N_2 Gas Absorption in Cathodic Arc Apparatus with an Al Cathode Under Medium Vacuum

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***Abstract*— Al evaporation and N_2 absorption rates during cathodic arc evaporation with an Al cathode and N_2 gas flow were measured as a function of process pressure under medium pressure. These rates decreased as the pressure increased. The ratio of the Al evaporation rate to the N_2 absorption rate was about 2 : 1. The film deposited on the anode chamber was analyzed by an X-ray diffraction analyzer and found to be aluminum nitride (AlN). This result indicates that N_2 gas is mostly absorbed and fixed in the deposits on the anode surface in the form of AlN.**

***Index Terms*—A1 evaporation rate, A1N film, N_2 gas absorption rate, pressure dependence, reactive cathodic vacuum arc.**

I. Introduction

Aluminum nitride (AlN) is a III–V compound with a hexagonal wurtzite crystalline structure. AlN film is a valuable or attractive material for electrical insulators with high thermal conductivity, piezoelectrical devices, very high frequency surface acoustic devices, surface-passivation of semiconductors, and medium refractive-index optical coatings. The film has been synthesized by reactive sputtering [1], chemical vapor deposition [2], the electron shower method [3], and magnetically filtered cathodic arc deposition [4], etc.

The authors [5] have prepared AlN film, as well as other ceramic films [6]–[8], by an unfiltered conventional cathodic vacuum arc deposition method and found that the crystalline orientation of the AlN film varies with RF power applied to the substrate [5]. We also solved the problem of the arc not sustaining at a pressure less than 3 Pa by using a power supply with a higher working voltage [9]. In this study, as a preliminary experiment, the Al evaporation rate was measured and the N_2 absorption rate was evaluated as a function of the process pressure under medium pressure. The films were analyzed with a scanning electron microscope (SEM; Jeol JSM-6300), an X-ray diffraction analyzer (XRD; Rigaku, RINT-2500), and an energy dispersive X-ray spectrometer (EDX; Horiba, EMAX 5770W) attached to a SEM (Topcon, ABT-150F), in order to examine the physical aspect of N_2 absorption in the film.

II. Experimental Apparatus, Procedure, and Conditions

The cathodic vacuum arc apparatus used is shown in Fig. 1. The Al cathode (64 mm in diameter, 25 mm thick) directly water-cooled from the back was located at one end plane of cylindrical vacuum chamber (320 mm long, 200 mm in diameter) which was also the anode. Magnetic discs were placed behind the cathode to steer the cathode spot in a retrograde direction in order to reduce the generation of cathodic macrodroplets. The arc was ignited with a trigger rod that was mechanically contacted with the cathode surface and then withdrawn. A diffuse plasma was formed between the cathode spot and the anode.

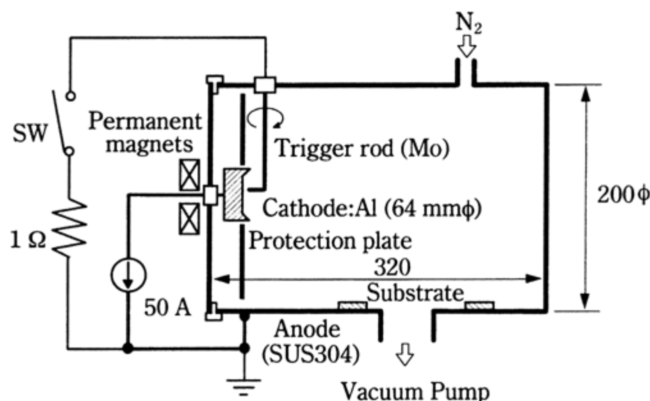

Fig. 1. Schematic diagram of vacuum arc apparatus.

A constant N_2 gas flow regulated by a mass flow controller was introduced into the chamber before arc ignition. At the same time, the chamber pressure was regulated with an exhaust valve. The arc was ignited under this condition and then terminated after a certain period, i.e., the input gas flow rate and the degree of the exhaust valve opening were not changed when the arc was either ignited or extinguished. The arc voltage, current, and chamber pressure were recorded using a digital storage oscilloscope.

Experimental conditions were as follows: arc current, 50 A dc; N_2 gas flow rate, 20 ml/min (1 atm, 300 K); discharge time, 10 min; process pressure, 0.3 Pa to 10 Pa. Mo and Si (111) substrates (20×20 mm^2) were positioned on the anode surface at horizontal distances of 80 and 250 mm from the cathode, in order to retrieve and analyze the deposits on the anode surface. All the flow rates in this paper are expressed in standard pressure and temperature (1 atm, 300 K).

III. Experimental Results

A. Arc Current, Voltage and Pressure

The arc current, voltage, and chamber pressure waveforms as a function of time for process pressures of 0.5 and 5 Pa are shown in Fig. 2. Arc currents for both cases were constant

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