PLASMA OF ARC DISCHARGE BETWEEN MELTING Cu- AND Ni-ELECTRODES

***A.N. Veklich*[1]*, M.M. Kleshich*[1]*, S.O. Fesenko*[1]*, V.F. Boretskij*[1]*, L.A. Kryachko*[2]**

[1]*Taras Shevchenko National University of Kyiv, Kyiv, Ukraine;*
[2]*Institute for Problems in Materials Science NASU, Kyiv, Ukraine*

E-mail: van@univ.kiev.ua*; *m.kleshych-frecs@ukr.net

The intensity of erosion processes of asymmetric single-component Cu and Ni electrodes of the free burning electric arc at current of 30 A is studied by measurements of a content metals vapour in plasma column. Optical emission spectroscopy was used to determine the radial distributions of plasma temperature and electron density in the middle section of a discharge gap. These experimentally obtained data were used in the calculation of equilibrium plasma composition. So, the evaporation intensity of each electrode material can be estimated in such indirect way.

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INTRODUCTION

The arc discharge occurs during switching of electrical devices [1]. As the result, the surface of the contacts can be damaged and the operating time of the contact pairs will be reduced. Low level of erosion resistance causes rapid wear of the contacts. This problem can be solved by optimizing of the contacts material composition in a manufacturing technology [2]. The study of physical processes in arc discharge plasma will allow better understanding of the mechanism and behavior of erosion processes on the contact surface during of an arc discharge. Furthermore, the overvoltage in power systems can lead to an emergency shutdown of their elements. A breakdown of insulation and damage to the surface of conductors arise during ignition of an arc discharge [3]. Hence, the power supply system fails and needs immediate repair. The use of new electrical materials will increase the lifetime of cables and improve their performance.

Sometimes, so-called asymmetric electrodes from different materials can be used in various practical applications. The behavior of each kind material in condition of arc discharge did not investigated yet nowadays. Previously authors tried to study the erosion intensity of asymmetric one-component Cu and Ni electrodes in free-burning electric arc at current of 3.5 A. The content of metal vapour in discharge plasma was determined by optical emission spectroscopy (OES) [4]. The main aim of this work is similar investigation in case of asymmetric copper and nickel electrodes in free-burning arc discharge at current of 30 A.

1. EXPERIMENTAL SETUP

The peculiarity of experimental set-up and OES is presented in details in paper [4]. Within the frame of this work, the electric discharge was realized at arc current of 30 A. To avoid the metal droplets appearing a pulsing mode was used: the current pulse up to 30 A was put on the "duty" weak-current discharge (3.5 A). The pulse duration was ranged up to 30 ms. The quasi-steady mode was investigated.

In this work, the polarity of vertically oriented upper and bottom electrodes of DC arc in different experiments can be able to reverse in the same manner as [4]. So, both materials, i.e. Cu and Ni were used as a cathode or an anode in upper and bottom position.

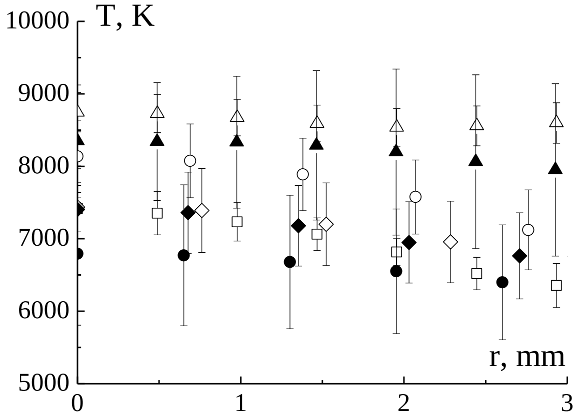

Fig. 1. Radial distributions of plasma temperature in arc discharge between one-component Cu&Ni electrodes at current 30 A, obtained with using Cu I (open symbol) and Ni I (filled symbol) spectral lines (Δ,▲,□ – Cu in upper position;○,●,♦,◊ – Ni in upper position; Δ,▲,♦,◊ – cathode in upper position; □, ○,● – cathode in bottom position)

