

Rapid thermal imprint of high-aspect-ratio nanostructures with dynamic heating of mold surface

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High-aspect-ratio nanostructures are thermally imprinted in a short cycle time. A thin-film current heater located at the back of mold realizes the rapid heating and an upper punch and the heater substrate as coolants make the cooling time short (Figure 1). We use Si molds with line-and-spaces fabricated with electron beam lithography and deep reactive ion etching (Deep-RIE), also electroplated Ni molds from Si masters that are fabricated with RIE. Imprinting of various high-aspect-ratio shapes of mold surface are studied (Figure 2(a, c)). Polymethyl methacrylate (PMMA) sheet surface are imprinted using the molds (Figure 2(b,d)). The imprinted PMMA trenches shown in Figure 2(d) are shallower than the height of Si mold blade (Figure 2(c)). A thermocouple is inserted between the mold and PMMA sheet. The homemade imprinting machine can heat up to 150 °C within 1 s and cool to room temperature (20 °C) in 3 s. The imprinted area was about 10×10 mm², however, there is still room for larger imprinting area or shorter cycle time. This equipment concept is practical for high throughput thermal nanoimprint.

References

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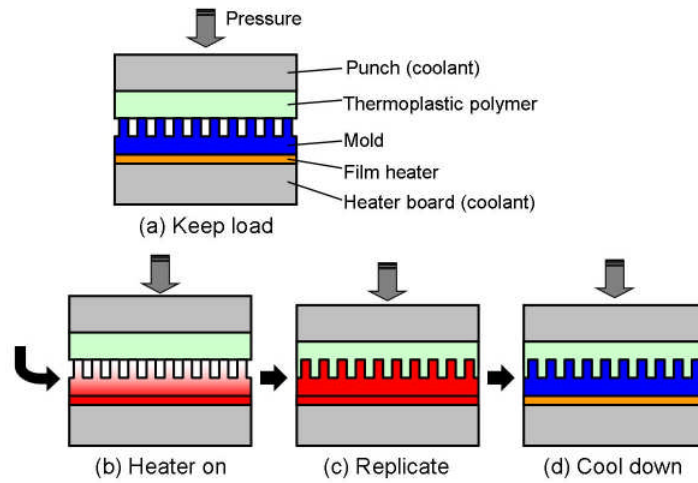


Figure 1. Schematic of rapid thermal imprint. It has main four steps; (a) pressurize the polymer sheet and the mold before heating, (b) heat by a film current-heater, (c) replicate the nanostructures when the temperatures of the mold surface and the polymer surface reach T_f , and (d) stop heating immediately after replication and cool down by the punch and the heater board.

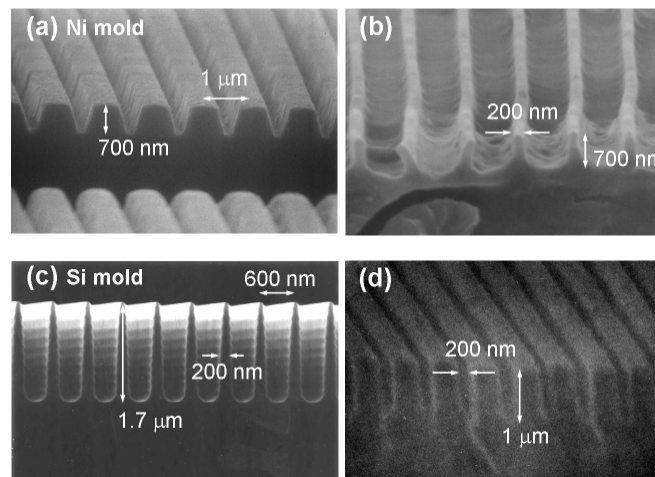


Figure 2. Cross-sectional SEM images of (a) Ni mold with high-aspect-ratio trenches (obtained by FIB machining), (b) replicated PMMA sheet surface with (a) (obtained by brittle fracture), (c) Si mold with high-aspect-ratio blades (obtained by cleavage cutting), (d) imprinted PMMA sheet surface with (c).