High-Speed and Low-Energy-Consumption Replication of Nanostructures with Laser-Assisted Roller Nanoimprinting

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Nanoimprinting is a mass fabrication method for nanostructured polymers.[1] However, the cycle time of conventional nanoimprinting is long because the polymer and mold are heated and cooled from the outside in the process. It was demonstrated that the method in which only the surfaces of the substrate and mold are heated leads to not only a short cycle time but also low energy consumption in the imprinting process.[2] To date, laser assisted roller nanoimprinting has been demonstrated.[3] In this study, using high power laser leads to high-speed and low-energy-consumption replication of nanostructures.

Figure 1 shows the schematic of experimental setup. We used a fiber laser (wavelength: 1064 nm, beam diameter: 0.45 mm). Reflected by a galvanometer mirror, the laser irradiated and heated the surface of the nanostructured roller through an $f\theta$ lens, a glass roller and a polymer. The mold has 600-nm-pitch line and space (L/S) pattern (Figure 2(a)). A used polymer was a polymethyl methacrylate (PMMA) film (thickness: 75 μm, T_g: 89 ˚C).We scanned the laser and replicated pattern in a line while feeding PMMA. The feeding speed was set high not to overlap the replicated lines (Figure 2(b)). We verified the laser power and the scanning speed. We measured the width of replicated lines and calculated the replication speed from the measured width and the scanning speed. Furthermore, we calculated the heat conduction analysis with finite element method (FEM). The replicated width was the width of the regions over 100 ˚C.

Figure 3(a) shows the replication speed as functions of laser power and irradiation time (beam diameter / scanning speed). High power and short irradiation time increase the replication speed. In this experiment, the highest replication speed was 650 mm^2/s at 100 W. Figure 3(b) shows the energy density (laser power / replication speed). High power and short irradiation time decrease the energy density. In this study, it was found that replication speed is higher and energy consumption is lower with the high power laser. It is also indicated that there are the optimal irradiation times for each power.

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[3] T. Sato, K. Nagato, T. Hamaguchi, M. Nakao, *Proc. IEEE NANO* (2012) 1.

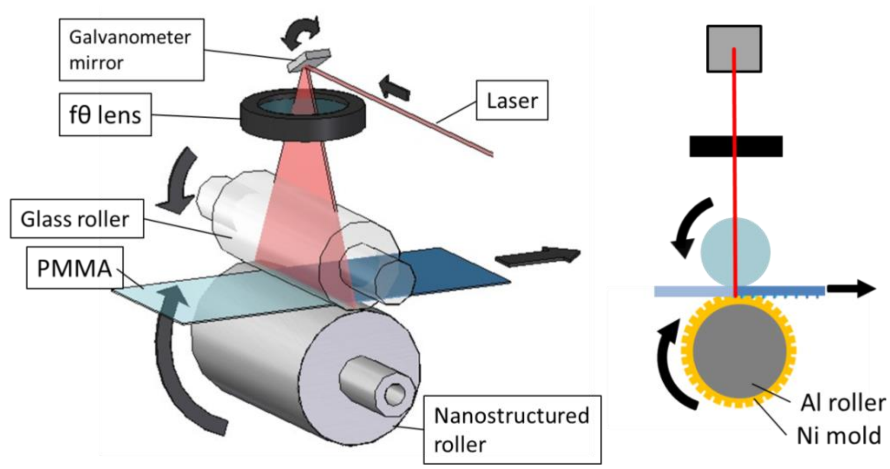

Figure1 The schematic of experimental setup used in this study.

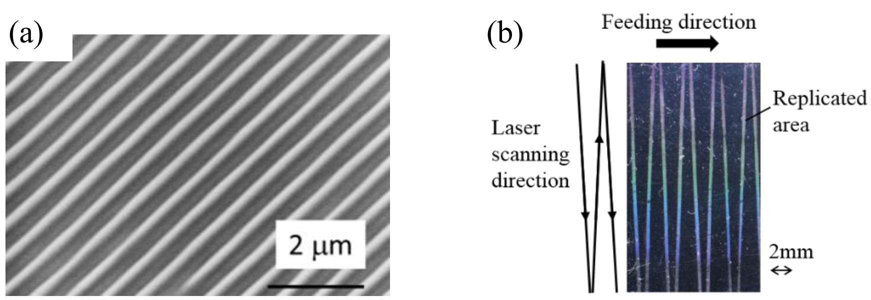

Figure2 (a)SEM image of 600-nm-pitch L&S pattern of Ni mold, and (b)Optical photograph of replicated PMMA.

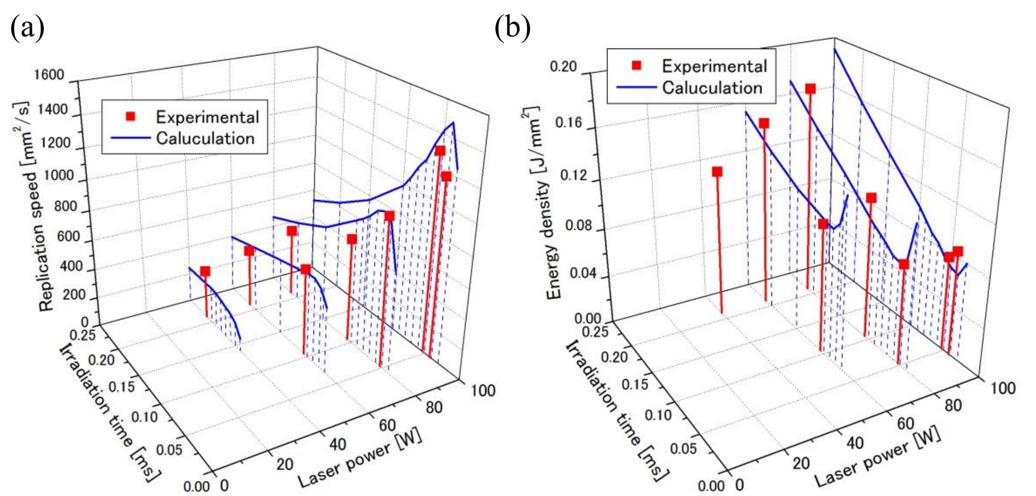

Figure 3 Experimental and calculation results of (a) replication speed and (b) energy density as functions of laser power and irradiation time (beam diameter / scanning speed).