§45. Irradiation Effects of Low Energy Helium Ions on Optical Absorption of CaF_2

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CaF_2 single crystals represent an excellent medium for optical applications because of its high transmissivity in the visible and IR regions and its resistance to acids and alkalis. Therefore, it is important to study irradiation effect on optical properties of CaF_2 single crystals for further processing or application in a radiation environment such as lens materials for fusion energy applications [1]. Extensive studies on irradiation damage, optical absorption and photoluminescence of CaF_2 induced by X-ray, c-ray, laser, neutron, electron, and ion beam have been reported [2].In the present work, effects of low energy helium ions irradiation on the optical absorption have been examined and tried to find their causes.

The material used in the present experiments was optical polished (1 0 0) CaF_2 single crystals. Irradiations of helium and deuterium ion at 8 keV were carried out in an ultra-high vacuum evacuation apparatus equipped with a small duo-plasmatron type ion gun. Helium ions at 8keV were irradiated up to the fluence of 1×10^{22} ions /m^2. The ion flux (He^+) was about 1×10^{18} ions /m^2. A mask made of stainless steel covered the sample to confine the irradiated area to a 8 mm diameter circle.

After the irradiation, optical transmission spectrum was measured with a spectrophotometer for the wave length between 190 and 900 nm. Microstructure of cross section of specimen near surface irradiated by helium ions was observed with a transmission electron microscope (TEM).

The optical transmission spectra of un-irradiated and helium ions irradiated up to 1×10^{22} ions /m^2 at room temperature were shown in Fig. 1. The transmissivity of the sample irradiated by helium ions decreases with increasing fluence. In particular, decrease of the transmissivity of samples irradiated by 1×10^{20} and 1×10^{21} ions /m^2 is significantly large. Furthermore, irradiated sample have three absorption peak at 340 nm, 420 nm and 540 nm. The helium ions irradiation colored the CaF_2 crystal a faint purple at the fluence above 1×10^{21} ions /m^2. From the shape of the spectrum in the visible wavelength (400 – 800 nm), the purple color of the implanted region is attributed to the absorption peak at 420 nm and 540 nm. The complexity of the transmission spectra indicates the presence of several types of color centers due to a variety of defects. In the present case, cross sectional TEM observation clarified that dense bubbles with a diameter of about 2 nm are observed in the sub-surface region from the surface up to 100 nm at the fluence of 1×10^{21} ions /m^2. These results suggest that strong absorption peak around 420 nm and 540 nm were associated with helium bubble.

Fig. 2 shows the optical transmission spectra of helium ion irradiated CaF_2 single crystals at the temperature varied from room temperature to 473 K. All samples were irradiated by helium ions at a fluence of 1×10^{21} ions /m^2. All the samples have similar peak shapes but different intensities in the spectra. The absorption peak of around 540 nm increase with irradiation temperature. As a result, the sample irradiated at 473 K was colored clear purple. It is necessary that detail understanding of physical relation between the transmissivity and sub-surface structure will be carried.

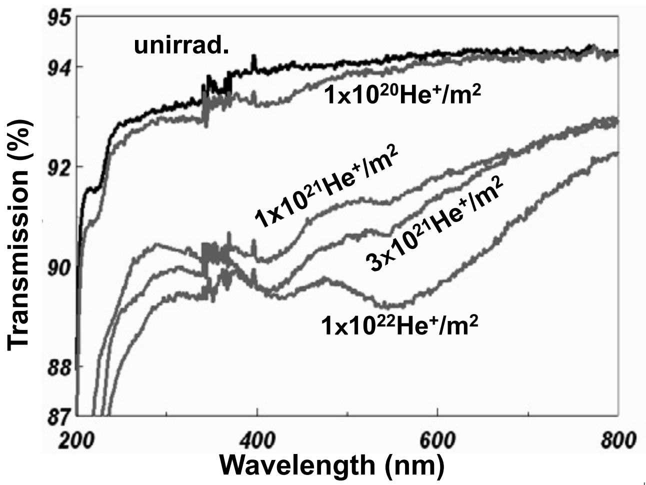

Fig. 1. The optical transmission spectra of as-received and He^+ irradiated CaF_2 single crystals at fluence ranging from 1×10^{20} to 1×10^{22} ions /m^2 at room tempareture.

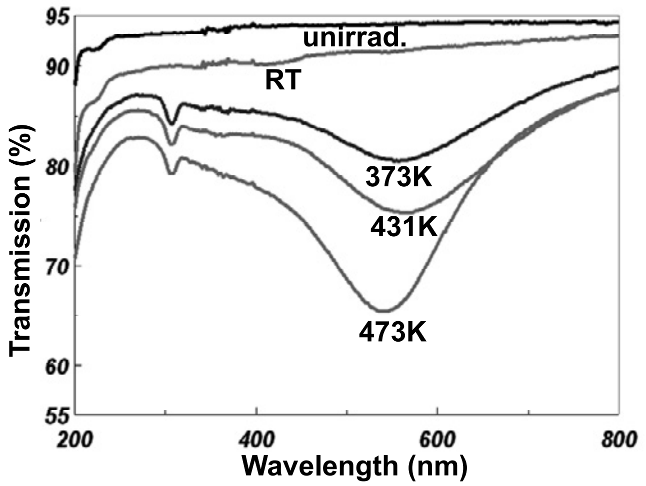

Fig. 2. The optical transmission spectra of helium ion irradiated CaF_2 single crystals at the temperature varied from room temperature to 473 K.

[1] S. Oh, S. Seo, KSTAR Team, Journal of Instrumentation, 7 (2012) C02041
[2] ex. D. W. Cooke, B. L. Bennett., J. Nucl. Mater. 321 (2003) 158.