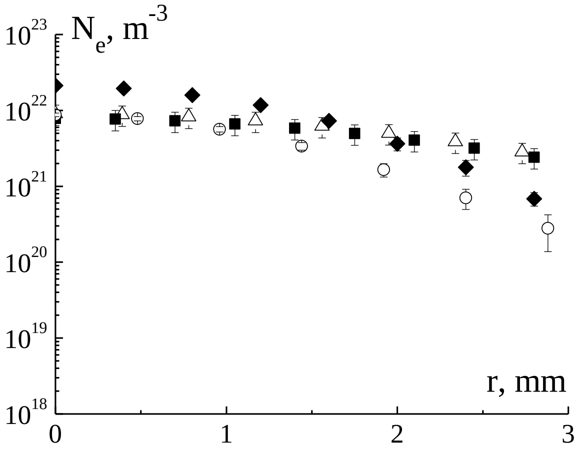

Fig. 2. Radial distributions of electron density in plasma of electric arc discharges between one-component Cu&Ni electrodes at current 30 A (Δ, and ■ – Cu in upper position; ○ and ♦ – Ni in upper position; open symbol – cathode in upper position; filled symbol – cathode in bottom position)

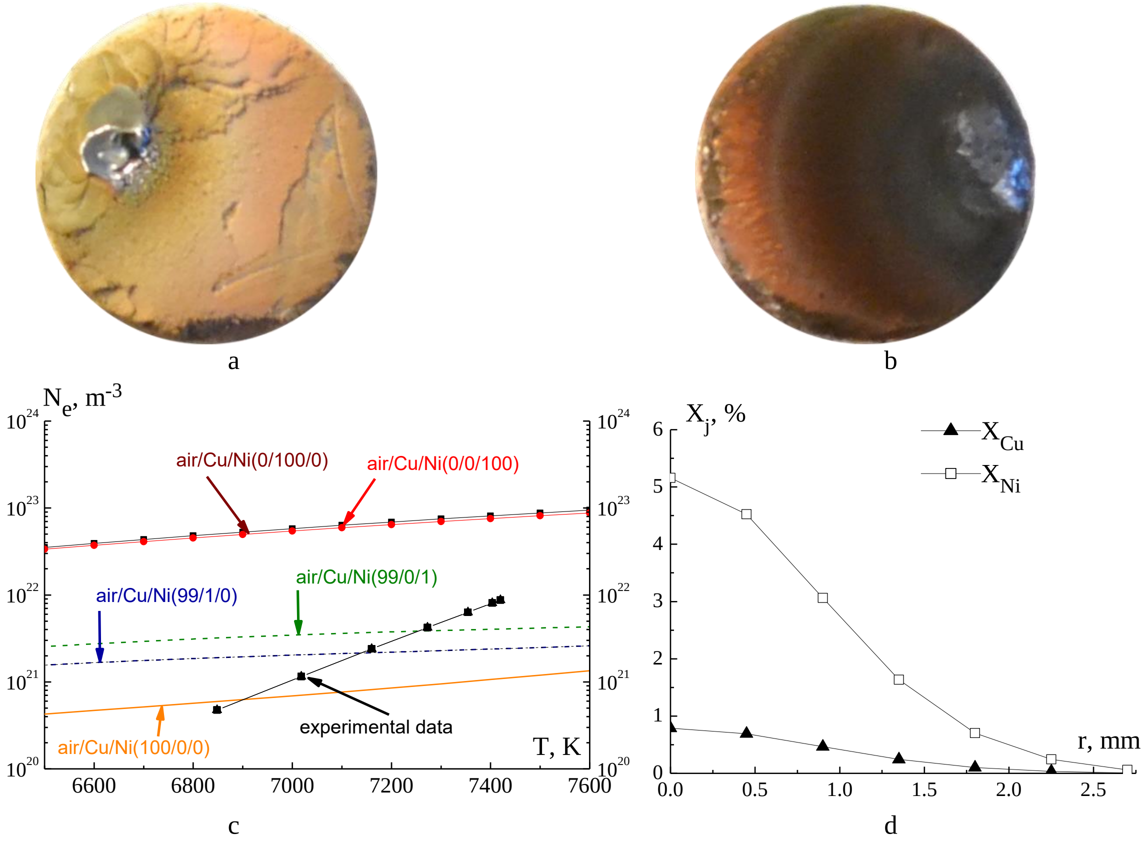

Fig. 3. Surface image of electrodes: a) Ni (cathode / upper position); b) Cu (anode / bottom position). The dependence