Regular Paper

Effect of Boronizing Pretreatment on B-doped Diamond Growth on Ti Substrates Using MWPCVD

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Abstract

Since the bonding dissociation energy follows the order of TiB > TiB_2 > TiC, introducing Ti-B into the intermediate layer of B-doped diamond (BDD) on a Ti substrate can be expected to be improved the adhesion strength between the Ti substrate and the BDD film. The boronizing of each Ti substrate with different reaction durations and the deposition of BDD on each Ti substrate with different reaction durations were conducted using a mode-conversion-type microwave plasma chemical vapor deposition apparatus, which is able to consistently process boronizing pretreatment and deposition of BDD, using a solution of trimethyl borate as the boron source. From the results of chemical bonding analysis by X-ray photoelectron spectroscopy of the surface of each Ti substrate after the boronizing, it was observed that the amount of Ti-B increased with the increase in the boronizing time. Further, the adhesion strength of BDD/Ti increased with the increase in the boronizing duration up to 20 min. However, the adhesion strength after 30 min of boronizing became lower than that after 20 min. It is considered that the adhesion strength was decreased as a result of progressing hydrogen embrittlement.

Keywords: Boron doped diamond, Ti, Boronizing, Adhesion, CVD

1. Introduction

Ti and Ti alloys are employed in various fields such as bioengineering, aerospace engineering, and chemical engineering, because they have excellent characteristics such as a high mechanical strength, high corrosion resistance, and low density [1,2]. However, they also have disadvantages such as low resistance to wear and fretting fatigue [3,4]. Diamond coating is one of the solutions for these problems because of diamond's characteristics such as extreme hardness, low friction coefficient, chemical inertness, and high thermal conductivity [1]. Although diamond is generally an insulator of about 10^{16} Ω × cm, a p-type semiconductor can be formed by doping of B, and the electrical conductivity of B-doped diamond (BDD) is controlled by controlling the B concentration. BDD is an ideal electrode material because the potential window is wide, the background current is extremely low, and it is insoluble in any solution [5]. The Ti/BDD electrodes are promising for application in wastewater treatment, because they exhibit the advantages of both materials [6]. However, the Ti/BDD is inferior to BDD-coated niobium, tantalum, tungsten, and silicon materials in terms of service life. Furthermore, the results of acceleration life test (ALT) conducted under severe conditions, i.e., 10 J/Acm^{-2} current density indicated that the delaminating of the BDD was one of the causes of electrode breakdown [7,8]. The high thermal stress caused by coefficient thermal expansion mismatch between BDD and Ti at the substrate temperature during BDD synthesis has been reported as one of the adversely affecting these problems [9], and electrochemical corrosion of the TiC intermediate layer during the electrolysis [10]. Although nanocrystalline diamond synthesis at a low substrate temperature

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