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Effect of substrate temperature on the microstructure and properties of Be_2C films: aim to advance its applications as ICF ablator

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Abstract:
Beryllium carbide films were deposited on quartz substrates by DC reactive magnetron sputtering of beryllium in the mixture of CH_4-Ar plasma. The influence of substrate temperature on the composition, microstructure and optical properties were characterized by suitable analytical techniques. Experimental results revealed that the composition is independent of substrate temperature and all films are mainly composed of Be_2C. Untextured polycrystalline Be_2C coatings with smooth surface (Ra < 4 nm) were obtained at low substrate temperature (85-175 ^oC), while it evolved into porous columnar crystal structure with rougher surface as the temperature increasing. These films exhibited fine grains (< 26 nm) and high densities. High speed deposition (> 220 nm/h) of Be_2C films was realized in this work, representing the current highest deposition rate by reactive magnetron sputtering. The optical measurements showed an average transmittance ~ 40% in visible region and ~ 84% in near-infrared region for Be_2C films. The optical bandgap, evaluated by Tauc's method, was about 1.9 eV despite of substrate temperature. This work represents a significant step toward preparing high quality Be_2C films and benefits the application of Be_2C as ICF ablator.

Key word: Beryllium carbide film, ICF ablator, Reactive sputtering, Substrate temperature.

1. Introduction

One key issue for the realization of controlled fusion reaction by inertial confinement fusion (ICF) is the selection of suitable capsule ablator. Ablative materials have to fulfill many requirements [1-3], such as a low atomic number (Z), uniform composition and microstructure, smooth surface, high density, and so on. In the current stage of ICF, hydrocarbon (CH), beryllium (Be) and high density carbon (HDC) are the prior alternative materials for capsule ablator in National Ignition Facility (NIF) [1-9]. The advantage of hydrocarbon is its transparency of visible-infrared light and the maturity of its preparation process [1, 10-11]. Beryllium has a higher ablation speed [4, 10-14]. HDC owns higher density (3.5 g/cm^3), which resulted in higher X-ray absorption efficiency [2,4]. Ignition experiments with CH, Be and HDC capsules have been performed on NIF [2,15-18]. Some great progresses have been achieved. However, the successful ignition is still unreachable. In this case, it is particularly important to unfold researches on potential ablative materials.

Beryllium carbide (Be_2C) has aroused researchers' interest for its potential usages in ICF as ablative materials [3,19-20]. It combines the advantages of CH, Be, HDC, and reaches a more balanced performance. Be_2C possesses a lower atomic number (compare to HDC), higher density (compare to CH and Be). Its anti-fluorite structure results in a smoother surface and benefits to grain refinement [3]. In addition, as a yellow-brown transparent crystal, the