of electron density from temperature; (c) and radial distributions; (d) of copper and nickel vapours contents in plasma of electric arc discharge at current 30 A

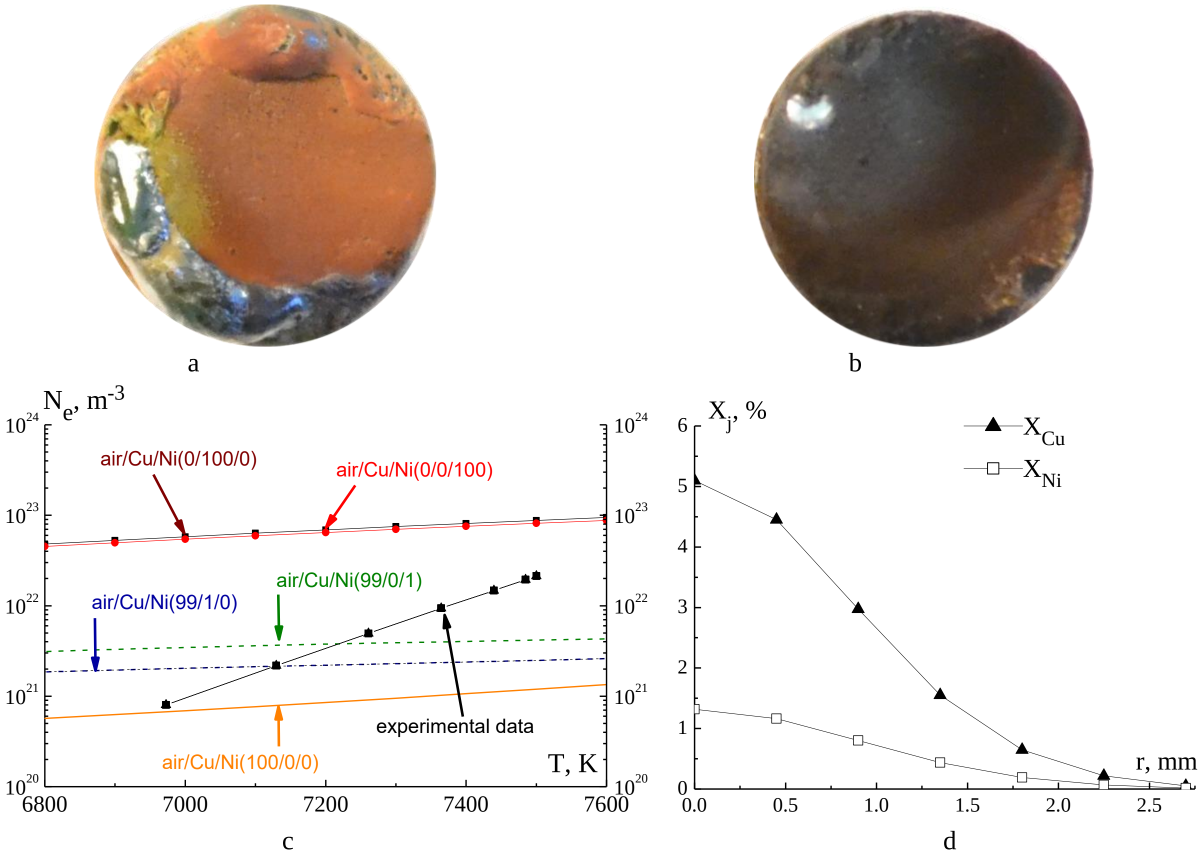

Fig. 4. Surface image of electrodes: a) Ni (anode / upper position); b) Cu (cathode / bottom position). The dependence of electron density from temperature; (c) and radial distributions; (d) of copper and nickel vapours contents in plasma of electric arc discharge at current 30 A

