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Development of shielded cathodic arc deposition with a superconductor shield

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Abstract

In cathodic vacuum arc deposition or arc ion plating, the shielded method provides the easiest way to reduce macrodroplet adhesion in preparing thin films. However, a shield traps not only the macrodroplets toward the substrate but also the plating ions, so that the deposition rate decreases. In order to attain a higher deposition rate in shielded cathodic deposition (SCAD), an improved and enhanced SCAD (IE-SCAD) has been developed in which the cathodic plasma was transported to the substrate by a magnetic field between the cathode and substrate. In the present study, in order to obtain a higher deposition rate, IE-SCAD was further modified by employing a superconductor shield (SC-SCAD). In SC-SCAD, the magnetic field is thought to be diverted from the shield due to the Meissner effect of the superconducting material, and thus the plasma is transported along the magnetic field. The plasma generated from the cathode in SC-SCAD seemed to be effectively transported beyond the superconductor shield with a lower ion loss. The deposition rate of TiN film by SC-SCAD was found to be 1.5 times higher than that by IE-SCAD.

Keywords: Cathodic arc deposition; Shielded method; Plasma transportation; Magnetic field; Superconductor shield; Meissner effect; TiN film

1. Introduction

Cathodic arc deposition (also called vacuum arc deposition or arc ion plating) is one of the more powerful ion plating methods and is employed industrially to prepare thin solid films of metals, nitrides, oxides and carbonaceous thin films [1,2]. In this method, a variety of metal ions are easily obtained, and the ion energy is comparatively high. A further advantage of this method is the free-arrangement of the cathode target and the ability to realize high deposition rate with high evaporation rate by increasing the arc current.

However, cathodic arc deposition (CAD) involves the frustrating disadvantage that a large number of macrodroplets are emitted from the cathode. Macrodroplet adhesion to the substrate degrades the uniformity of the film surface smoothness, film composition and function of the film. The reduction of such macrodroplets is an important problem in the use of cathodic arc deposition. A variety of methods have been developed to overcome the problem [1–4], one of which is the shielded method (shielded cathodic arc deposition: SCAD) in which a thin plate is placed between the cathode ion source and substrate [5,6]. This shield plate intercepts the macrodroplets flying directly toward the substrate. The light electrons initiated from the cathode easily move beyond the shield plate, and the ions then follow due to an ambipolar diffusion mechanism [7]. The film is prepared in the area shadowed by the shield so that macrodroplet adhesion to the film is dramatically reduced in some cases [2]. However, the shield plate also blocks some of the plating ions, thus decreasing the deposition rate. To increase the rate, we have developed a modified SCAD by means of the magnetic transportation of plasma. When a small permanent magnet was placed behind the substrate (so-called enhanced shielded cathodic arc deposition: E-SCAD), the deposition rate increased at the substrate center, and when an electromagnetic coil was located around the substrate (a method called improved E-SCAD: IE-SCAD), a flat distribution with a higher deposition rate was achieved [8].

In the present study, in order to obtain higher deposition rate, a new modified SCAD, called SC-SCAD (superconductor-shielded cathodic arc deposition), was

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