Microspheres Function as Microlenses for Projection Photolithography

Arrays of patterns with features smaller than 200 nm are being generated using a form of photolithography employing transparent polystyrene microspheres as microlenses. George M. Whitesides and Ming-Hsien Wu, both of Harvard University, report in the February 26 issue of *Applied Physics Letters* that their method offers a size reduction of features by factors of ≥1000 in a single exposure, thus producing submicron features starting from a pattern on a transparency with millimeter-size features.

Polystyrene microspheres (with diameter d = 1.5–10 μm, and refractive index of the sphere n_s = 1.59) were positioned in a two-dimensional array by placement in a poly(dimethylsiloxane) layer (PDMS, with refractive index of the membrane n_m = 1.40). This was accomplished by spin-coating a PDMS solution onto a passivated silicon wafer. The microspheres were then crystallized onto the PDMS layer, followed by another spin coating of PDMS. The cured membrane is then removed from the surface of the wafer. For d = 6 μm, n_s = 1.59, and n_m = 1.40, the focal length is ~6 μm. Therefore, the sphere must be positioned accurately to perform as an imaging lens. The elastomeric membrane, which conforms to the surface of the photoresist, assists in accomplishing this. With an optical projector (area of illumination ~25 × 25 cm^2) as the light source, the researchers have generated uniform micropatterns over a circular region with diameter about 0.5–2 cm. The area of high and uniform definition is basically determined by two factors: the distance between the mask and the spheres, and the size and shape of the pattern.

This technique provides a simple and direct method to make submicron structures with large size reduction, although limited to simple array structures with some distortion of the pattern. However, these patterns have characteristics appropriate for applications such as frequency-selective surfaces, photonic crystals, information-storage devices, and flat-panel displays.

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Monolithic SiGeC/Si Superlattice Structures Cool Electronic Devices

Thermoelectric (TE) refrigeration is a well-known technique for cooling and controlling the temperature of microelectronic and optoelectronic components. However, since many of the efficient TE cooler designs are based on bulk processing, it is often difficult to incorporate these coolers into the integrated-circuit (IC) fabrication process. Solid-state coolers, comprised of semiconductor materials that can be monolithically integrated into an electronic package, typically possess low TE figures of merit and thus poor cooling characteristics. However, a research collaboration led by John Bowers of the University of California—Santa Barbara and Ali Shakouri of the University of California—Santa Cruz has designed and grown a SiGeC/Si superlattice that is both compatible with IC production and capable of efficient refrigeration.

In the March 12 issue of *Applied Physics Letters*, Xiaofeng Fan at UC—Santa Barbara, in conjunction with additional research groups at HRL Laboratories, California Institute of Technology, and UC—Berkeley, describe a technique for fabricating SiGeC/Si microcoolers on a Si wafer. A SiGeC/Si superlattice was grown in a molecular-beam epitaxy system by evaporating Si, Ge, and C onto a 125-mm diameter (001) Si substrate doped to <0.005 Ω cm with As. Prior to deposition, the Si wafer was stripped using 5% HF and rinsed with de-ionized water. To remove any remaining oxide and to prepare the sample for epitaxial growth, the substrate was heated to 850°C and