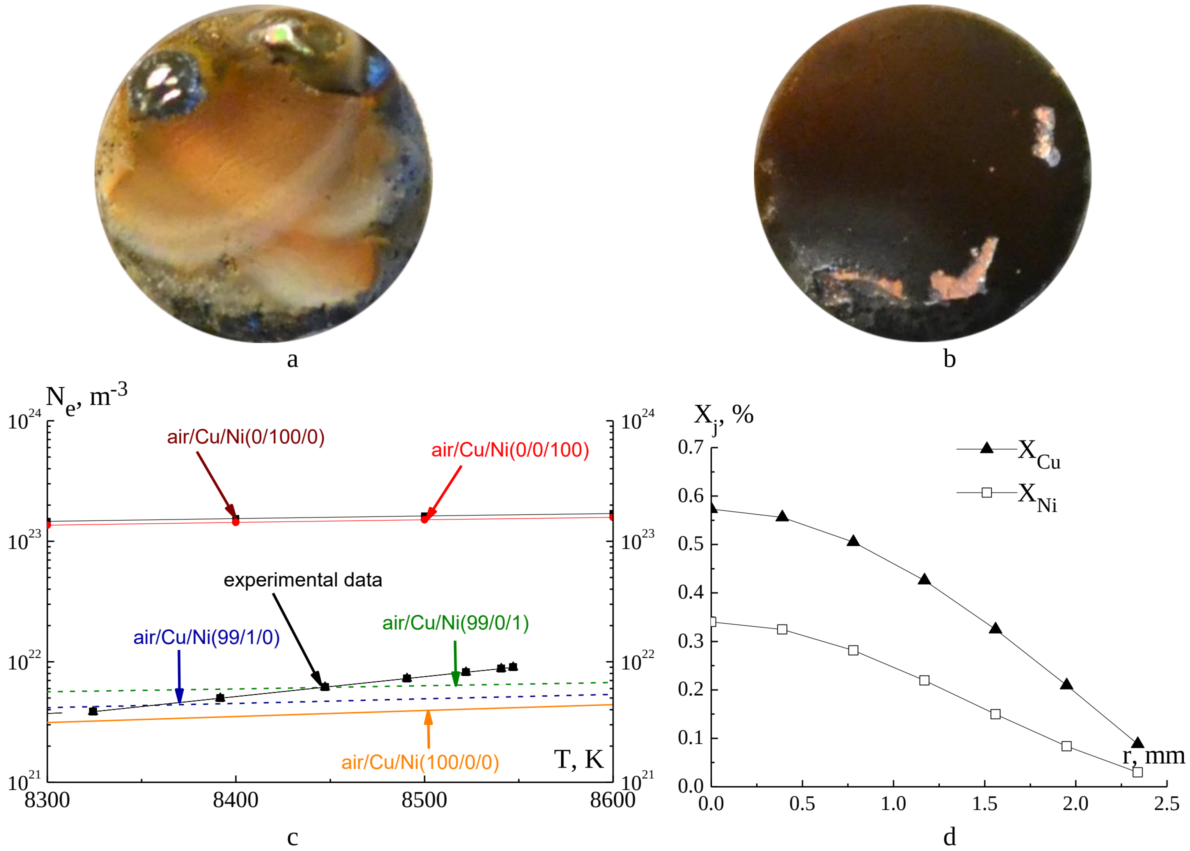

Fig. 5. Surface image of electrodes: a) Ni (anode / bottom position); b) Cu (cathode / upper position). The dependence of electron density from temperature; (c) and radial distributions; (d) of copper and nickel vapours contents in plasma of electric arc discharge at current 30 A

