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Self-supporting tetrahedral amorphous carbon films consisting of multilayered structure prepared using filtered arc deposition

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ABSTRACT

Self-supporting 110-nm-thick tetrahedral amorphous carbon (ta-C) films with a multilayered structure were fabricated as a carbon film target for the laser-driven ion acceleration. The self-supporting ta-C films consisted of three layers with the thicknesses of 35 nm, 40 nm, and 35 nm thick, and the film density of 3.0 g/cm^3, 2.7 g/cm^3, and 3.0 g/cm^3, respectively. The multilayered ta-C film was fabricated using the T-shape filtered arc deposition method on a Si substrate coated water-soluble material. Silk fibroin and dextran were used as the water-soluble material. The water-soluble material formed between a ta-C film and a Si substrate was dissolved, and then, the ta-C film released from the substrate. Thick single-layer ta-C films partially peeled off on the water-soluble material and broke during the dissolving process. Self-supporting ta-C films were obtained by scooping the released ta-C film on a perforated substrate. The laser was irradiated on the self-supporting ta-C films, and the ta-C film with a higher film thickness and/or film density showed a higher laser irradiation tolerance.

1. Introduction

A laser-driven ion accelerator has been expected as a small-size ion accelerator. In the laser-driven ion acceleration method, high-energy ions originated from thin film elements can be obtained by irradiating a high-intensity short-pulse laser to a thin film target [1–7]. The thin film target used for the laser-driven ion acceleration needs to be a self-supporting thin film without a supporting substrate. One of the uses of high-energy ions is heavy-particle radiotherapy for cancer treatment. Carbon ions are used for heavy-particle radiotherapy.

One candidate for a carbon thin film target material is a diamond-like carbon (DLC) film [8,9]. DLC films are amorphous carbon films in which the sp^2 and sp^3 structures of carbon are mixed, and it is divided into four main groups based on the sp^3 ratio and hydrogen content [10,11]. A tetrahedral amorphous carbon (ta-C) film is a DLC film with a high film density owing to a high sp^3-ratio and hydrogen-free film. Smooth ta-C films with a high film density can be fabricated by using the filtered arc deposition method [11–18]. However, in the film formation process of DLC films that are an amorphous structure, a base substrate is necessary. Therefore, to obtain a self-supporting DLC film, the DLC film must be released from the substrate after its formation. Furthermore, as the film thickness and film density of a DLC film increase, the internal stress of the DLC film increase. An increase in the internal stress of a DLC film leads to its breakage before the self-supporting process.

As a self-supporting method of a DLC film formed on a substrate, there are a method of dissolving the substrate [19,20] and a method of dissolving a sacrificial layer that is formed between a substrate and a DLC film [21,22]. A DLC film with a thickness of 100 nm is formed on a solid soap by using the pulsed laser deposition (PLD) method, and the DLC film is released by dissolving the soap [19]. In the case of NaCl substrates or sacrificial layers, DLC films are prepared on NaCl by sputtering, PLD, and filtered arc deposition [9,20–22]. When a NaCl layer as a sacrificial layer is formed on a substrate by the vacuum vapor deposition method, the NaCl layer becomes a polycrystalline layer, and the surface roughness of the NaCl layer is transferred to the DLC film [21]. In our previous study, several materials were used as sacrificial layers or substrates in the preparation of self-supporting gold-sputtered

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