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Influence of gap length and pressure on medium vacuum arc with Ti cathode in various ambient gases

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Abstract

Voltage, plasma potential and electron temperature of a medium vacuum arc ignited between Ti cathode and disk stainless steel anode were measured in various ambient gases; H_2, N_2, He and Ar. Gap length was varied from 75 to 450 mm. The result showed that the voltage increased with gap length and gas pressure, and that the voltages in H_2 and N_2 were higher than those in He and Ar. The influence of the gas species on the voltage was explained on the basis of: the mean free path; ionization and excitation processes of the gas; and ambipolar diffusion.

Keywords: Deposition apparatus; Cathodic arc discharge

1. Introduction

Recently, a medium vacuum arc has been applied for functional ceramic film coatings [1,2]. The technique is called vacuum arc deposition, cathodic arc deposition, or (vacuum) arc ion plating. However, medium vacuum arc phenomena are neither well known nor well understood thus far.

On the other hand, phenomena of high-pressure arc and high-vacuum arc have been studied comprehensively. Especially, in a high-current vacuum arc that ignites in the vacuum bulb of an electrical circuit breaker, anode appearance is known to change as a function of gap length, current and pressure [3–5]. The appearance is called diffuse arc, footpoint, anode spot and intense arc modes.

Until the authors' studies [6–8], this kind of investigation had not been observed at the low current used for cathodic vacuum arc deposition. The result showed that, as pressure was increased, the anode mode changed from diffuse arc to footpoint, to plane luminous and to anode spot modes at a relatively higher pressure, and that its transition pressure strongly depended on gas species, but weakly on cathode material. In general, footpoint occurrence is not desirable in film fabrication since it makes for poor film quality. Hence, the investigation was useful from the technological point of view.

However, the anode of the apparatus is a cylindrical vacuum chamber, so the apparatus is inadequate for fundamental investigation of the arc. Hence, a facing electrode system was used in this study. First, the arc voltage was measured with Ti cathode in various gases, as pressure gradually increased from 0.1 to 400 Pa with constant gap length, and as the gap length was varied under constant pressure. Next, axial distributions of plasma potential, electric field strength and electron temperature of the arc under 5 Pa with 450 mm gap were measured by the Langmuir probe method.

2. Vacuum arc apparatus

A schematic image of the vacuum arc apparatus used was shown in Fig. 1. The vacuum chamber was made of SUS304, and was 400 mm in diameter and 600 mm in length. A Ti cathode of 64 mm in diameter was fed on one end, and a water-cooled stainless steel anode of 340 mm in diameter through the other.

The experimental procedure was as follows. Once the apparatus was evacuated down to 5×10^{-3} Pa, ambient gas of He, Ar, H_2, or N_2 was introduced into the apparatus at a rate of 40 ml/min. When the pressure became approximately 0.1 Pa, the arc was ignited by bringing the subelectrode into contact with the cathode surface. Power supply was used in the constant current

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