Processing of Ni thin film by sub-micron focusing of high-order harmonic pulses in the XUV region

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Keywords: High-order harmonic generation, Laser processing

Non-thermal laser processing using femtosecond near-infrared (NIR) laser pulses has been widely used for microfabrication because of its high processing resolution. However, considering the diffraction-limited size of the NIR laser pulses, the spatial resolution is limited to a few micrometers due to the long wavelength of around 1 μm. Therefore, a laser processing technique with a sub-micron spatial resolution has been awaited for further development of micro- and nano-fabrication processes.

To meet this demand, we have been developing a laser processing system using femtosecond laser pulses in the extreme ultraviolet (XUV) region of around 30 nm [1, 2]. By focusing femtosecond NIR laser pulses on a rare-gas medium, we generated femtosecond XUV pulses as the high-order harmonics and irradiated a thin acrylic resin film with the focused XUV pulses to drill sub-micron holes on the surface [2].

In the present study, we demonstrate sub-micron machining of metallic materials having a much higher damage threshold than an acrylic resin. Using a Wolter mirror with a large aperture, we focus the generated XUV pulses whose pulse energy is at most 1 nJ into a sub-micron spot to achieve a sufficiently high fluence of 100 mJ/cm^2. We irradiate Ni thin films with the focused XUV pulses and measure the surface morphology of the irradiated position using an atomic force microscope. We have revealed that, when the thickness of the Ni thin film coated on a silicon substrate is 5 nm, Ni atoms in the irradiated area whose diameter is ~1 μm are removed and the surface of the silicon substrate is exposed to the vacuum as shown in Fig. 1, indicating that laser machining of a variety of metallic materials with a sub-micrometer resolution can be achieved using our submicron XUV focusing system.

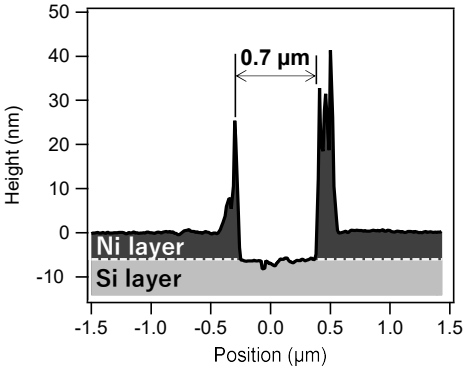

Fig. 1 The cross-section profile of the atomic force microscope image of the sub-micron structure on the Ni surface created by the irradiation of the focused ultrashort XUV laser pulses.

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