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Influence of Power Supply on Continuity of Vacuum Arc with Al Cathode and N_2 Flow Under Medium Vacuum

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SUMMARY

The continuity of a steered vacuum arc with Al cathode and N_2 flow at a pressure between 0.1 and 5 Pa is investigated. Two constant-current power supplies (60 V open-circuit voltage/30 V load voltage and 310 V/240 V) and a constant-voltage power supply with open-circuit voltage 550 V are used. The arc current is 30 A, the N_2 flow rate is 20 ml/min, and the transverse magnetic field density at the cathode edge is 1.2 mT. The following results are obtained. (1) When the power supply with lower open-circuit and load voltages is used, a decrease in pressure causes the arc to lose sustainability. (2) When the power supply with high open-circuit and load voltages is used, the arc can continue even at lower pressure. (3) When the power supply with higher load voltage is used, abnormal discharge behind the magnet field guide-disk may occur at lower pressure.

The above-mentioned influence of power supply on arc continuity is interpreted in terms of column fall and generation of a new cathode spot. © 1999 Scripta Technica, Electr Eng Jpn, 128(3): 9–15, 1999

Key words: Vacuum arc for formation of AlN; medium-vacuum region; discharge continuity; power supply.

1. Introduction

Accompanying the large-capacity implementation of power devices, the utilization of nitrided aluminum (AlN) film as an electrical insulating film between the device itself and the heat sink or cooling water is being considered. Conventionally, alumina [resistivity: 10^{12}–10^{14} Ω·m, thermal conductivity: 20–25 W/(m·K)] is utilized as the insulating film; however, with AlN [resistivity: 10^{11}–10^{14} Ω·m, thermal conductivity: 60–80 W/(m·K)], whose thermal conductivity is superior to alumina, the cooling efficiency can be improved, and the small-size, large-capacity implementation of the devices will become possible.

The authors have so far deposited ceramic films by the vacuum arc deposition method and carried out device development [1–4]. This method has the advantage that the deposition rate is significantly faster than the sputtering method and CVD method. It has already been reported that AlN films can be synthesized by this apparatus [1]. However, we have confronted several problems in the deposition of AlN films by the conventional apparatus. For example, the arc discharge becomes unstable with time and the arc will self-extinguish before long, because an AlN film will also be deposited on the anode surface and will block the current path. This problem can be solved by making an arrangement such that a perforated metal anode screen covers the anode surface [4]. One more problem is that in order to generate a good-quality AlN film, it may be desirable to set the pressure between about 0.1 and 1.0 Pa to obtain ions with higher energy; however, under present conditions, the arc will not be sustained at a pressure below about 3 Pa.

The reason the vacuum arc with Al cathode and N_2 flow will not be sustained when the pressure is low is not the deposition of AlN film on the anode surface but is probably extinction of the cathode spot. On the other hand, when a dc voltage of about 1000 V is applied between cathode and anode, the arc can be ignited. In the case of Al cathode under N_2 atmosphere, the arc can be ignited at lower pressure than in the case of a Ti cathode in Ar atmosphere [5]. This fact suggested the possibility of using power supplies with high open-circuit voltage and load voltage in order to maintain the vacuum arc with Al cathode and N_2 flow at a lower pressure. In this paper, for the vacuum arc with Al cathode and N_2 flow for AlN film deposition, we will determine, by changing the power supplies, whether or not the discharge can be sustained in the pressure range from 0.1 Pa to 5 Pa.

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