Thermal Roll-to-Roll Imprinted Nanogratings on Plastic Film

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A strong need exists for effective nanopatterning technique to fabricate the next generation devices at low cost and high volumes. Nanoimprint lithography (NIL)[1] has received a lot of attention, because of its process simplicity. Roll to Roll nanoimprint (R2RNIL)[2] can be used for optics and electronics, such as wire grid polarizers[3] and transparent conductive sheet[4]. In this study, we have examined R2RNIL high speed patterning of nanogratings on a plastic film. Our mold design consists of nanoscale line and space (LS) pattern. In order to fabricate the nanoscale pattern by using R2RNIL it is very important to understand replication behavior at the nanometer scale to predict the fabricated pattern. We focus on the replication behavior for a cellulose acetate film via thermal R2RNIL.

Figure 1 shows the schematic view of our thermal-type R2RNIL experimental setup. A flexible nickel replica mold was attached to the upper roll, which was be heated to target temperature. We have used the master nanogratings mold with line and space width of a 580 nm and 2160 nm, respectively. The pressure applied from the lower roll by air cylinder was 6.5 MPa. The temperature of the upper roll was varied from 31 to 120 °C when line feeding speed was constant (0.4-0.5 m/min). The T_g of cellulose acetate film (90 μm thickness) is 120 °C. The heights of the mold and the transferred pattern on the film were measured using atomic force microscopy (AFM, Digital Instrument Co., Dimension 3000). Figure 2 shows the height and shape of the nickel mold after R2RNIL process. Wearing of the Ni-mold is small and the heights of structures are close to the original 640 nm.

Figure 3a and 3b shows an AFM view of printed gratings at 109 °C and 120 °C. The depth of a transferred pattern at 120 °C was shallower than that at 109 °C because thermal R2RNIL process at near Tg causes reflow of a plastic material.

The pattern depth shows a linear behavior between 65 – 110 °C as shown in figure 4. We show controllability of the pattern depth with the process temperature, as well as with the pressure. The replication behavior in the nanogratings with spacing down to nanometer scale will be shown.

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[3] Y. J. Shin, et al., Nanotechnol. 23, 344018 (2012).

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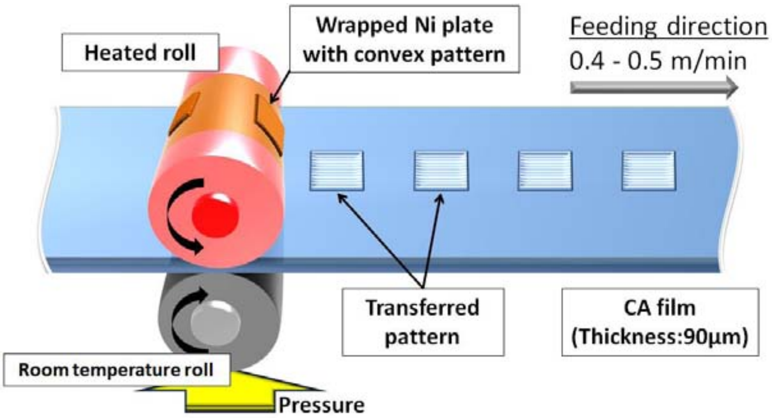


Figure 1: Schematic view of R2RNIL experimental setup.

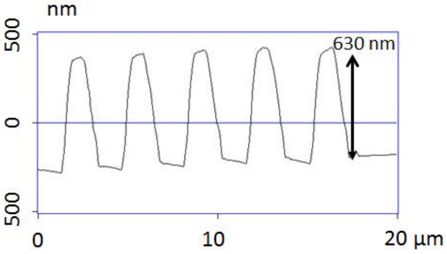
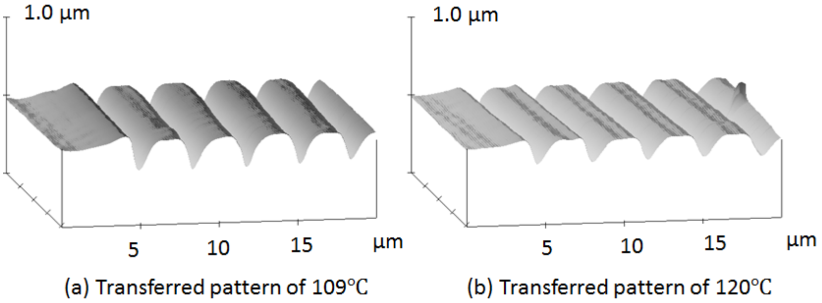


Figure 2: AFM Cross-section of a Ni master mold after 70 printed features. No wearing of the mold can be seen. The original height of the mold was 640 nm.



(a) Transferred pattern of 109°C

(b) Transferred pattern of 120°C

Figure 3: Transferred pattern features at optimal process temperature 109 °C (with pressure 6.5 MPa) and with temperature close to the Tg (120 °C).

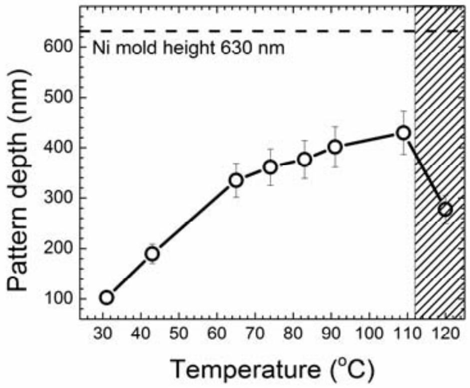


Figure 4: Pattern depth as a function of temperature show linear behavior when typical process temperature range 65 °C - 110 °C is used.