Effect of offset temperature on replication of laser-assisted imprinting

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Thermal nanoimprinting is a low-cost mass fabrication method of various products such as microreactors, diffraction gratings, organic electroluminescence devices and other optical devices. However, the cycle time of conventional nanoimprinting is long because the substrate and mold are heated and cooled from the outside in the process. To date, we have proposed and demonstrated a high-throughput method, the laser-assisted imprinting of nanostructured glass[1] and polymer[2], in which only the surfaces of the glass and mold are heated with a laser, and only the mold surface is directly heated with the laser. This method leads to not only a short cycle time but also low energy use in the imprinting process. In this paper, we investigated the effect of offset temperature of the mold and substrate on the replication area and replication degree.

The mold we proposed consists of two layers; a layer transparent to light (quartz) and a thin light-absorption layer (diamond-like carbon, DLC). The laser is irradiated from the backside of mold and absorbed by DLC film, and the surface of the nanostructured mold surface and substrate are heated. After the laser is turned off, the mold and substrate are cooled down together. We used a Nd:YAG laser (wavelength: 1064 nm) and its diameter, average power density, and the irradiation time are 75 μm, 11 kW/cm^2, and 33 ms, respectively. Figure1 shows the scanning electron microscopy image of the imprinted glass (glass transition temperature: 506 ˚C). In Fig. 1, 8-μm-pitch lines-and-spaces are finely replicated. The ridges with a width of about 100 nm were formed along the top corners on the imprinted lines.

Figure2 shows the relationship between offset temperature and diameter of replicated area. With higher offset temperature, larger area was replicated. The experimental results well agree with those of two-dimensional heat-transfer calculation. Using this offset technique, extra energy for preliminary heating is needed, however, the cycle time is shorter and whole energy is less than using conventional thermal nanoimprinting. Furthermore, the laser-assisted imprinting with offset temperature can be applied to continuous imprinting, i.e., roller imprinting.

[1] T. Sato, K. Nagato, T. Hamaguchi, M. Nakao, *Proc. of 2011 11th IEEE Int. Conf. on Nanotechnol. (NANO)* 1-4.
[2] T. Sato, K. Nagato, T. Hamaguchi, M. Nakao, *Digest of 37th Int. Conf. Microprocess and Nanotechnol. Conf. (MNE)* 2011.

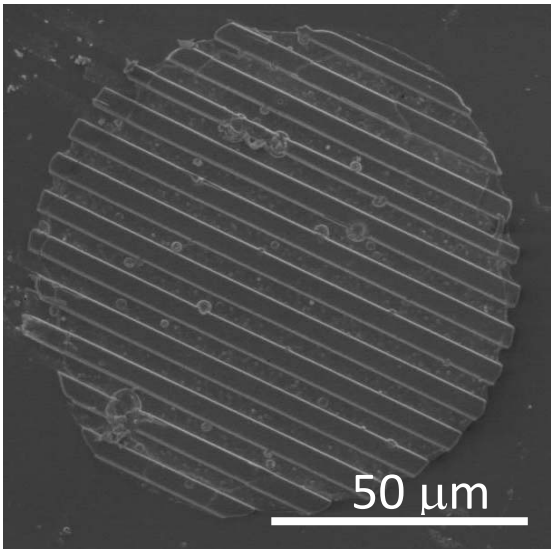

Figure 1: SEM image of replicated area of glass surface.

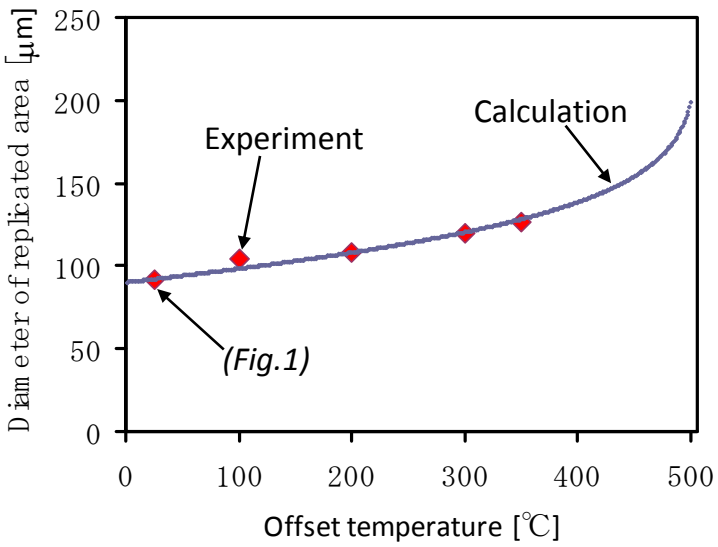

Figure 2: Diameter of replicated area as a function of offset temperature.