in defects and in crack edges (see Fig. 2). At segregation, apparently, there is dissociation oxide of cadmium. It is known that the dissociation temperature of oxide is lowered with a decreasing of the contents of oxygen in a material.

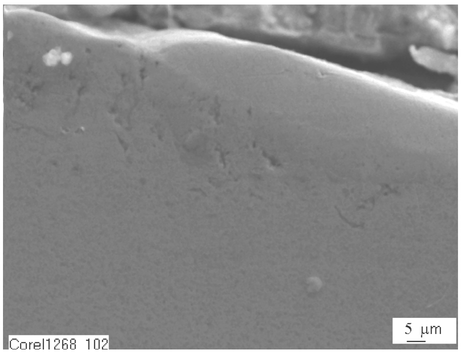
The structure change of a working layer can exert influence on the mass transfer in an arc discharge gap. The decrease of electrical and thermal conductivity of areas enriched by oxide and fixation of an arc discharge on these parts of surface can promote an overheating of areas of a material enriched by silver and their ejection into a discharge gap. This mechanism of erosion can promote a decrease of temperature of an arc discharge caused by the intensive silver ejection. In this case the electrical erosion of contacts accompanied also by dissociation oxide of cadmium is increased. The probability of welding together of contacts is increased too. These results do not contradict results obtained by the authors of paper [2].

In case of electrodes from Ag-Ni composite materials another kind of secondary structure on a surface is observed. The vaporization of a phase on the basis of more fusible silver is occurred under thermal effect of electric discharge. The fragments of high-melting component are sintered. So, the rough surface is realized. The melt on the basis of silver with a dissolved nickel and impurity spreads on this surface. Vaporization of silver and the sintering high-melting component result in relative increase of a nickel in a working layer [3].

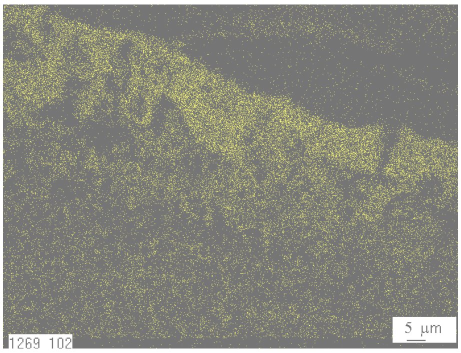
It is possible to suppose from distinctions in secondary structures of working layers of the composite materials Ag-Ni and Ag-CdO that the plasma temperatures of electric arcs, burning between such electrodes, will differ.

There is not enough information about spectroscopy constants of silver in literature. Therefore in diagnostics of plasma of electric arc between composite electrodes on the base of silver we had mainly to use spectral lines of impurity. As to the investigation of plasma of discharge between silver electrodes we nevertheless had to use the spectral lines of AgI. So, we for the first time developed the spectroscopy techniques in such investigation.

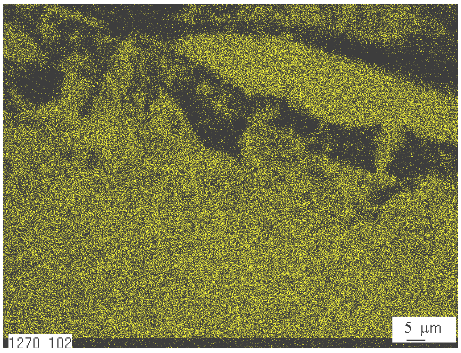
The radial profiles of temperature are determined in the average cross section of the discharge gap l_{ak} = 2, 4, 6 and 8 mm in air at arc currents 3.5 A.



REM (second. electrodes)



RX Cd Kα



RX Ag Rα

Fig.2

In plasma investigations of electric arc discharge between silver electrodes spectral lines AgI 520.9, 768.7, 827.3 nm were used. Spectroscopy constants were taken from Ref. [4]. As an example in Fig. 3 radial profiles of temperature measured from relative intensities of two pairs of silver spectral lines are shown. The discharge gap l_{ak} was 4 mm. The precision of measurements was not exceeding 10 %. The results of measurements obtained by different pairs of spectral lines practically are in close agreement.

In plasma temperature measurements of electric arc between Ag-CdO electrodes silver spectral lines as well as lines CdI 479.9, 508.5 and 643.8 nm were used. In Fig.4 the example of measured radial distributions of temperature is shown. The temperature profiles obtained by different pairs of spectral lines CdI were calculated. We used spectroscopy constants from Ref. [4] and from

Ref. [5] as well. Obviously spectroscopy constants from Ref. [4] are unsuitable in plasma diagnostics. The temperatures obtained by spectral lines AgI and CdI using spectroscopy constants from Ref. [5] agree with plasma temperature of arc between silver electrodes. It is an expected result based on the analysis of the secondary structure on a surface of Ag-CdO electrodes (see above).

