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Numerical Calculation of High-Temperature Properties of Hot-Gases and Arc Discharges Formed in Electric Fuse

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Arc interruption and electric insulation after the arc interruption are crucial roles of electric system protection devices such as gas circuit breakers and electric fuses. Clarification of high-temperature(T) properties of arc and hot gases is important to improve their interruption and electric insulation performances. This paper briefly introduces our research result for analysis of high gas properties of hot gas and arc by focusing on the fuse.

The conventional fuse uses the SiO_2-sand to interrupt the high-T Cu arc discharge. Thus, high-T gas properties of Cu/SiO_2 vapor mixture is important to interpret the phenomena of arc interruption and electric insulation after the arc interruption. Therefore, first, we calculated chemical composition of Cu/SiO_2 vapor mixture in a T range between 3-20 kK. As a result, atomic species such as O, Cu and Si are formed as predominant chemical species at T below 10 kK. At T below 5 kK, SiO and SiO_2 are formed as predominant species with other atomic species. By considering chemical composition, we calculated the electrical resistivity(ρ) and the thermal diffusivity(α) of the Cu/ SiO_2 vapor mixture under various Cu/SiO_2 vapor ratio conditions.

As a result, ρ of the Cu/SiO_2 vapor mixture rose with T decaying. On the other hand, admixing of SiO_2 vapor into the Cu arc slightly increased ρ while significantly increased α at T below 10 kK. The present less change in ρ was originated from low momentum transfer collision cross section of O atom[1]. The present result also shows that increasing ρ(i.e. increase in ρ due to admixing of arc quenching medium vapor into the Cu arc) is necessary to improve the arc interruption performance of the fuse.

After the arc interruption in the fuse, the Cu/SiO_2 hot gas still remains inside the fuse. The Cu/SiO_2 hot gas should withstand for the transient recovery voltage to insulate electric system. The critical electric field strength E_{cr}/N can be estimated from electron attachment coefficient(η/N) and ionization coefficient(α/N) of the Cu/SiO_2 hot gas. These two coefficients can be obtained through solving the electron Boltzmann equation taking into account electron collision phenomena and chemical compositions. Fig.1 shows typical results of η/N and α/N. As results of E_{cr}/N, 10%Cu slightly decays E_{cr}/N compared with 0%Cu. In contrast, 30%Cu shows rising E_{cr}/N. The decreasing E_{cr}/N under 10%Cu is due to low ionization potential and large ionization cross section of Cu atom[2]. The increasing E_{cr}/N under 30%Cu is due to large excitation cross section of Cu atom[2]. Thus, Cu vapor concentration isn't an issue for electrical insulation of fuse after the arc interruption.

As in another study, we developed a novel arc quenching medium of DC arc interruption [3,4] based on the arc properties analysis. In this study, we clarified polymer vapor admixing into the arc significantly improves gas properties(Fig.2) of arc and arc interruption performance [3]. The application of Si_3N_4 powder also improved the arc interruption performance [4].

References
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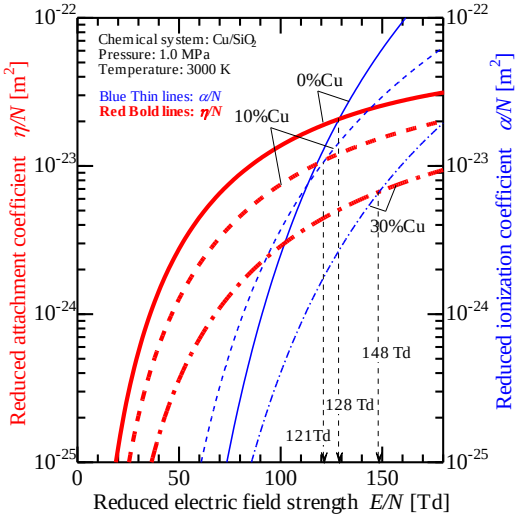
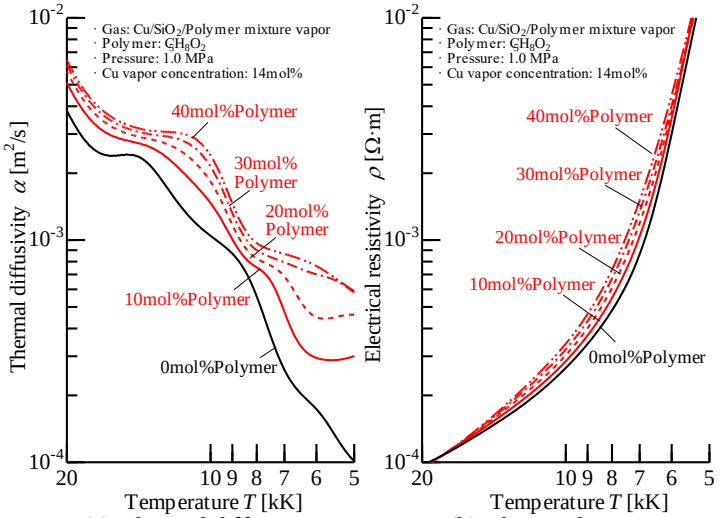


Fig.1 Critical electric field strength for Cu/SiO_2 vapor mixture



(a) Thermal diffusivity α (b) Electrical resistivity ρ

Fig.2 High temperature gas properties of Cu/SiO_2 arc mixed with polymer vapor