Three-Dimensional Patterning Using Ultraviolet Curable Nanoimprint Lithography.

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Although a large number of works on nanoimprint lithography (NIL) techniques have been reported, the the ability for three-dimensional (3-D) patterning using NIL has not been fully addressed in terms of the mold fabrication and imprint processes. Patterning 3-D and multilevel features are important because they eliminate multiple steps and complex interlevel alignments in the nanofabrication process. The 3-D and multilevel mold design and fabrication, and imprint processes have been studied and investigated in this research work.In the UV-NIL technique, a transparent mold with micro/nanostructure patterns on its surface is allowed to be replicated on UV curable polymer without the need of high applied pressure or temperature. UV-NIL has the potential to fabricate micro/nanostructures with high resolution, high reproducibility, low cost, high throughput and is capable of 3-D patterning. This research focuses on two aspects; the development of mold making and imprint processes. In the process of making a master mold, an EBL technique was employed for writing patterns on e-beam resists. PMMA positive resist was used for 2-D patterning and ma-N2403 negative resist from Microresist Technology was used for 3-D patterning. After being developed, the 3-D mold pattern was transferred onto quartz substrate using a single-step reactive ion etching (RIE) technique.A number of challenging issues such as surface charging, electron scattering and proximity effects surfaced during the EBL pattern writing on insulating and transparent molds. A number of new approaches have been developed for suppressing the charging effects in the 2-D and 3-D patterning. Using thin metallic coating on the quartz substrates or on top of the resist, or conductive polymer coating using PEDOT/PSS on top of the resist has demonstrated excellent results in a 2-D structure with a high aspect-ratio of 1:10 and feature sizes down to 60 nm. In 3-D patterning, two approaches have been followed; the critical energy method and/or a top coating of conductive polymer (PEDOT/PSS) layer. Isolated 3-D structures with feature sizes down to 500 nm were successfully fabricated using the first method while by using the second method, dense 3-D structures patterns with feature sizes down to 300 nm, on 400 nm pitch have been demonstrated.In UV-NIL, the surface roughness Rq(rms) should be less than 5 nm, which is important for replicating optical structures and devices. In this work, the RIE process been optimized to yield 2 nm roughness on a patterned quartz surface. This was achieved by optimizing the RIE process pressure of below 6 mTorr.The other part of this thesis is on replication or imprinting of 2-D and 3-D structures. In the process of replicating the master mold profiles, the imprint processes were carried out using a vacuum operated manual imprint tool which was attached to a Mask Aligner UV illumination system. In 2-D imprinting, resist sticking on the vertical side wall was the main issue, especially on high aspect ratio structures. Meanwhile in 3-D imprinting, the imprint results have shown good reproducibility in up to 15 imprint cycles, where the issue of Ormocomp soft/daughter mold cracking after long UV exposure had limited the repetition of the imprint cycles.In this thesis, the 2-D and 3-D resist patterning on

insulating substrates using the EBL technique have been demonstrated with the assistance of a number of developed charge suppression methods. Single-step RIE pattern transfer onto quartz substrates with surface roughness below 5nm has been achieved. Replication of 3-D and multilevel structures reliably make the UV-NIL technique suitable for future applications such as surface texturing, optical devices and many other complex structures including MEMS.

Subjects

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