Simulation of Breakdown in Cu-Cr Metal Vapor after Vacuum Arc Extinctions

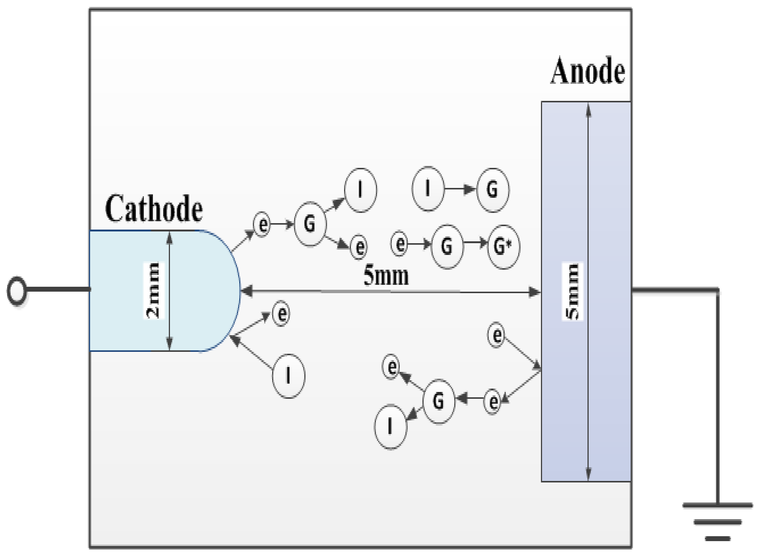
Zhenxing Wang, Yunbo Tian,Yingsan Geng, Zhiyuan Liu

State Key Laboratory of Electrical Insulation and Power Equipment, Xi'an Jiaotong University, Xi'an 710049, China

Introduction

Metal vapor has a significant influence on dielectric recovery behaviors after interrupting a high vacuum arc. The objective of this paper is to study breakdowns in copper, chromium and copper-chromium vapors employing the PIC-MCC method. A 2D model with a given DC voltage is applied to study the breakdown processes in the metal vapor after vacuum arc extinctions taking into account thermal-field emission, secondary electron emission, plasma and neutral transport. The results confirm that the breakdown voltage decreased with the increase of the surface temperature. At the same surface temperature, the breakdown voltages for different metal vapors follow the trend of copper> copper-chromium>chromium .

Model

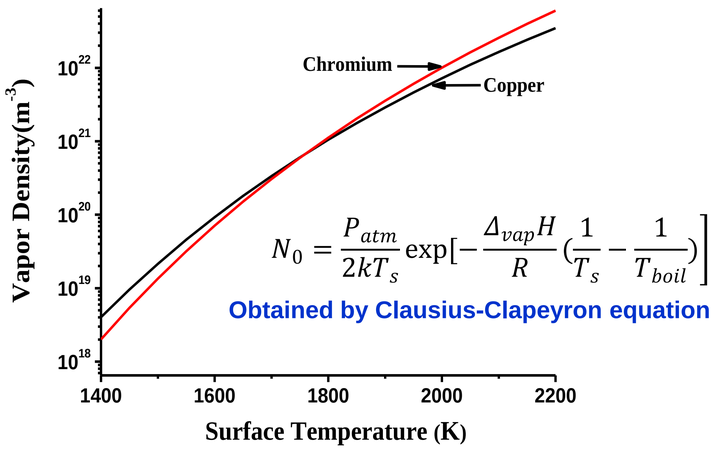


Schematic diagram of the simulation model

- ✓ **2d3v model**
- ✓ **Negative voltage**
- ✓ **Cu, Cr and Cu-Cr as background vapor**
- ✓ **Rod cathode vs. plate anode**
- ✓ **Taking account of ionization, excitation, elastic collision and charge exchange :**

$$Cu \quad (Cr) + e^- \rightarrow Cu^+ (Cr^+) + 2e^-$$
$$Cu \quad (Cr) + e^- \rightarrow Cu^* \ (Cr^*) + 2e^-$$
$$e^- + Cu \quad (Cr) \rightarrow e^- + Cu \quad (Cr)$$
$$Cu \ (Cr) + Cu^+ \ (Cr^+) \rightarrow Cu^+ \ (Cr^+) + Cu \quad (Cr)$$

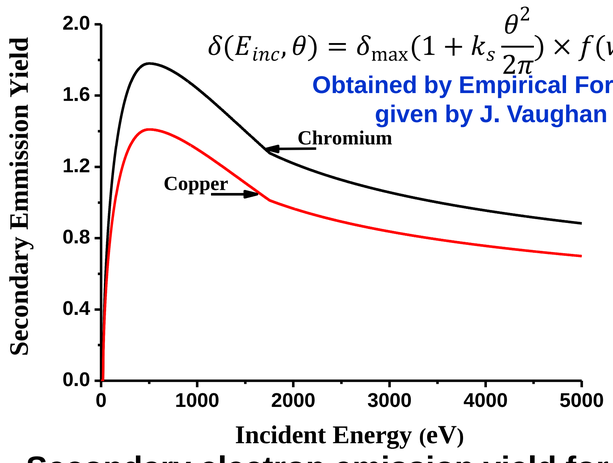
Simulation Parameters



$$N_0 = \frac{P_{atm}}{2kT_s} \exp\left[-\frac{\Delta_{vap} H}{R}\left(\frac{1}{T_s} - \frac{1}{T_{boil}}\right)\right]$$

Obtained by Clausius-Clapeyron equation

Background Vapor Density as Function of Surface Temperature



$$\delta(E_{inc}, \theta) = \delta_{\max}\left(1 + k_s \frac{\theta^2}{2\pi}\right) \times f(w, k$$

