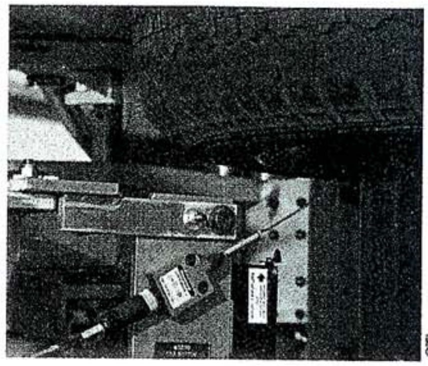
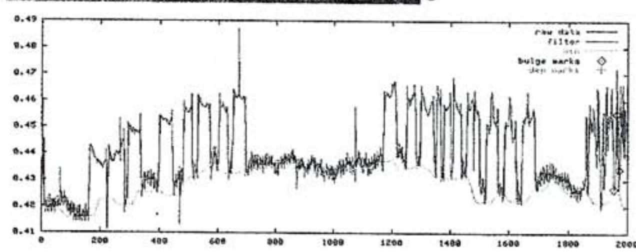


CTI

A tire-uniformity machine measures sidewall deformities on both sides of a rotating tire at the same time with two noncontact laser-based sensors (top). Each sensor terminates in a "whisker" safety switch (a spring-shaped device that protects the laser sensor from damage by shutting the machine down if the tire gets too close; a third can be seen at the left of the photo). The signal is processed to produce a plot showing the sidewall surface profile (bottom). The successions of regula features in the plot are lettering on the tire.



16 kHz. In use, a tire-uniformity machine rotates a tire at up to 60 rpm, with the laser-spot scanning the sidewall all the while. The return signal from the sensor is not affected by sidewall surface-color differences (motor oil on the tire, for example, or contrast due to black or white lettering), texture, speed of the tire rotation, or differing ambient light conditions. Software provides an *x-y* plot of bulges, dents, depressions, and the location of lettering on the sidewall (see figure). In addition, radial runout (out-of-roundness of the tire) can be measured.

Symens notes that one tire manufacturer took tires inspected by another system, ran them through the laser-triangulation system, and found that two of every three tires rejected by the other system were not defective. "False-positive tests are generally referred to as alpha misses," he says. "The alpha-miss rate is higher for capacitive probes, and also for tires that do not have a clear path on the sidewall (one unobstructed by letters, logs, or pin vents)." Hard-to-test tires may produce an alpha-miss rate as high as 15% to 20% for some tire-inspection systems.

The technology developed at CTI has been integrated into tire-uniformity machines built by several companies, including Akron Special Machinery, CTI's parent company. Laser triangulation is not new, even as applied to the characterization of tires; CTI's efforts have gone into more-tightly integrating the laser-sensor-based system with the testing and optimization control unit, which replaces existing controllers on four-post tire-test machines. To speed up measurements, engineers at CTI are in the process of increasing the sample rate of the system to 32 kHz.

John Wallace

MICRO-OPTICS

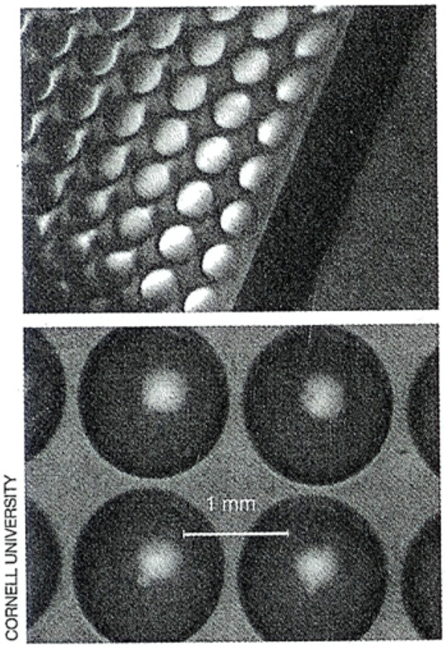
Silica-filled epoxy forms accurate lens arrays

Microlens arrays are used in optical switches for telecommunications, in charge-coupled-device cameras to increase the amount of light reaching the pixels, and for other uses that potentially require them to be made in medium to large volumes. The ideal fabrication technique for a microlens array would result in accurate and tailorable lens shapes using relatively simple equipment. Real-life techniques have disadvantages: embossing can result in deformation-causing shrinkage, while ink-jet and photoresist-reflow techniques limit the choice of lens-element surface profiles. Replication may solve these problems, as demonstrated by an approach developed by scientists at

Cornell University (Ithaca, NY), Clariant (Somerville, NJ), Lawrence Berkeley Laboratory (Berkeley, CA), and Lucent Technologies' Bell Labs (Murray Hill, NJ).

A stamp is first made that is a negative replica of a precisely made master; this is done by coating the master with an antistick film, placing a glass substrate 1 mm away from the master, filling the gap with a monomer that is heated to change it to an elastomer, and pulling the master away. To create a replicated array, the cavities in the stamp are filled with ultraviolet (UV)-curable epoxy and a lens-backing plate placed against the stamp. After UV curing, the stamp is removed, leaving a microlens array.

Important to the makeup of the epoxy is its 19%-weight fill of silica nanoparticles of 9 to 11 nm in diameter. Madanagopal Kunnavakkam, a senior research associate at Cornell, explains the advantages of adding the nanoparticles. "First, they reduce the organic material content of the lens," he explains. "This reduces moisture absorption and extends the life of the lens array. Moisture absorption can lead to swelling in organic materials that could lead to change in focal lengths and increased losses due to absorption of light by water, especially in the 1.3- to 1.5-µm communications band. Eventually the material would turn hazy if too much water is absorbed. Reducing the organic contents reduces all these effects." A second advantage, he says, is that the cured



CORNELL UNIVERSITY

Replicated lenses with a pitch of 1.25 mm are arrayed on a quartz backing plate (top and bottom); the central 10 × 10 section of the 12 × 12 array is usable.

lens material exhibits improved mechanical properties, such as increased hardness and resistance to scratching.

"Third, the coefficient of thermal expansion of the cured epoxy is closer to that of the substrate and this reduces stresses induced by variations in temperature due to differential expansion," says Kunnavakkam. "We find that lenses made with pure epoxies often crack under thermal cycling, whereas the loaded epoxy lenses do not. This also has an added advantage of minimizing the focal-length shifts with temperature."

Profiles of the lenses taken with a scanning optical profilometer show that the central portions of the replicated lenses accurately duplicate the originals and have positional placement errors of less than 2 μm up to temperatures of 65°C. The researchers envision fabrication of gratings, waveguides, and other micro-optical components using this technique.

John Wallace

REFERENCE

1. M. V. Kunnavakkam et al., *Appl. Phys. Lett.* (Feb. 24, 2003).

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