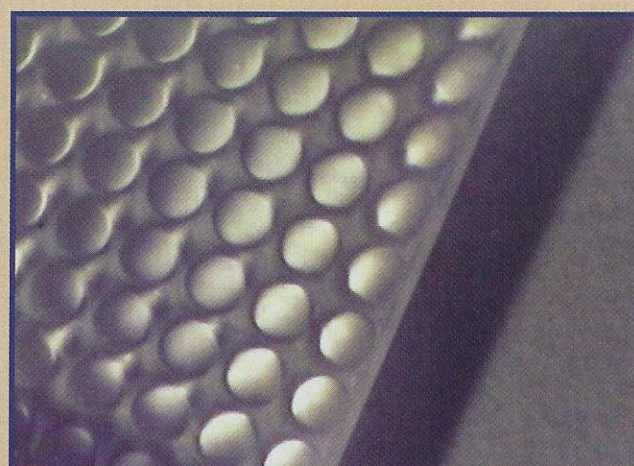
Soft Lithography Reproduces Microlenses

As we move from the electronics to the photonics age, micro-optics are finding a place in more and more applications. Now researchers have introduced a soft lithography process that they hope will enable the low-cost, mass production of microlenses for applications such as telecommunications, optical memory and imaging.

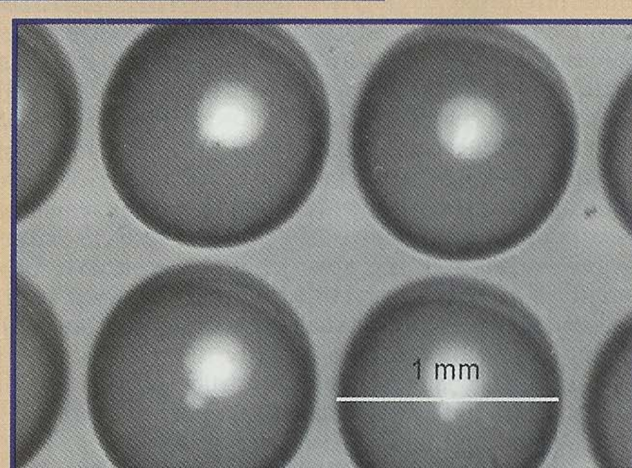
Several approaches exist for fabricating microlenses, but optical quality tends to come at the price of process complexity and higher expense. Soft lithography strikes a balance, by requiring the production of only one high-quality master from which many low-cost copies may be duplicated.

"The main driving force behind this work was cost and reliability," said Madanagopal V. Kunnavakkam, a senior research associate at Cornell University's Alliance for Nanomedical Technologies in Ithaca, N.Y. Photoresist reflow with dry etching, for example, yields excellent spherical surfaces, but this is an expensive process. It would be more advantageous if a few good lenses could be made using the reflow techniques and then replicated at a fraction of the cost.

Moreover, the available techniques are not suitable for the production of lenses for all applications. The reflow process and ink-jet techniques have difficulties fabricating aspherical elements. "Multilevel lithography needs to be used to pattern the desired surface," he said. "Here, the replication process can be used to



Using a soft lithography process, researchers are reproducing arrays of microlenses. The approach promises to reduce manufacturing costs by replicating lenses from a high-quality master.



In a demonstration of the technique, the team produced arrays of 1-mm-diameter lenses. Scanning optical profilometry and loss measurements indicated that the process yields elements with physical and optical characteristics comparable to those of the originals.

manufacture them once a good master has been fabricated."

In the new approach, the scientists coat a microlens array with trichlorosilane, an antistiction agent, and place it in a similarly treated petri dish. A quartz plate is stacked atop the master, separated by 1-mm-thick spacers, and dimethylsiloxane monomer with a polymerizing catalyst is poured into the dish. Oven curing and removal from the dish yield a negative mold of the master in polydimethylsiloxane attached to the quartz plate, which minimizes thermal distortion of the elastomer.

To reproduce lenses, they fill the cavities with a UV-curable epoxy that is loaded with 9- to 11-nm-diameter functionalized silica nanoparticles to improve the mechanical properties of the finished lenses and to lower moisture absorption. Then they gently place a quartz plate on top of the filled cavities to serve as a backing. After the curing process, they remove the plate, freeing the replicated lenses.

To verify the optical quality of the lenses, the researchers measured the surface profiles, lattice spacing, focal lengths and insertion loss of the masters and two batches of replicas. They found that the focal length distribution and insertion loss of the replicas were comparable to those of the masters. Oven curing the molds at 40 °C for 24 hours rather than at 65 °C for five hours, however, better reproduced the lattice spacing of the master.

Kunnavakkam noted that one issue the scientists face in developing the technique is the formation of bubbles in the epoxy. "The epoxy is rather viscous, and any bubble trapped during its manufacture tends to remain unless removed under vacuum," he said. To eliminate air inclusions, they have employed a vacuum dispenser but would like to automate this process. "To minimize human handling, some sort of an automated vacuum dispensing system that can drop measured quantities of the epoxy into the stamps would be useful." □

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