Argon-dominated plasma beam generated by filtered vacuum arc and its substrate etching

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1. Introduction

Amorphous carbon film which has an sp³ structure is a so-called diamond-like carbon (DLC) film and has gradually spread in use as a protective film in various fields, such as cutting tools (razor, knife, drill, end mill), sliding parts (fork absorber in motorcycles, faucet valve, valve lifter in engines, slider in hard disk drives), molds, PET bottles for winter version tea, and decollation (watch) [e.g. 1–6]. DLC has various unique properties; high hardness, low-friction, harmless, etc. The hardness strongly corresponds to the density of the film, and some properties are associated with the hardness and density. For example, harder DLC is electrically non-conductive due to rich sp³ structure, but softer DLC without hydrogen is conductive since the sp² (graphite) structure is rich. DLC films have been prepared by various physical vapor depositions (PVDs) and plasma enhanced chemical vapor depositions (PECVDs). The properties of DLC films depend somewhat on the preparation method as well.

It is well known that the harder DLC is difficult to adhere firmly to the substrate. The hardest DLC, the so-called ta-C (tetrahedral amorphous carbon), is especially difficult. In order to attain practical firm adhesion, the substrate is typically slightly etched by Ar ions irradiation or bombardment for the purpose of surface cleaning. In general, an ion gun [7] or RF plasma [8] is employed for supplying Ar ions. However, in the case of RF plasma, a micro-discharge sometimes occurs at the edge of the substrate and the vapor generated by the micro-discharge is re-deposited on the substrate, making the surface rough and contaminated. Ion guns are known to be quite expensive. We have been developing the T-shape filtered arc deposition (T-FAD) system, which is a type of PVD system with a solid graphite target, based on cathodic vacuum arc discharge plasma with macro-particle filtering geometry [9]. It can provide all kinds of DLC films of high quality, hydrogen (H) free, H-rich, hard and soft, by controlling the substrate temperature, substrate bias, and introduction gases [10–12]. Recently, we have also been developing a small table-top type T-FAD, called µT-FAD, for R&D in the laboratory or for on-site