Nanoimprint Mold with Integrated Heater for Synergistic Thermal and UV Nanoimprint

Zhong Zhang[1], Bingqing Luo[2] and Xing Cheng[1]
[1]Department of Materials Science and Engineering, South University of Science and Technology of China, Shenzhen, Guangdong 518055, China
Email: cheng.x@sustc.edu.cn
[2]Department of Electrical and Computer Engineering
Texas A&M University, College station, TX 77843-3128, USA

Nanoimprint lithography (NIL) is a lithographic technique which can fabricate nanoscale structures with high resolution, low cost and high throughput[1,2]. However, conventional thermal NIL needs long process cycle time and has the issues of thermal expansion mismatch and mechanical abrasion. UV NIL is usually done at room temperature and has its own limitations, such as liquid resist films which can increase the possibility of sticking to molds. In this work, nanoimprint mold with integrated heater is designed for synergistic thermal and UV NIL so that the advantages of both thermal and UV NIL can be utilized. We expect that the synergistic thermal and UV NIL can fabricate nanostructures with much more versatile processes.

In our technique, transparent and conductive indium tin oxide (ITO) is deposited on the fused silica mold in a uniform layer (Fig. 1(a)). Alternatively, ITO can be patterned into distributed resistive wires in meander form (Fig. 1(b)). Fig. 1(c)-(f) shows the synergistic thermal and UV NIL process by nanoimprint mold with integrated heater. Thermal treatment of resists is provided by mechanical contact of the mold and the resist shown in Fig. 1(d) and (e). Although the transmittance of ITO declines significantly in the UV region, near-UV or blue light can be used, such as 365- 435 nm light. Consequently thermal and UV NIL is achieved simultaneously in this process. Simulation was conducted with heaters in both uniform layer form and meander wire form. Considering heat generating by applied voltage and heat dissipation by natural convection of air whose heat transfer coefficient (HTC) is typically in the range of 5-25 W/(m^2·K), the relationship of stable temperature of the mold and the voltage is simulated and shown in Fig. 2(a) and (b). The results suggest that the process temperature can be precisely controlled by adjusting the input voltage. The time needed to reach stable temperature at HTC = 5 and 25 W/(m^2·K) in the layer heater was also evaluated as shown in Fig. 3(a) and (b). The time needed to reach stable temperature is about 200-400 seconds at a HTC of 25 W/(m^2·K).

We will report further work on the simulation of shortening process time through dynamic voltage application and experimental verification of the synergistic thermal and UV NIL. The synergistic thermal and UV NIL with a heater-integrated mold brings forth greater flexibility in NIL process. First it allows for UV NIL to be done at a temperature 30 to 80^{o}C above room temperature to greatly accelerate resist curing. This will result in better cured resist to reduce defect generation at the demolding stage. Demolding at a temperature higher than room temperature may also help in reducing mold-resist adhesion and hence defect mitigation. Second this technique can simplify the processing of materials such as SU8 that requires both heat and UV light. It can reduce the multiple mix-and-match processing steps into one simple step.

---

1 S. Y. Chou, P. R. Krauss, and P. J. Renstrom, Appl. Phys. Lett. **67**, 3114 (1995).
2 J. Haisma, M. Verheijen, K. van den Heuvel, and J. van den Berg, J. Vac. Sci. Technol. B**14**, 4124 (1996).