Obtained by Empirical Formula given by J. Vaughan

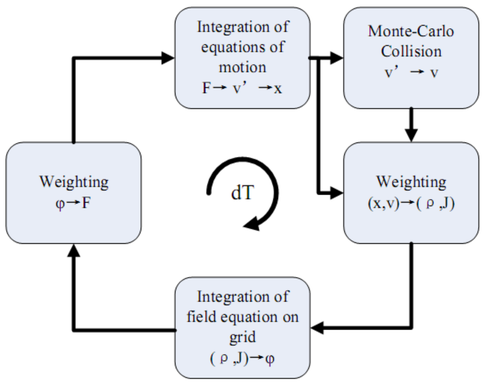
Secondary electron emission yield for copper and chromium

- ✓ **Emission from the Cathode Surface(Richardson-Dushman equation):**

$$J = M \frac{4\pi me}{h^3} T^2 \exp\left(-\frac{W}{T}\right)$$

- ✓ **The cross sections for Cu and Cr metal vapor is obtained from EEDL(Evaluated Electron Data Library)**

Method

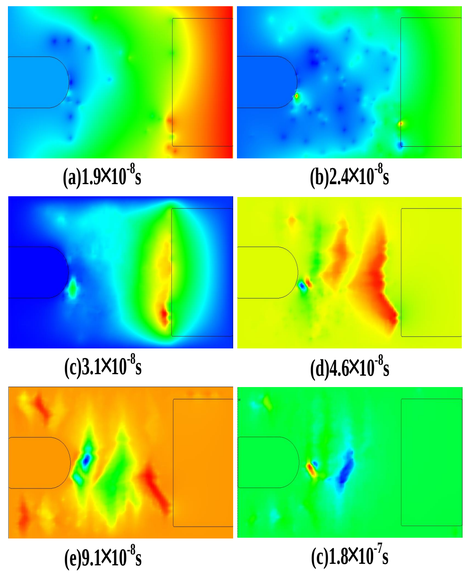


Computing sequence for PIC-MCC method

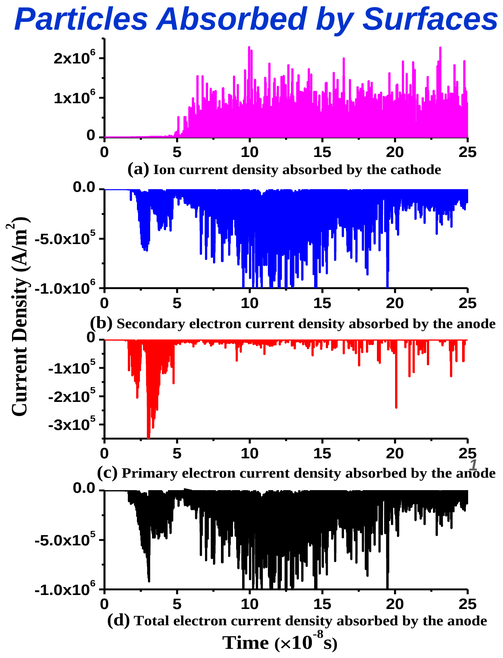
PIC-MCC simulation solved by VSim software package

Evolution of Breakdown

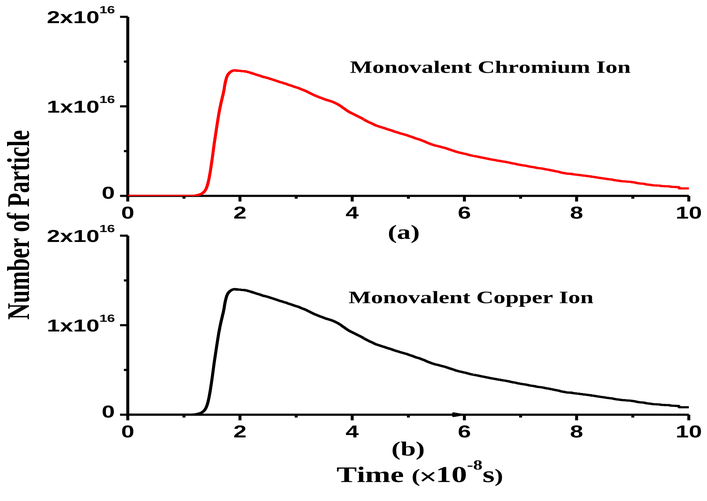
Electric Field Distribution



Particles Absorbed by Surfaces

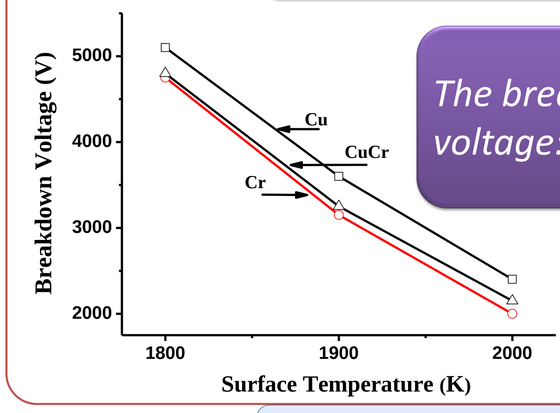


Result



This result implies that it is difficult to distinguish the effects of two species vapor on breakdowns

Result



The breakdown voltage: Cu>Cu-Cr>Cr

Conclusion

At the same surface temperature, the breakdown voltages for different metal vapors follow the trend of copper> copper-chromium >chromium.