Coaxial Arc Plasma Deposition of Ultrananocrystalline Diamond/ Amorphous Carbon Composite Film at Different Substrate Parameters for Hard Coating Applications

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論 文 名　：Coaxial Arc Plasma Deposition of Ultrananocrystalline Diamond/ Amorphous Carbon Composite Film at Different Substrate Parameters for Hard Coating Applications
（硬質被膜応用に向けた異なる基板パラメータにおける超ナノ微結晶ダイヤモンド/アモルファスカーボン混相膜の同軸型アークプラズマ堆積法による成膜）

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論文内容の要旨

Thesis Summary

Coaxial arc plasma deposition (CAPD) has been recently employed as a promising physical vapor deposition technique to fabricate artificially structured nanomaterials specially ultra-nanocrystalline diamond for hard coating applications. CAPD offers many pros over chemical vapor deposition growth techniques, which has essentially employed for nanodiamond films deposition. Like lower deposition temperature, higher growth rate, and enhanced control of morphology and thickness, as well as its applicability to versatile substrates without surface pretreatments or seeding process, are the main advantages of CAPD to mention.

To improve the deposition ability of CAPD system and enhance the mechanical and structural properties of the deposited films a development of coating systems was driven by controlling the substrate parameters during the deposition. The substrate temperature and the energy of deposited species are two major factors in CAPD, which controlling the adhesion strength and film properties. Whereas the substrate temperature controlled the mobility of substrate surface atoms and caused high diffusion rate at the interface. Also, the energy of the deposited species, which controlled by negative substrate bias, is necessary to compensate for the deeper penetration of the arriving species as their energies increase.

This study is organized as follows:

Chapter 1 presents a brief survey of the different classes of carbon nanomaterials and a comparison of their purity, structure, and physical properties. The primary focus of this chapter is on ultrananocrystalline diamond films produced by coaxial arc plasma deposition. Selected deposition techniques of nanodaimond films are discussed, including high pressure high temperature technique, plasma-discharge-stimulated chemical vapor deposition methods, hot-filament technique, laser ablation, and coaxial arc plasma deposition.

Chapter 2 provides an experimental setup for synthesis of UNCD/a-C films and the analysis of the deposition system for electrical diagnostics in arc discharge. Also, introduces an explanation of the physical background of the mechanical and structural analyses of the optioned films. Whereas the synthesized UNCD/a-C films were chemically characterized by far- and near-field Raman, X-ray photoemission, and near-edge X-ray photoemission spectroscopies and energy-dispersive X-ray (EDX)

analysis. In addition, the mechanical properties were examined by nanoindentation, blast adhesion, scratch testers. Moreover, the films morphology and internal stress were investigated by scanning electron and 3D laser microscopes.

Chapter 3 reveals the effects of pulsed bias voltage and frequencies generated by bipolar power supply on the mechanical and structural properties of the deposited UNCD/a-C films. Application of bias voltage to the substrate during the deposition enhances the film growth rate and adhesion. However, an unintentional positive charge up on the substrate surface was observed during the film deposition, and it evidently degrades the effective negative bias voltage and the kinetic energy of positively-ionized carbon species at the high bias frequencies, which probably facilitate the formation of sp^2 bonds in the resultant films.

Chapter 4 exhibits a selective bias frequency suitable to grow UNCD/a-C films with excellent mechanical properties. the deposition was performed at different substrate unipolar bias frequency (from 10 to 90 kHz) using a pure graphite target of arc gun at pressure less than 10^{-4} Pa without inserted gases. Selective bias voltage was adapted to induce energetic carbon species towards the substrate and avoid unintentional substrate surface charge up, which effectively maximizes the film hardness with optimal mechanical and structural properties. At appropriated selective bias frequency, the accelerated positive carbon ions have shown a prudent plasma energy favorable for nanocrystalline diamond growth.

Chapter 5 reports on the mechanical, structural and adhesion properties of UNCD/a-C films on Si deposited by Coaxial Arc Plasma Deposition. The main focus is to study the effect of the deposition temperature on the film properties. The excellent properties of UNCD/a-C films make them of great interest for several applications. In addition, it introduces a new technique for depositing UNCD/a-C film on silicon substrate with enhanced adhesion strength by employing an adhesion intermediated layer. The chemical and mechanical analyses support the conclusions towards formation of SiC bonds causing an improved adhesion the NCD layer. The reduction of the residual stress in the two-layer system is also illustrated. it was demonstrated that UNCD/a-C films can be fabricated on smooth-surface Si substrates without easily being peeled off.

Chapter 6 is concerned with far and near-field Raman spectroscopic studies on UNCD/a-C films, comprising nano-sized diamond grains and an amorphous carbon (a-C) matrix. The films were obtained with coaxial arc plasma deposition. There was approved that near-field optical resolution achieved via tip-enhanced Raman spectroscopy is a powerful method for the investigation of nanodiamond grains embedded in a-C matrices. The size of the nanocrystals could additionally be estimated from the profile and position of a diamond peak. This work demonstrates that TERS is a powerful, nondestructive method for investigating advanced nanodiamond composite films.