Effect of copper metal vapour on the properties of microarcs in air-copper mixtures at atmospheric pressure

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Abstract: In this contribution, we report results from modelling studies of microarcs in gas mixtures of air and copper vapour at atmospheric pressure and investigate the effect of the amount of the metal vapour on the plasma parameters. Findings demonstrate the spatial structure of the microarc and the behaviour of the electron and gas temperature, the electric potential and plasma chemistry for mixtures of air with 10% and 90% copper vapour.

1. Introduction

Discharges in metal vapour can occur at low voltages during contact opening in switching devices. A bridge of molten metal can form and break close to the boiling temperature of the material so that the gap between the electrodes is filled with metal vapour. The metal atoms are easily ionized due to their low ionization potential and a discharge ignites. The properties of microarcs in presence of metal vapour are not well studied yet.

In a previous work [1], plasma properties of microarcs in atmospheric pressure air between cold copper electrodes were studied. Recently, we carried out a modelling study of microarcs in air dominated by copper metal vapour [2]. In this work, we consider the effect of the amount of copper vapour and compare the properties of microarcs with a length of 30 µm and a radius of 155 µm in atmospheric pressure air-copper mixtures containing 10% and 90% copper metal vapour at a current level of 1 A.

2. Methods

The non-equilibrium microarc plasma is described by means of a fluid model applying the drift-diffusion approximation for the conservation of electrons and electron energy. The model further solves the general species equation for heavy particles, the Poisson's equation for the electric potential, and the heat transfer in the plasma and the electrodes [2].

The plasma chemistry with the consideration of the air components involves the 11 species model of air (e, N_2, O_2, NO, N, O, N_2^+, O_2^+, NO^+, N^+, and O^+). The model further includes atoms (Cu) and singly charged ions (Cu^+) of copper in their ground state. In order to account for ionization and recombination processes involving the excited atomic levels of the Cu atom, the modified diffusion approach is considered.

3. Results and Discussion

Figure 1 compares the distribution of the temperatures of electrons and heavy particles (a), the electric potential (b) and the number densities of electrons and singly charged copper ions (c) along the distance from the cathode (distance 0) toward the anode (distance 30 µm) for mixtures containing 10% and 90% of copper vapour. In the mixture air-90%Cu, the electron and gas temperatures are lower than in the air-10%Cu mixture. The electron temperature in the latter mixture reaches a value of about

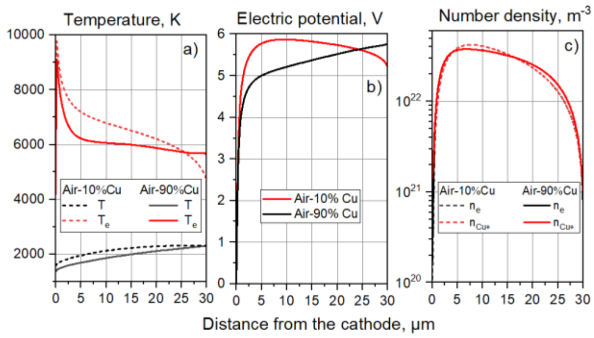

Fig. 1. Distributions of a) electron and gas temperature; b) electron potential; c) number densities of electrons and Cu^+ ions in microarcs (length 30 µm, radius 155 µm) in mixtures air-10% Cu and air-90% Cu at atmospheric pressure. The electric current is 1 A.

10000 K in the region of space charge adjacent to the cathode, while it decreases progressively in the plasma bulk. In the mixture air-90%Cu, the electron temperature peaks at about 9000 K and drops down to about 6000 K for distances from the cathode larger than 5 µm. Evaporation from the electrodes occurs in both cases as it is stronger on the anode. Furthermore, the electric potential indicates no reversal of the electric field near the cathode and a slightly higher discharge voltage in the mixture air-90%Cu. Even in the mixture with the lower amount of copper vapour, the quasineutrality in the bulk of the microarc is governed by the metal ion. The contribution of the ions of the air components is much less important in both cases.

4. Conclusion

The present modelling studies are related to early stages of contact separation in low-voltage, low-current switching devices, where the discharge is dominated by the presence of copper vapour. The amount of metal vapour has a stronger influence on the distribution of the electron temperature and the electric potential.

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References

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