Direct Nanomachining of Inorganic Transparent Materials Using Laser Plasma Soft X-Rays

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Micromachining inorganic transparent materials at high precision is required for nanometric chemical analyzers and chemical reactors in medicine and biotechnology, and for optical devices such as gratings, photonic crystals and optical waveguides. For these applications, it is required to machine a wide variety of materials precisely at low cost. We have investigated direct nanomachining of inorganic transparent materials using laser plasma soft X-rays [1, 2]. The soft X-rays were generated by irradiation of Ta targets with 532 nm Nd:YAG laser light with a pulse duration of 7 ns, at an energy density of $\sim 10^4$ J/cm^2. The soft X-rays were focused on samples, using an ellipsoidal mirror that we desined so as to focus soft X-rays at around 10 nm efficiently. We found that synthetic quartz glass, fused silica, Pyrex, LiF, CaF_2, Al_2O_3, $LiNbO_3$ can be machined smoothly. Typically, quartz glass is ablated at 40 nm/shot, and has a surface roughness less than 10 nm after 10 shots. In order to investigate lateral resolution, we fabricated a WSi contact mask with 200-nm-pitch line-and-space patterns on quartz glass. Figure 1 shows an atomic force micrograph of the quartz glass plate, after a single shot irradiation with laser plasma soft X-rays and etching the WSi mask. We found that quarts glass plates can be machined at a resolution less than 100 nm. In conclusion, we have established a technique for nanomachining inorganic transparent materials using laser plasma soft X-rays at a precision less than 100 nm.

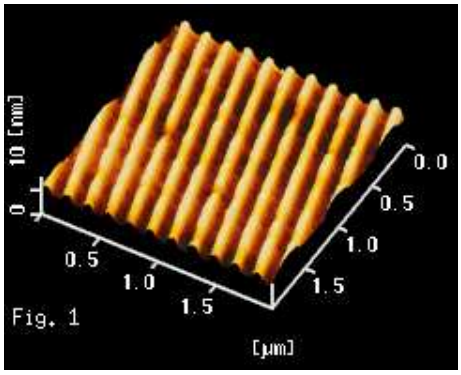

Fig. 1

[1] T. Makimura, S. Mitani, Y. Kenmotsu, K. Murakami, M. Mori, and K. Kondo, Appl. Phys. Lett. **85**, 1274 (2004).

[2] T. Makimura, H. Miyamoto, Y. Kenmotsu, K. Murakami, and H. Niino, Appl. Phys. Lett. **86**, 103111 (2005).

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