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

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A new technique to etch a substrate as a pre-treatment prior to functional film deposition was developed using a filtered vacuum arc plasma. An Ar-dominated plasma beam was generated from filtered carbon arc plasma by introducing appropriate flow rate of Ar gas in a T-shape filtered arc deposition (T-FAD) system. The radiation spectra emitted from the filtered plasma beam in front of a substrate table were measured. The substrate was etched by the Ar-dominated plasma beam. The principal results are summarized as follows. At a high flow rate of Ar gas (50 ml/min), when the bias was applied to the substrate, the plasma was attracted toward the substrate table and the substrate was well etched without film formation on the substrate. Super hard alloy (WC), bearing steel (SUJ2), and Si wafer were etched by the Ar-dominated plasma beam. The etching rate was dependent on the kind of substrate. The roughness of the substrate increased, when the etching rate was high. A pulse bias etched the substrate without roughening the substrate surface excessively.

1. Introduction

Amorphous carbon film which has an sp^3 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 sp^3 structure, but softer DLC without hydrogen is conductive since the sp^2 (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 argon (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

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