Advances in Soft-Nanoimprint Lithography

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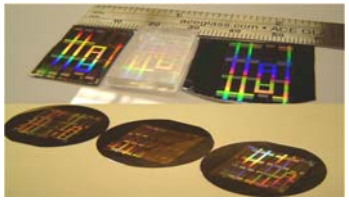
Presentation

Short Description: **Soft UV-nanoimprint lithography (S-NIL) in thin films of photopolymer resist at sub-micron dimensions is demonstrated enabling pattern transfer and device fabrication.**

Keywords: Pattern transfer, thin film, PDMS, device fabrication

Abstract: The advent of soft-lithography techniques has generated a number of variant approaches to patterning substrates using elastomeric templates. In general, as an alternative to photo or e-beam lithography, the use of inexpensive nanostructured polydimethylsiloxane (PDMS) molds to impart surface patterns to substrates has been considered highly effective based on the ability of PDMS to achieve conformal contact over large areas due to its low modulus (~2-3 MPa) and low surface energy (20 mJ/m^2). These attributes are exploited in many forms of soft lithography including nanotransfer (nTP)[1] and microcontact printing (μCP)[2]. However, such processes, in which material is transferred from the PDMS stamp to the substrate, tend to be restricted by material specific chemistries (i.e. thiols for nobel metals) and hampered by the need to continuously load material onto the stamp in order to produce pattern transfer. Furthermore, interaction between the stamp and transfer material can yield contaminated features, especially in regards to patterning copper.[3] Soft-nanoimprint lithography (S-NIL) provides access to PDMS generated surface patterning in a more generalized fashion. As a subset of nanoimprint lithography (NIL), S-NIL applies the concept of patterning a UV curable photopolymer based resist through filling of features on a mold's surface while exploiting the unique mechanical properties of PDMS to promote conformal contact between mold and substrate which is difficult to achieve with two rigid surfaces as typically done in traditional NIL. S-NIL has seen extensive use in the patterning of surface features on thick resist films (>1 um) yet virtually no reports exist demonstrating equivalent patterning in submicron films to produce straightforward lift-off masks for conversion of imprinted features to active materials or transfer the underlying substrate.



The factor limiting S-NIL in thin films of UV-curable resists is the propensity for PDMS to absorb organic compounds. Accordingly, thin films of resist permeate into the PDMS mold upon contact during imprinting; negating pattern formation. We have developed two approaches[4,5] to overcoming the this limitation ion S-NIL, the first being modification of the PDMS mold to construct a thin, resist impermeable fluorinated oxide (F-ox) barrier layer through surface oxidation and assembly of a fluorinated alkyl silane. These new PDMS$^{F\text{-}ox}$ molds effectively imprinted into thin films (70 nm – 630 nm) of UV curable resins consisting of either polyurethanes or acrylates, replicating high fidelity features over the surface of wafer substrates. The second development encompasses the tuning of molecular-weight in a thiol-ene based resist by a simple pre-cure procedure prior to imprinting resulting in sufficient buildup of resin molecular weight to prevent its absorption into PDMS molds yet maintain a low enough viscosity to allow for rapid molding of nanoscale features during the subsequent imprint-and-cure stage of the process. Both methods allowed direct transfer of the imprinted features to either active materials such as gold, nickel, and aluminum as well as to the underlying substrate by traditional reactive ion etch and lift-off processes. The later technique, involving the pre-cure step, obviated the need for mold modification and was used to fabricate organic field effect transistors, representing the seminal use of a soft *imprint* lithographic process to make such devices.

References:

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