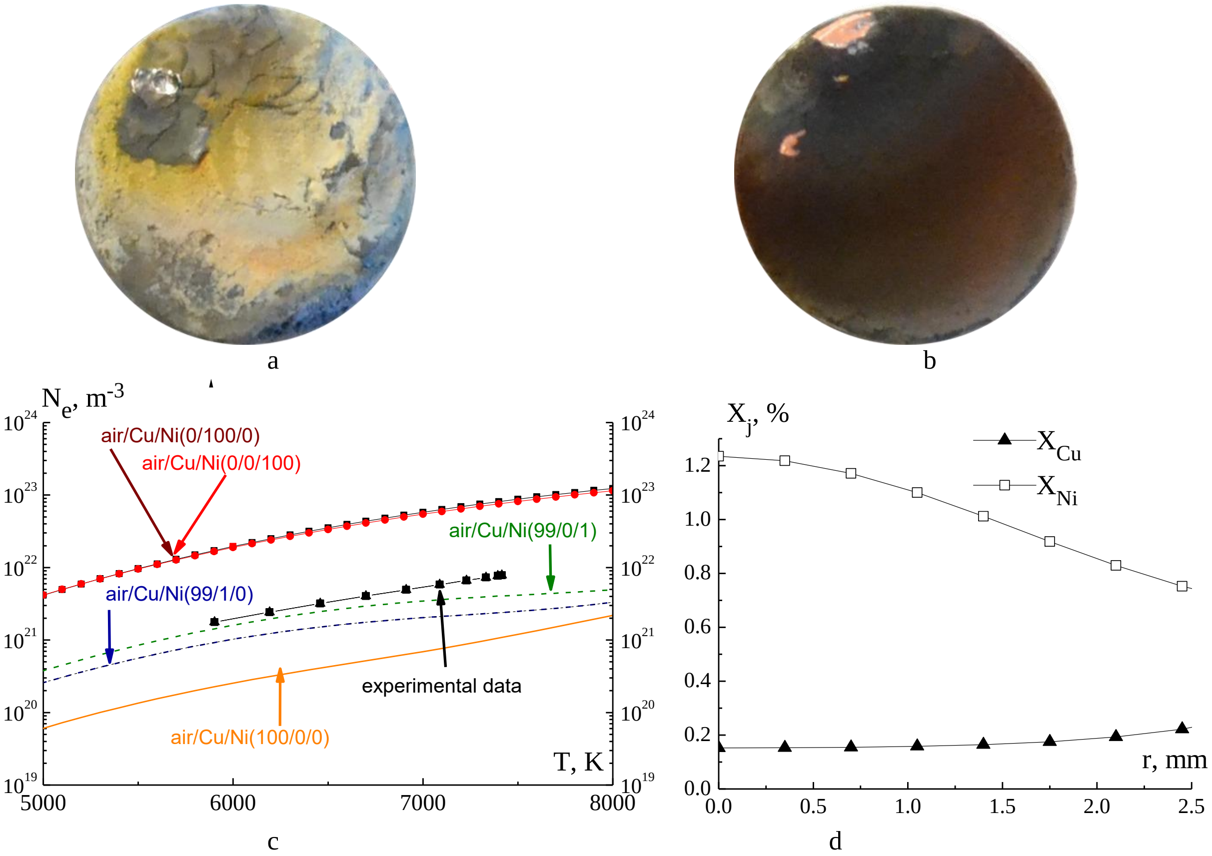

Fig. 6. Surface image of electrodes: a) Ni (cathode / bottom position); b) Cu (anode / upper position). The dependence of electron density from temperature; (c) and radial distributions; (d) of copper and nickel vapours contents in plasma of electric arc discharge at current 30 A

RESULTS AND DISCUSSIONS

The radial distributions of plasma temperature were determined in the middle section of the discharge gap. The technique of Boltzmann plot in the assumption of local thermodynamic equilibrium (LTE) was used. Up to 300 samples of registered radial distributions of intensities for each copper and nickel spectral lines were used to measure temperature. All radial distributions of temperature for both types of voltage polarity and spatial configuration coincide within the measurement error (see Fig. 1). At the arc core, the plasma temperature is about 8000 K.

