Development of Y-Shaped Filtered-Arc-Deposition System for Preparing Multielement Composition-Controlled Film

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***Abstract*—In recent years, multielement films have been required for high-performance cutting tools. In this paper, a Y-shaped filtered-arc-deposition (Y-FAD) system with two vacuum-arc sources was developed. First, an optimum magnetic coil arrangement was experimentally established to transport two plasma beams through the Y-shaped duct at the same time. Since the two plasma beams have the same electrical polarity, they naturally tend to repel each other. Therefore, in the second step, the two plasma beams were combined into one plasma beam through a mixer part by vibrating the plasma beams with a laterally oscillating magnetic field. Third, the electrical bias applied to the duct was optimized to obtain a higher transportation rate of plasma and deposition rate. After these design developments and tuning, titanium–aluminum (Ti–Al) film with a combined deposition pattern was finally obtained with Al and Ti cathodes. The controllability of the composition ratio by the arc current was verified.**

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***Index Terms*—Current ratio, duct bias, multielement film, titanium–aluminum (Ti–Al) film, Y-shaped filtered arc deposition (Y-FAD).**

I. Introduction

THE FILM coating of solid materials is a practical technology to improve material functions or add new functions, such as wear resistance, abrasion resistance, high hardness, oxidation resistance, and high sliding property. Such coating has been widely applied to protect the surface of cutting tools, metal molds, etc. In recent years, more functional coating has been required in the field of dry cutting and/or higher speed cutting. Multielement nitride coating is considered as one of the solutions [1]–[3].

The dry process for protective hard coating on cutting tools can be carried out by plasma chemical vapor deposition [4], sputtering [5], hollow cathode arc deposition [6], ion beam deposition [7], cathodic arc deposition (CAD), and electron-beam-excited plasma. CAD [8]–[10], which is one of the physical vapor deposition methods, has been widely employed in the industry and has also been called arc ion plating, vacuum-arc deposition (VAD), cathodic VAD, etc. This method requires a composition-controlled metal-alloy target (= cathode of arc discharge) to prepare the multielement nitride. To obtain the best composition ratio through a systematical parametric study, many cathode targets with different compositions are required and, thus, are not cost-effective.

On the other hand, vacuum-arc plasma has a problem in that the cathode emits many macrodroplets as well as ions and electrons. The droplets undermine the film properties, including uniformity, surface roughness, coefficient of friction, and hardness. To overcome this droplet problem, the magnetically filtered arc methods developed to remove the droplets from the plasma have been most effective [10]–[12].

Given the above industrial requirement and technological background, a new filtered-arc-deposition (FAD) apparatus with two arc evaporators, which is called Y-shaped FAD (Y-FAD), was developed. Double-source FADs with separate ducts have been previously developed for revolving substrates [13], [14]. As it is different from such FADs, Y-FAD has a common duct part for transporting the plasma to the process chamber. In this paper, first, the magnetic field configuration was