Polymer filling and mold durability for different shape cavities in nanoimprint lithography

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As a simple, inexpensive process used to fabricate micro- and nanometer-sized patterns with high throughput and resolution, nanoimprint lithography (NIL) has become not only popular in laboratories but also applicable in mass production to produce large-scale parallel replication. Although there are many advantages in NIL, some problems have appeared in the process achieving industrial production. From the perspective of the process flow, product defects appear in the imprint process and demolding process. Some defects such as incomplete filling during imprint, breaking of polymer embossment during demolding, and poor mold durability seriously affect pattern transferring fidelity. Pattern transferring fidelity is the most important indicator to evaluate imprinting quality. How to improve pattern transferring fidelity becomes the primary task of current NIL. A large number of scholars made great efforts to study effect of various factors on pattern transferring fidelity. However, researches of mold are mainly focused on effect of mold material, aspect ratio, duty ratio and various taper angles with mold on pattern transferring. It is neglected that contact surfaces of cavity sidewall and cavity shape have an impact on filling quality and service life of mold during imprint process. In this paper, the three kinds of molds with rectangular cavity, trapezoidal cavity, and semicircular cavity are established to research polymer flow and filling mechanism under cavity sidewalls of vertical surface, inclined surface, and curved surface in embossing stage during T-NIL. The stress distributions on three kinds of mold patterns are compared to evaluate mold durability under different imprint pressure. Research results show that different shape cavity sidewalls have an important impact on polymer filling ratios and mold durability.

Figure 1 shows the schematic diagram of geometric models and boundary conditions for three molds with cavity in different shapes. The maximum Von Mises stresses according to imprint pressure for three molds are shown in Fig. 2. With an increase of imprint pressure, the maximum Von Mises stress of three molds constantly increases. In the comparison of the maximum Von Mises stress, the maximum stress of semicircular cavity mold is always the maximum, then followed by rectangular and trapezoidal cavity mold successively. There are sharp corners at the bottom and no sharp corner at the top of curved sidewall surface in semicircular cavity, which increases the maximum stress of sharp corners at the bottom to a certain extent. So, semicircular cavity mold is most likely to deformation under the same material and imprint pressure. Compared with rectangular cavity mold, inclined sidewall surface of trapezoidal cavity effectively reduce the maximum stress and can get effect of dispersive stress. The stress state of trapezoidal cavity mold is conducive to inhibit mold deformation.

References

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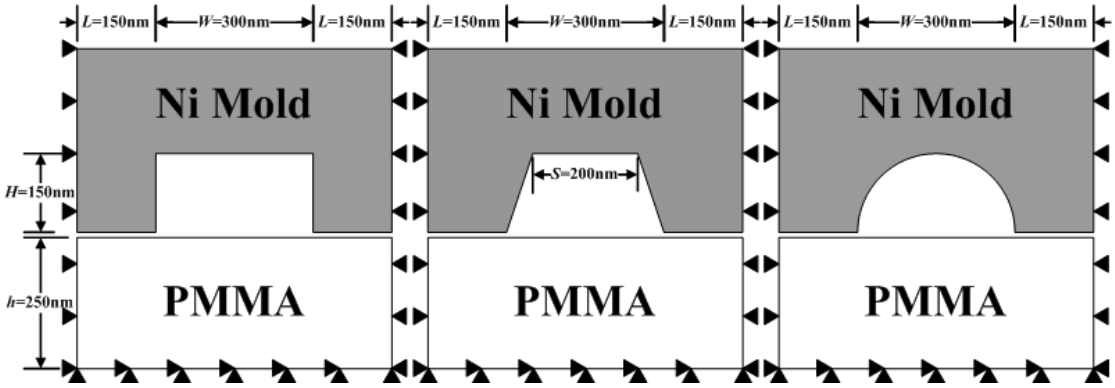

Fig.1. The maximum Von Mises stress according to imprint pressure for three molds..

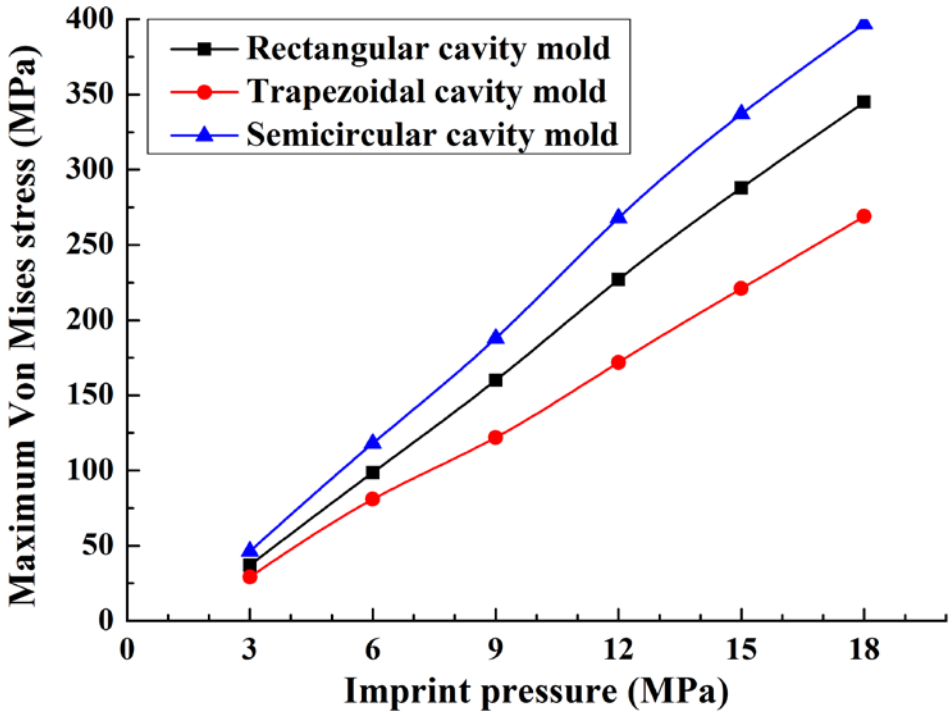

Fig. 2. The maximum Von Mises stress according to imprint pressure for three molds.