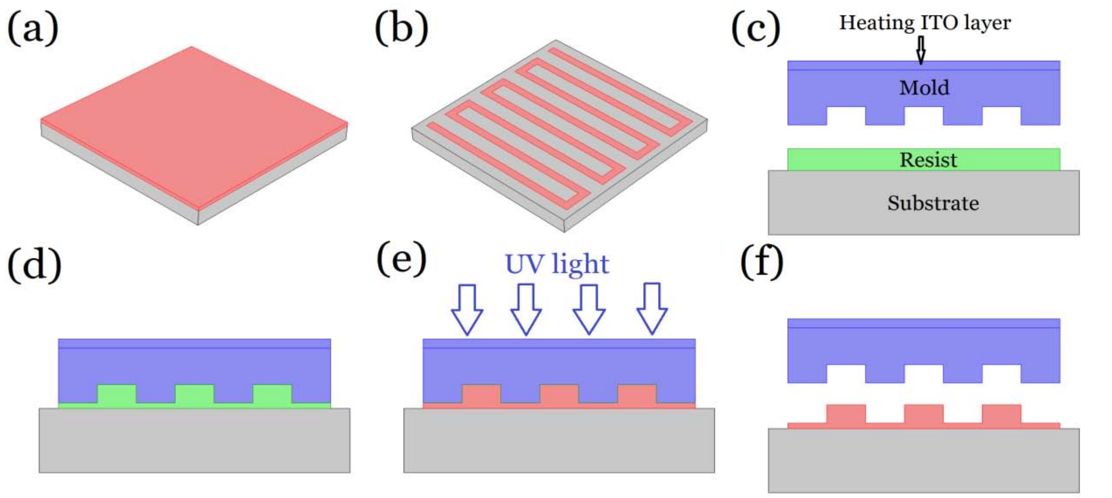

Fig.1. (a) uniform layer heater: the whole ITO layer (red part) as the heating source; (b) meander-shaped resistor: S-shaped wire (red part) as the heating source; (c)-(f) synergistic thermal and UV NIL process with heating ITO layer on mold.

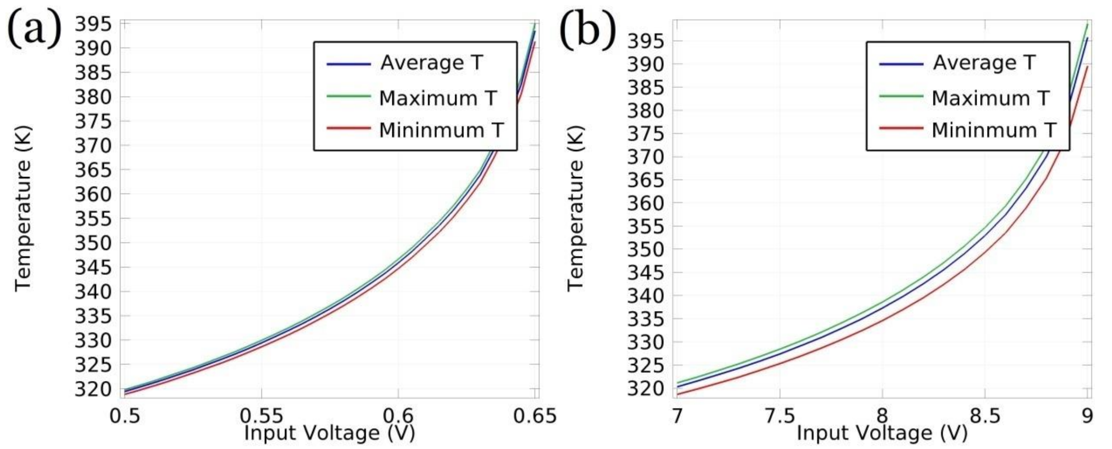

Fig. 2. Temperature-voltage curve of the mold for (a) uniform layer heater and (b) meander-shaped wire heater in the condition of HTC=5 W/(m^2·K)

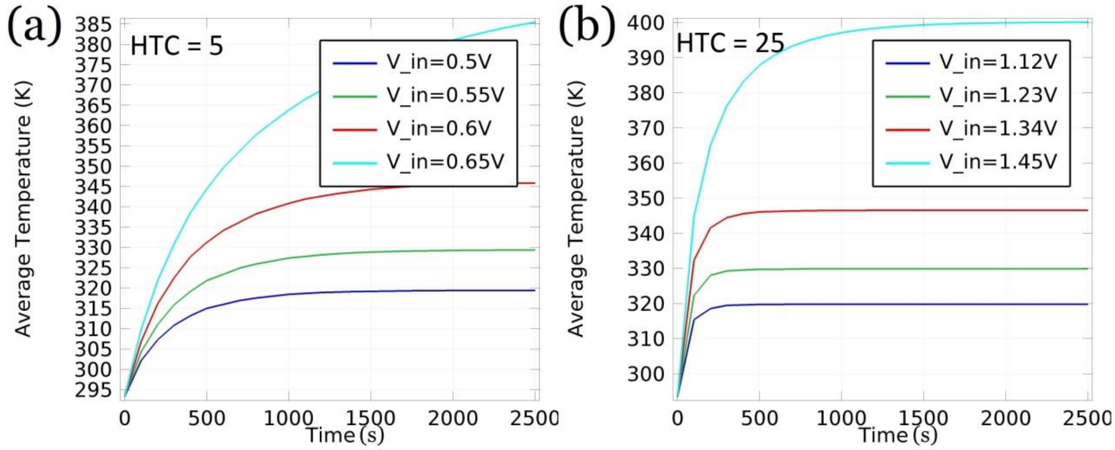

Fig. 3. Simulated temperature of the mold as a function of heating time with the uniform layer heater at HTC = (a) 5 and (b) 25 W/(m^2·K) for reaching stable temperatures of 320, 330, 347, and 399 K.