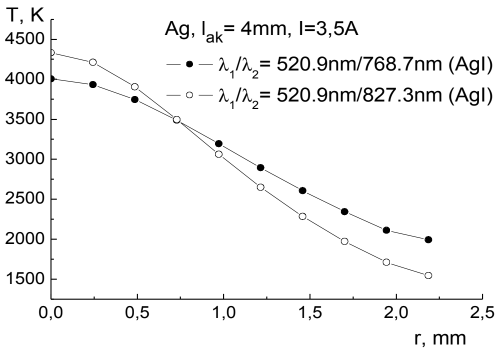


Fig.3

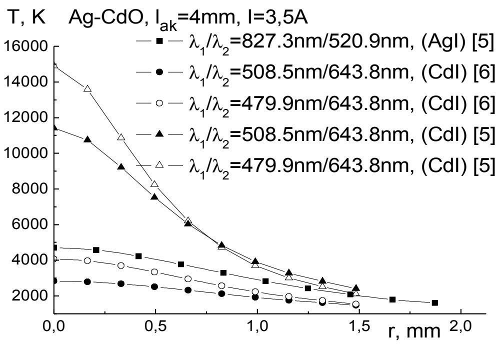


Fig.4

In temperature measurements of plasma electric arc between Ag-Ni electrodes silver spectral lines as well as lines NiI 547.7, 512.9 and 513.7 nm were used. Spectroscopy constants were taken from Ref. [4]. In Fig.5 the example of measured radial distributions of temperature is shown. As is easy to see from Fig. 3 – Fig. 5 the temperatures obtained by silver spectral lines are less than the temperatures measured by nickel lines. In case of optically thin plasma for the used spectral lines it can be explained by the nonisothermal state of plasma or by the incorrectness of the spectroscopy constants. The additionally investigations must be carried out to determine the proper temperature.

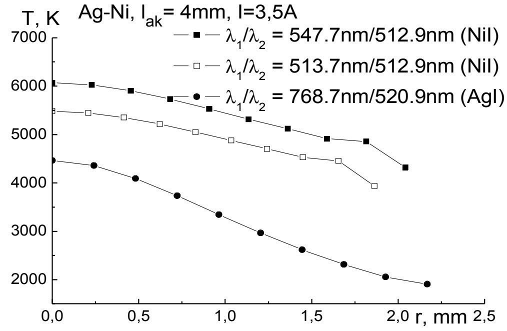


Fig.5

CONCLUSIONS

The investigations of temperature radial distributions in plasma of arc discharge between composition electrodes are carried out. The secondary structure on a surface of electrodes from composition materials on copper or silver base is realized during the arc discharge operation. The influence of such secondary structure on the arc plasma temperature was found.

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ТЕМПЕРАТУРА ПЛАЗМЫ ЭЛЕКТРИЧЕСКОЙ ДУГИ: ВЛИЯНИЕ ВТОРИЧНОЙ СТРУКТУРЫ РАБОЧЕГО СЛОЯ КОМПОЗИЦИОННЫХ ЭЛЕКТРОДОВ

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Методами оптической спектроскопии исследованы радиальные профили температуры плазмы электрической дуги между электродами из композиционных материалов на основе меди (Cu, Cu-Mo, Cu-Mo-LaB_6) и серебра (Ag-Ni, Ag-CdO). Металлографическими методами установлено возникновение вторичной структуры в рабочем слое электродов под влиянием электрического разряда. Показано влияние состава исследуемых электродов и природы их вторичной структуры на температуру плазмы на оси разряда и ее радиальное распределение.

ТЕМПЕРАТУРА ПЛАЗМИ ЕЛЕКТРИЧНОЇ ДУГИ: ВПЛИВ ВТОРИННОЇ СТРУКТУРИ РОБОЧОГО ШАРУ КОМПОЗИЦІЙНИХ ЕЛЕКТРОДІВ

І.Л. Бабіч, А.М. Веклич, Л.О. Крячко, Р.В. Мінакова, В.Є. Осідач

Методами оптичної спектроскопії досліджені радіальні профілі температури плазми електричної дуги між електродами з композиційних матеріалів на основі міді (Cu, Cu-Mo, Cu-Mo-LaB_6) і срібла (Ag-Ni, Ag-CdO). Металографічними методами виявлене утворення вторинної структури у робочому шарі електродів під впливом

електричного розряду. Показаний вплив складу досліджуваних електродів і природи їх вторинної структури на температуру плазми на осі розряду та її радіальний розподіл.