Thermal roll to roll nanoimprint using replica mould made by UV curable resin

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Ultra violet NIL (UV-NIL) [1] and thermal NIL (T-NIL) [2] are expected to be next-generation patterning techniques for fabricating nanopatterns. UV-NIL method uses UV curable resins and enables a very high throughput with nano-scale resolution (e.g. 18 m/min with UV- roll to roll NIL (R2RNIL) [3]). This is possible because of the short curing time of UV curable resin. On the other hand, the material cost of UV resins is expensive and the flexibility of the material design is low. In contrast, T-NIL, that uses thermal plastics as transferred substrates, is greatly required to fabricate nanopatterns at a low cost. This is due to the price of thermal plastics which is lower than that of UV resins. Furthermore, there are many choices of thermal plastic with desired properties on the contrary than the UV curable resins since thermal plastics have various properties respectively, such as superior transparency, chemical durability or high hardness. In the case of the T-NIL process, master moulds made by silicon or quartz substrates are normally used because of its high resolution. However, the fabrication cost of master moulds is very expensive, because complex processes such as electron beam lithography, metal deposition, lift-off and dry etching are typically required. In addition, the silicon and quartz substrates are not flexible, so it is impossible to perform thermal R2RNIL (T-R2RNIL) using the master mould. Therefore, replica moulds made by nickel electroplating are used for the T-R2RNIL process [4]. Although the nickel replica mould is widely used because it has a high resolution and does not require a release agent, some chemicals are needed for the electroplating, resulting in an environmental load. Therefore, the effective and eco-friendly method for fabricating a release-agent-free replica moulds for T-R2RNIL is also strongly expected.

In this study, we perform T-R2RNIL using a replica mould made by a special UV curable resin (PARQIT OEX-028-X433-3, Autex Co., Ltd., hereafter X433-3). Previously, we have reported that the replica mould fabricated by X433 shows high performance for UV-NIL process [5]. The UV-cured resin had a high hardness (pencil hardness of 4H) and the fluorinated component contained in X433-3 segregates at the surface of the cured resin after heat treatment. This effect allows release-agent-free NIL process.

To investigate the T-NIL performance of X433, we prepared the replica moulds using three kinds of UV curable resins, not only X433-3, but also PAK-01-CL (hereafter PAK, TOYO GOSEI. Co.) and ETAX-003XC (hereafter ETAX, Autex Co., Ltd.). The hardness order of the cured resins are X433 > PAK > ETAX. Figure 1 shows that the transform of the pattern height of the fabricated moulds before and after planar T-NIL process. The transferred substrate was a polymethylmethacrylate (PMMA) film. In this case, the release agent was coated on three resin patterns each other because the release property of the mold made by PAK and ETAX is poor. As a result, the pattern height of PMMA using the replica mould made by X433-3 produced the sufficient height and it becomes clear that the mould made by X433 has higher possibility to perform T-NIL, compared to the mould made by PAK or ETAX.

Next, we examined T-R2RNIL using the replica mould made by X433. In this case, no release agent was used. Figure 2 shows the schematic view of our T-R2RNIL equipment. In this study, the upper roll was heated by an internal electrical heater, whereas the lower roll was unheated. The imprinting load was 800 N and the imprinting speed was constant 0.4–0.5 m/min. The widths of line and space of the fabricated replica mould made by X433-3 were 400 nm and 670 nm, respectively. As a result, we succeeded in T-R2RNIL using replica mould made by UV curable resin without any release agent. We will exam the transfer characteristics of T-R2RNIL in detail using the three kinds of UV curable resin.

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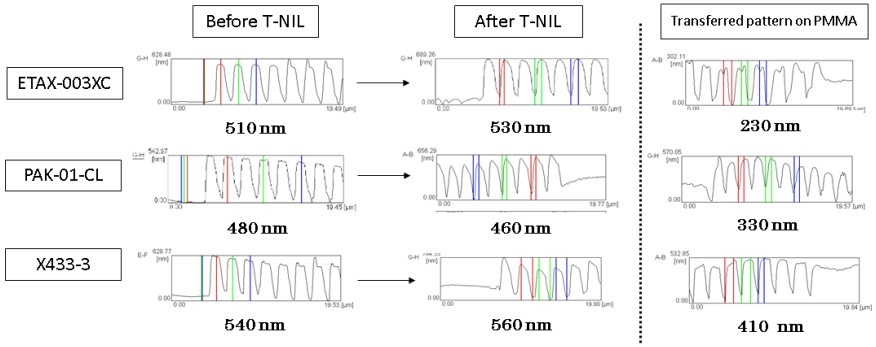

Figure 1. The pattern heights of the fabricated moulds before and after the planar T-NIL process, and the obtained PMMA patterns. The T-NIL conditions were 715 N for 1cm^2, 120 °C for 5 min. The pattern height of PMMA using the replica mould made by X433-3 produced the sufficient height.

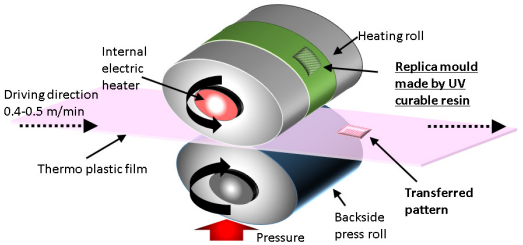

Figure 2. Schematic view of our T-R2RNIL equipment. The imprinting load was set to 800 N and the process temperature was raised up to 138 °C.

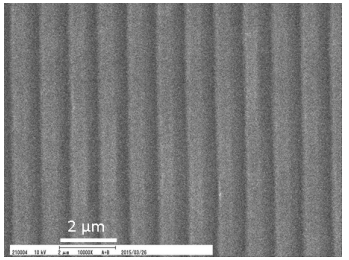

Figure 3. T-R2RNIL pattern at 129 °C on cellulose acetate (CA) film.

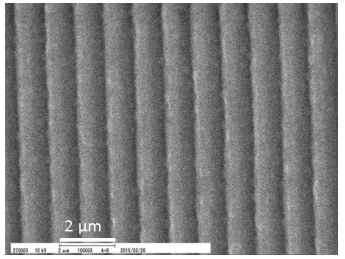

Figure 4. T-R2RNIL pattern at 138 °C on polymethylmethacrylate (PMMA) film.