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Helium ion implantation dose dependent microstructure and laser damage of sapphire

Sapphire is used in diagnostic systems for the International Thermonuclear Experimental Reactor (ITER), where it will play important roles as electrical insulation and optical components. It is one of the optical candidate materials to be used in the high power solid-state laser driver for inertial confinement fusion (ICF). It is thus necessary to investigate the radiation effect in alumina generated by radiation such as energetic electrons, ions, neutrons or photons.
In this work, the (0001) sapphire samples are irradiated with 60 keV helium ions at the fluences up to 1×1018 ions/cm2 at room temperature. The microstructure evolution and optical properties as well as laser induced damage threshold are investigated. The density and amount of defects increase with the increasing implantation fluence. The surface becomes rough because of the aggregation of helium bubbles and migration towards the surface. There is a lattice expansion up to ~4.5% in the implanted area and the lattice distortion measured from dispersion of (110) diffraction is ~4.6 degree. Such strain of crystal lattice is rather large and leads to contrast fluctuation at scale of 1~2 nm (the bubble size), shown in Fig. 1. The laser induced damage threshold (LIDT) is investigated to understand the effect of helium ion beam irradiation on the laser damage resistance of sapphire components and the results show that the LIDT decreases from decreases significantly from 5.43 J/cm2 to 4.62, 3.71, 2.64, and 1.80 J/cm2, respectively, with the increasing implantation fluence due to the absorptive color centers, helium bubbles and defects induced by helium ion implantation. The laser damage morphologies of samples before and after ion implantation are also presented in Fig. 2.

Primary author(s) : Dr SUI, Zhan (Shanghai Institute of Laser Plasma, Shanghai, 201800, China)

Presenter(s) : Dr SUI, Zhan (Shanghai Institute of Laser Plasma, Shanghai, 201800, China)