Development of carbon deposits cleaning technique for metallic mirrors in HL-2A

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\textbf{A B S T R A C T}

In order to develop effective techniques for the cleaning of in-vessel optical components from deposited carbon films, a Q-switched Nd:YAG laser cleaning system for HL-2A tokamak first mirrors has been tested in the laboratory recently. A polycrystalline molybdenum mirror sample exposed in HL-2A tokamak with a deposited carbon film of 1 μm was used to demonstrate the feasibility of the proposed laser cleaning technique. The test was performed on a Mo mirror with an area of 20 mm × 20 mm. The carbon deposits were almost completely removed by multiple pulses repeated spatial scans. Reflection of the Mo mirror was investigated before and after the laser cleaning. In the wavelength range of 1200–2500 nm we found that the reflectivity of the metallic mirror was recovered to ~90% after the cleaning procedure.

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1. Introduction

The reflectivity of unprotected in-vessel optical components (first mirror) in reactor grade fusion device such as ITER will be degraded significantly in a short time because of carbon contamination. Therefore, the mitigation of carbon deposition is critical to ensure the performance of ITER optical diagnostics throughout the entire working cycle of the machine. In order to solve the first mirror carbon deposition problem, different methods have been tested, such as selection of optical component materials, mechanical protective, and electron cyclotron wave discharge cleaning [1–3]. Recently, pulsed laser cleaning has also been proposed [4–6].

Laser cleaning technology has many advantages such as accurate focusing, high efficiency [6], and remote operation. It has been used widely to clean oxide from paints, contamination from silica, and rust from apparatus surface [7]. In nuclear fusion research, nanosecond pulse laser has been tested for detritiation from materials [8–10]. Although laser ablation of carbon deposits on the first wall has been demonstrated with good results, this technique when applied to the first mirror has to be demonstrated. The goal of this study is to provide information that will aid performance optimization for in situ cleaning of first mirrors.

2. Samples preparation and exposure

To study cleaning of a mirror exposed to a fusion environment, a polycrystalline molybdenum sample was exposed in the HL-2A, which is a medium-sized tokamak with major radius and minor radius are 1.65 m and 0.4 m, respectively. It has graphite limiter and divertor, and the divertor chamber surface is covered with CFC tiles [11]. The molybdenum mirror has dimensions of 60 mm × 62 mm, was polished finish and gilded with 1 μm gold film. The mirror reflection was over 96%. The mirror sample was placed in the high field side at the equatorial plane and was kept at a distance of 120 mm from the last closed flux surface (LCFS) (see Fig. 1a). The sample was exposed to 2550 pluses of deuterium ohmic discharge (plasma current of 200–300 kA, electron density of 2–4 × 10\textsuperscript{20} m\textsuperscript{-3}), 130 pluses of deuterium H-mode with Edge Localized Mode discharges (plasma current of 120–150 kA, electron density of 1–2.5 × 10\textsuperscript{21} m\textsuperscript{-3}), 10 h siliconization, and 100 h of helium glow discharges during 2008–2009 campaigns.

Fig. 1b and c are photos of the mirror before and after plasma irradiation. Irradiated sample surface was covered with a dark gray film composed of carbon, hydrocarbons, Si and Fe impurities. The film thickness was determined by surface profilometry to be about 1 μm.

3. Experimental set-up

The experimental set-up of the laser cleaning in the laboratory is shown in Fig. 2. The system consists of a laser, an optical transmission, and a sample holder. A Q-switched Nd:YAG laser is the optical source with wavelength of 1.06 μm, maximum output energy of 100 mJ. It has a beam diameter of 5 mm, pulse repetition frequency of 1–10 Hz, pulse width of 10 ns and the spot energy has a Gaussian distribution. In order to improve the uniformity of the energy of the laser spot, a variable aperture is set in the vicinity of the laser output. The beam splitter divides the laser beam into two parts: one is...