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Response of optical materials to high heat load given by laser pulses
光学材料の高熱負荷時の光応答

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Ceramics or glasses such as alumina (Al_2O_3) or silica (SiO_2) are candidate materials for optical or electrical devices for fusion reactor. However, it is concerned degradation of optical or electrical properties caused by irradiation. Since these materials are forecasted to be subjected high heat load, it needs to find out the optical response from materials under such a condition.

1. Introduction

Optical, electrical and thermal properties of ceramics or glasses such as alumina (Al_2O_3) and, silica (SiO_2) which will be used optical or insulating materials in fusion reactors are degraded by irradiation of energetic photons and/or particles appearing as radiation-induced electrical degradation (RIED) and radiation-induced conductivity (RIC). Degradation of optical properties, such as coloring and loss of transparency caused by the irradiation to optical materials are also concerns for their use as fiber optics and windows. Because electric excitation plays important role in some of the degradation of the optical properties, in-situ observation under the irradiation is required to understand the optical degradation.

In a fusion reactor, glasses or ceramics are exposed to high thermal load (energetic particles and photons) escaping from edge or core plasma, however, the optical response of materials under such conditions have not been studied well.

In this work, we have observed light emission from alumina induced by high power (approximately MW/cm^2- GW/cm^2) Nd:YAG laser exposure. Because laser irradiation damage in materials occurs in connection with photochemical reaction, it needs to examine effects of surrounding atmosphere and irradiation temperature.

2. Experimental

Fig. 1 shows a schematic diagram of experimental arrangement. A specimen disc made of a single crystal sapphire (Al_2O_3) was used. A specimen disc was 10 mm in diameter and 1 mm thickness. A pulsed laser light was irradiated normal to the specimen and light emissions to both backward and forward directions were observed. The laser light used here was the Fourth harmonic of Nd:YAG laser (wavelength 266 nm) with a pulse width of 20 psec and frequency was 10 Hz, and the energy density was up to 1.5 J/cm^2/pulse.

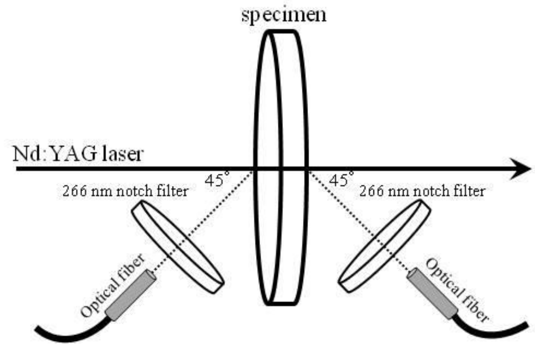

Fig. 1 schematic diagram of experimental arrangement

The laser light was focused on the sample surface by a quartz lens of the focal length of 300 mm. Light Emission was detected by a spectrometer through optical fibers and a notch filter to cut the incident light.

3. Result and discussion

Fig. 2 shows observed light emission spectrum of alumina induced by 266 nm Nd:YAG laser irradiation with 500 mJ/cm^2/pulse laser energy density. Observed emission spectrum shows three broad band centered at 320 nm (3.8 eV), 420 nm (3.0 eV), attributed to F^+, F center. And 720 nm broad emission band was likely caused by impurities such as Fe^{3+} and Ti^{3+}. In addition, black body radiation due to the temperature increase of the sample surface could have some contribution. The F^+, F center emission bands observed here were very similar to those observed in cathodoluminescence (CL) [1] or in the other energetic particle induced luminescence [2]. In addition, several line emissions were observed. The 693 nm (1.7 eV) emission is attributed to chromium impurity in alumina (Cr^{3+} center), and the 396 nm (3.1 eV) emission is from Al I caused by laser ablation.

The forward emission intensities of both F^+ and F center stayed nearly constant with the number of laser pulse shots. While, the reflection of primary laser beam monotonically increased. These observations suggest that the laser irradiation is not likely to create oxygen deficiencies. However, the increase of the reflection suggests some modification of surface and subsurface region owing to ablation.

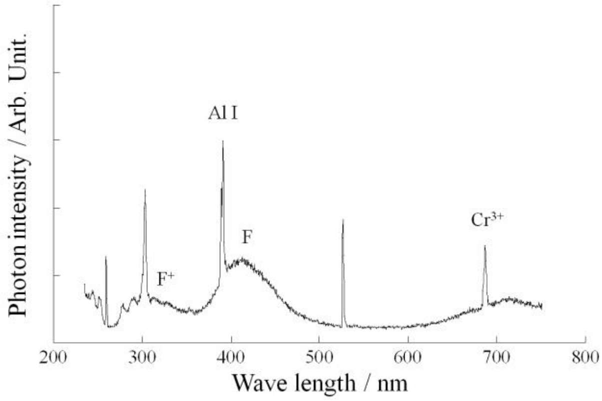

Fig.2 luminescence spectrum induced by 266 nm Nd:YAG laser irradiation

4. Conclusion

We have conducted laser induced luminescence studies. The observed emission spectra were constructed from the emissions due to oxygen deficiency defect centers (F and F^+ centers), and various line emissions caused by Cr^{3+} impurity, ablated Al atoms and ions. The emission intensities were different for backward and forward emissions. Therefore detailed studies of the laser induced luminescence would give useful information on laser damaging of ceramics or glasses.

References

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[2]A. Al Ghambi, P.D. Townsent, Nucl. Instr. Meth. B **46** (1990) 133-136