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Anode mode in cathodic arc deposition apparatus with various cathodes and ambient gases

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Abstract

The anode mode of a vacuum arc in a cathodic arc deposition apparatus was observed as a function of ambient gas pressure ranging from 0.01 to 300 Pa. The chamber (400 mm in diameter and 600 mm in length) made of stainless steel (SUS304) acted as the anode. The arc was operated at a relatively low constant current of 50 A. The cathode materials used were Al, Ti, Fe, Ni, and Cu, and ambient gases were He, Ne, Ar, H_2, N_2, O_2, and CH_4. The principal results are as follows. (1) As the pressure was increased, the anode mode changed from diffuse-arc to footpoint to plane luminous to anode-spot mode. (2) The anode mode and resultant arc voltage increase were strongly dependent on gas species, and weakly on the cathode material. (3) Comparing diatomic and polyatomic (H_2, N_2, O_2, and CH_4) with mono-atomic molecule gases (He, Ne, and Ar), the onset pressure of the anode mode transition in the former was lower, the arc voltage higher, and the footpoints more numerous, smaller, and clearer. Both the dependence of the ambient pressure and the influence of the cathode materials and gas species on the anode mode changes were explained by the ion deficiency theory.

Keywords: Cathodic arc deposition apparatus; Anode mode; Pressure dependence; Cathode material; Ambient gas

1. Introduction

The cathodic vacuum arc is known to be the simplest metallic or carbon ion source and is industrially applied to the preparation of thin solid films [1]. A variety of films of metals, nitrides, oxides, carbides and carbonaceous materials can be fabricated using a cathodic vacuum arc. The technique is called vacuum arc deposition, cathodic arc deposition, or (vacuum) arc ion plating. The authors have prepared various nitrides and oxides by this method to date [2].

On the other hand, a vacuum arc can also be observed in the vacuum bulb of an electrical circuit breaker. Such arcs are known to present a variety of anode appearances, depending on arcing conditions. In order to understand the basic characteristics of an arc in the vacuum bulb, and to improve bulb performance, a number of studies on anode phenomena of vacuum arcs have been carried out and the results are summarized in some reviews [3–5]. The anode mode is usually mapped as a function of the arc current and electrode gap length, and sometimes of the arc current and pressure. The anode mode is characteristically classified as follows:

1. Diffuse-arc mode: the anode is inert, acting merely as a collector of particles emitted from cathode spot.
2. Footpoint mode: one or more luminous points exist on the anode surface.
3. Anode-spot mode: one large or several small anode spots appear on the anode surface. The anode spot is active and erodes the surface.
4. Intense-arc mode: the anode spot is very active and severely erodes the surface.

However, the anode mode at currents as low as that used for cathodic vacuum arc deposition has not been

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