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Hydrogen-free fluorinated DLC films with high hardness prepared by using T-shape filtered arc deposition system

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ABSTRACT

Fluorinated diamond-like carbon (F-DLC) films have good surface properties. DLC films with high mechanical hardness are prepared using filtered arc deposition, which is a physical vapor deposition method. In this work, the fabrication of F-DLC films using filtered cathodic arc deposition while introducing a fluorocarbon gas was carried out, and the characteristics of the F-DLC films were investigated. The F-DLC films were deposited on Si and WC substrates using the T-shape filtered arc deposition (T-FAD) system while introducing fluorocarbon gases. The fluorocarbon gases used for this purpose were C_3F_8, C_6F_{14}, or C_7F_{14}. The F-DLC characteristics such as surface appearance, film structure, film density, nanoindentation hardness, substrate adhesion, and water contact angle were investigated. The characteristics of the fabricated DLC films were as follows: the fluorine content ranged from 0 to 22 at.%, film density ranged from 2.1 to 3.1 g/cm^3, nanoindentation hardness ranged from 10 to 48 GPa, elastic modulus ranged from 140 to 360 GPa, and water contact angle ranged from 66 to 95°. In addition, the F-DLC films showed good adhesion strength on WC substrates. F-DLC films with high mechanical hardness and water repellency were obtained using T-FAD.

1. Introduction

Diamond-like carbon (DLC) is an amorphous carbon material composed of sp^2 and sp^3 structures [1]. DLC films are formed by a variety of methods such as plasma chemical vapor deposition (CVD) [2], plasma based ion implantation and deposition [3], balanced and unbalanced magnetron sputtering [4], and cathodic vacuum arc deposition (CVAD) [5]. DLC films have excellent properties such as high mechanical hardness, high electrical insulation, high chemical inertness, and a low frictional coefficient. In addition, DLC films containing other elements show interesting properties. DLC films improve heat resistance by the addition of silicon atoms [6,7], and increase electrical conductivity by the addition of boron atoms [8–10]. Nitrogen atoms also improve the electrical conductivity and friction property of DLC films [10–12]. In particular, DLC films with fluorine atoms (Fluorinated DLC, or F-DLC) have good surface properties such as high water repellency, surface lubricity, biological compatibility, and low biofouling adhesion [13–25].

Su et al. [13] formed F-DLC films on 10-mm stainless steel discs by RF plasma-enhanced CVD. The surface free energy of F-DLC film decreased as the F content increased, through the formation of CF_x bonds, in the film. F-DLC films with a higher fluorine content reduced bacterial attachment, which causes the biocorrosion of metals. Ishihara et al. [14] fabricated F-DLC films on Si substrates by using plasma-assisted CVD with various CF_4/CH_4 flow ratios. The water contact angle (WCA) of F-DLC film surfaces increased as the fluorine content increased in the films. A tribological test of F-DLC films using a ball-on-disk friction tester in a deionized water environment showed that F-DLC films had low friction and that the wear rate was significantly low. Yao et al. [15] fabricated F-DLC films on Si wafers by plasma immersion ion implantation and deposition. The F-DLC films exhibited a high WCA close to polytetrafluoroethylene (PTFE). F-DLC films have been often

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