Thin Solid Films 518 (2009) 1498–1502

Contents lists available at ScienceDirect

Thin Solid Films

journal homepage: www.elsevier.com/locate/tsf

T-shape filtered arc deposition system with built-in electrostatic macro-particle trap for DLC film preparation

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ARTICLE INFO

Article history:
Received 1 March 2009
Received in revised form 16 June 2009
Accepted 22 September 2009
Available online 2 October 2009

Keywords:
DLC film
T-shape filtered arc deposition (T-FAD)
Droplet reduction
Electrostatic trap (ES-trap)

ABSTRACT

A T-shape filtered arc deposition system (T-FAD) is a powerful tool to prepare high-quality diamond-like carbon (DLC) films. Most macro-particles (droplets) emitted from the graphite cathode are caught at the extension duct of the droplet catcher or collector facing the cathode, and then the clean plasma bent 90° is transported toward the substrate. However, further droplet reduction is still required in order to realize a higher quality film without droplet incorporation. In the present study, T-FAD employed an electrostatic droplet trap (ES-trap). A cylindrical ES-trap was placed in the extension duct part of the T-shape duct of an electromagnetic plasma transportation and droplet filter. The ion current at the exit of the T-filter duct and the current flowing to the ES-trap were measured as a function of the ES-trap bias voltage for various ES-trap positions. The deposition rate and number of droplets were also measured. As a result, it was found that the optimum voltage of the ES-trap was +35 V and that it was better to place the ES-trap closer to the plasma beam in order to obtain fewer droplets on the film without an excessive decrease in the deposition rate. In the optimum condition, the number of droplets on the DLC film prepared with ES-trap was reduced to 1/3 of that without the ES-trap.

1. Introduction

A cathodic arc discharge in a vacuum has been employed in industrial manufacturing processes to coat protective or decorative films, and is one common physical vapor deposition technique. In most cases, metal nitride films have been deposited by this method. Metals, alloys, oxides, and carbides are also possible. Much research and development have been carried out in this field [1,2]. However, the cathodic arc process has a problem in that the macro-particles, called droplets, which are of submicron to tens of microns in size [2,3], are emitted from the cathode spot. The droplets are incorporated in the film and sometimes cause deterioration of the film quality in terms of homogeneity, surface flatness, and result in delamination. The most efficient method to overcome the droplet problem in cathodic arc deposition is to employ a macro-particle filter. The cathodic arc plasma is transported to the substrate located out-of-sight from the cathode by a magnetic field [1–4].

One of the FAD applications is to prepare a diamond-like carbon (DLC) film. The hard and high-density DLC film is attractive for use as a read/write magnetic head in hard disk drives [5,6] and high temperature molds [7] especially for lenses [8,9], which require high-precision surfaces. The authors have developed a unique T-shape filtered arc deposition (T-FAD) system [10], which can prepare various kinds of DLC films [11,12]. Unlike other FADs, T-FAD has a droplet collection part facing the cathode, where the droplets are caught. In principle, droplets are geometrically removed in the T-FAD. However, in practice, a few droplets still exist on the prepared DLC film, presumably because some droplets are occasionally crushed or broken into smaller pieces when they collide with the T-duct wall. A photograph of a typical example is provided as proof with an explanatory illustration in Fig. 1. If this phenomenon occurs, some pieces of the crushed droplets move toward the substrate. Otherwise some droplets were considered to be electrically charged by several investigators [13,14]. The magnetized duct to transport the plasma is positively biased due to the efficient plasma transportation [15]. Furthermore, the positively biased duct was related to the droplet reduction due to the trapping in the duct wall sheath [16]. Inaba *et al.* have attempted to use a thick ring-type electrical filter between the double-bend filter duct and the process chamber, namely, in the path of plasma transportation to the substrate [17–19]. As the plasma beam passed through the ring filter biased at higher voltage than plasma potential, some of the charge droplets were caught. Further reduction

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doi:10.1016/j.tsf.2009.09.091