The electron densities were obtained from the half-width of spectral lines Cu I 515.3 nm in case of dominating quadratic Stark effect at arc current 30 A (Fig. 2). The measured radial distributions of temperature and electron density were used to calculate the equilibrium plasma composition and, respectively, metal content in plasma (see Figs. 3-6,d). Moreover, experimentally obtained data of electron densities and temperatures can be plotted on the diagram in the coordinates N_e and T (see Figs. 3-6,c). Additionally, the curves of electron density in air plasma with different contents of metal vapours as a function of temperature can be plotted in these figures as well. As one can see, the experimental points cross the theoretically calculated curves for the content of metal in the amount of 1%. So, these figures are serving as convenient tool in the simple estimation of metal vapour content in plasma and erosion properties of electrode material. In addition, the obtained N_e (T) profiles are within the boundaries of the existence of LTE in plasma. Finally, one can conclude that the local thermodynamic equilibrium can be mostly realized in the thermal plasma of the arc channel in the studied cross section.

Moreover, the photos of electrodes' surface were proceeded for all electrode combinations (see Figs. 3-6,a, b). The images were registered after processing of the electrode surface by 30 ms pulse current of 30 A in the amount of thirty pulses within 1 minute of DC arc discharge at low current 3.5 A. One can see, arc erosion mostly damages the surface of that electrode which is used as a cathode. This conclusion wholly corresponds to those in work [5]: erosion takes place in long arcs predominantly at a cathode. A similar result was obtained earlier for an arc discharge with a current of 3.5 A between single-component copper and nickel electrodes [4]. Usually, the erosion crater is formed on the surface of a cathode, regardless of material of electrodes.

CONCLUSIONS

It was found in the study of plasma of electric arc between asymmetric one-component Cu and Ni electrodes at current 30 A by optical emission spectroscopy, that:

- the local thermodynamic equilibrium can be mostly realized in the thermal plasma of the arc channel in the studied cross section;
- the total content of metals in the plasma varies with the spatial location of the electrodes;
- the most intensive metal erosion takes place from the electrode that is used as a cathode.

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ПЛАЗМА ДУГОВОГО РАЗРЯДА МЕЖДУ ПЛАВЯЩИМИСЯ Cu- И Ni-ЭЛЕКТРОДАМИ

А.Н. Веклич, М.М. Клешич, С.А. Фесенко, В.Ф. Борецкий, Л.А. Крячко

Исследовали интенсивность эрозионных процессов свободногорящей электрической дуги силой тока 30 А между асимметричными однокомпонентными Cu- и Ni-электродами. В среднем сечении разрядного промежутка с помощью оптической эмиссионной спектроскопии измеряли радиальные распределения температуры и электронной концентрации, которые были использованы для расчета равновесного состава плазмы. Таким косвенным образом может быть оценена интенсивность испарения электродного материала.

ПЛАЗМА ДУГОВОГО РОЗРЯДУ МІЖ ПЛАВКИМИ Cu- ТА Ni-ЕЛЕКТРОДАМИ

А.М. Веклич, М.М. Клешич, С.О. Фесенко, В.Ф. Борецький, Л.О. Крячко

Досліджували інтенсивність ерозійних процесів вільноіснуючої електричної дуги струмом 30 А між асиметричними однокомпонентними Cu- та Ni-електродами. У середньому поперечному перерізі розрядного проміжку за допомогою оптичної емісійної спектроскопії вимірювали радіальні розподіли температури та електронної концентрації, які використовували для розрахунку рівноважного складу плазми. Отже, у такий непрямий спосіб може бути оцінена інтенсивність випаровування електродного матеріалу.