Modelling of micro-discharges in metal vapor of zinc for applications in explosion protection

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Abstract: In this contribution, a modelling study of a zinc metal vapor discharge is carried out in order to determine the heat generation in the contact breakdown. The latter is relevant for the development of the testing tool for explosion protection. The fluid-Poisson model is validated by comparing the results with electrical measurements providing the discharge voltage at various gap lengths. The plasma parameters and the released heat are obtained.

1. Introduction

Gas heating during the contact-opening discharge in a flammable atmosphere (e.g., H_2-air mixture) is important due to potential gas ignition that could lead to hazardous effects. The application of an experimental testing apparatus based on the standardized spark test device with a tungsten (W) wire (the anode) moved along the cadmium (Cd) cathode was systematically investigated [1]. The modelling study of the contact-opening discharge with Cd electrodes was reported in [2]. This work aims to extend this model to the discharge between a Zn cathode and a tungsten anode, determine the heat generation and validate the model with the measurements. To this end, the computed and measured discharge voltages are compared.

2. Methods

The fluid model based on the unified non-equilibrium model described in [3] was employed to describe the micro-discharge in the Zn vapor between the Zn cathode and the W anode at atmospheric pressure. The model accounts for electrons, excited Zn atoms and singly charged Zn ions. It solves the conservation of species, the energy balances of electrons and heavy particles, the Poisson's equation for the electric field, and the heat transfer in the electrodes. An external electrical circuit is used to adjust the electric current. The electrons are characterized by a Maxwellian velocity distribution function, while the heavy species are assumed at equilibrium at a common temperature. The operation of the cathode employs a thermo-field emission of electrons that is evaluated using the transferred matrix method [4].

3. Results and Discussion

Figure 1 shows the measured and the computed voltage-length characteristics for gap lengths in the range 60–160 μm. The DC power supply is operated with a constant current of 60 mA and a limitation of the maximum voltage of 30 V. A good agreement is observed for the single set of experimental data based on electrical and optical measurements applying a field enhancement factor of 300 to account for surface roughness in the evaluation of the thermo-field electron emission. The results show an almost linearly increasing burning voltage with the discharge length during the contact opening. The

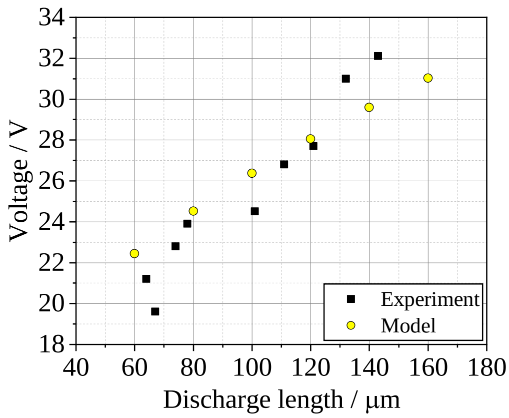

Fig. 1. Comparison of computed and measured voltage of the Zn vapor discharge for gap lengths in the range 60-160 µm and a current of 60 mA.

spatiotemporal evolution of the discharge exhibits similar behavior (not shown here) as in the case of the Cd cathode, with a pronounced cathode fall and heating of the gas and the electrodes. During the contact opening the gas is heated up to a temperature exceeding 3000 K, which is well above the ignition temperature of the H_2-air gas mixture.

4. Conclusion

The fluid model of the contact-opening discharge can predict the burning voltage and reproduces the measured course for gap lengths of 60-160 µm. Similar trends in the charge production and the gas heating are observed like in the case of a discharge with a Cd cathode. Further development of the Zn model and the tool are in progress.

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