Short Pulse Soft X-Ray Laser Ablation Research

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The short pulse laser ablation have been extensively studied for confirmation and discussion of damage formation including estimations of thresholds, and surface machining, because the short pulse laser can suppress the heat affected zones (HAZs). Owing to the development of the x-ray free electron lasers, it can be possible to use the femtosecond soft x-ray laser pulses for ablation studies. Irradiation examines for silicon and silica glass samples at the soft x-ray free electron laser (SXFEL) beamline at SACLA reveals that the SXFEL pulses can make HAZ-less smooth craters on silica glass surfaces [1], and the appropriate selection of the SXFEL wavelength can make the nano-size modification on silicon surface in the vicinity of the damage threshold [2]. These results will be contribute to deep understandings of the direct surface processing including the damage formation process.

On the other hand, advances in physical studies and high-power laser technologies enabled us to realize the laboratory-size laser-driven plasma based soft x-ray lasers (SXRLs). We have examined ablation/damage phenomena for dielectric, insulator, metal materials and multilayer optics by use of the picosecond SXRL pulses. It was confirmed that morphologies of ablation structures strongly depended on the sample materials. And damage thresholds and modification structures obtained by the picosecond SXRL provide the same results by the femtosecond SXFEL. This means that picosecond SXRL irradiation experiments can give a good benchmark for femtosecond SXFEL irradiation experiments. However, the SXRL is a self-amplified spontaneous emission laser source, so that the shot-by-shot output energy has a relatively large fluctuation. Recently, we have developed the SXRL beamline equipped with an intensity monitor in order to correct accurate energy values during the irradiation experiment [3].

We will present the recent achievements of ablation studies obtained by the SXFEL and the newly constructed SXRL beamlines.

[1] K. Mikami et al., *Opt*. *Lett*. **2020**, *45*, 2435.
[2] T. –H. Dinh et al., *Commun*. *Phys*. **2019**, *2*, 150.
[3] M. Ishino et al., *Appl*. *Opt*. **2020**, *59*, 3692.