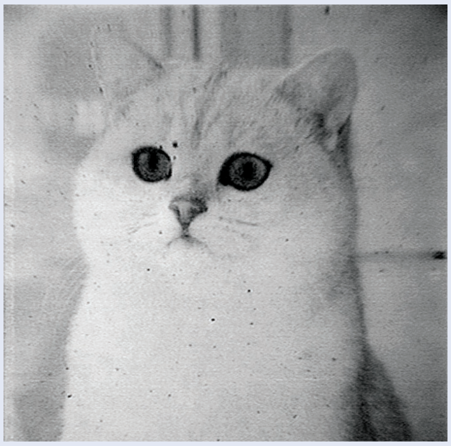
LITHOGRAPHY

Chalcogenide promise

Chalcogenide thin films are versatile phase-change materials that are currently used as optical information storage and solid-state memory media; these applications respectively make use of the different optical and electrical characteristics of the amorphous and crystalline phases of chalcogenide materials. Now, by exploiting four phases of chalcogenide thin films — the liquid and gaseous phases, in addition to the amorphous and crystalline solid phases — Rui Wang, Jinsong Wei and Yongtao Fan in China have demonstrated the use of these materials as greyscale photolithography materials (*Opt. Express* **22,** 4973–4984; 2014).

Greyscale photolithography has been used to produce three-dimensional microstructures, microfluidic devices and microlens arrays, but the two main methods that are currently employed (one which involves film deposition, lithography, etching and resist removal of chrome on glass and the other electron-beam writing of high-energy-beam-sensitive glass) are complex and costly.

In contrast, Wang *et al.*'s technique is simple and cost effective, as it merely involves inscribing greyscale patterns



on chalcogenide thin films by direct laser writing. This processing forms bumps in chalcogenide thin films on glass substrates through the heat generated by pulsed laser irradiation. By controlling the pulse energy of the laser irradiation, bumps with different heights and volumes can be formed. As these bumps exhibit different optical reflection and transmission characteristics, high-resolution continuous-tone greyscale patterns can be readily produced on chalcogenide thin films.

Laser irradiation produces four kinds of structures depending on the laser pulse energy used. Low pulse energies result in the formation of small concave dimples in the film due to the higher density of the crystalline phase relative to the amorphous phase. Irradiation at high pulse energies produces protruding solid bumps through melting of small volumes of the film. Still higher pulse energies generate bumps containing cavities as the result of vaporization. Finally, these bumps rupture when even higher pulse energies are used.

The researchers demonstrated their technique using Sb_2Te_3 films on glass and a homebuilt direct laser writing system. They found that the reflectivity of processed films in the wavelength range 450–600 nm increased with increasing laser power density as the result of the formation of larger microstructures in the film. They then used the technique to produce high-resolution greyscale images. The team anticipates that the technique could be used to produce high-resolution images for micro- and nanoimage storage, microartwork and greyscale photomasks.

SIMON PLEASANTS

SOFT-X-RAY SOURCES

X-ray laser plasma amplifiers

The realization of an X-ray laser plasma amplifier using a stretched X-ray pulse leads to higher intensity and better quality X-ray laser pulses.

Masaharu Nishikino and Tetsuya Kawachi

Since the first demonstration of a soft-X-ray laser based on a laser plasma in 1985[1], the development of a laser-driven coherent X-ray source has been intensively pursued, resulting in significant advances, including high peak brilliances, high average powers and miniaturization of technology. At international laser facilities that generate extremely high powers[2] (especially those in Europe), which were developed for high-field science, the development of coherent X-ray sources with higher photon energies and higher peak brilliances has become one of the main subjects of research, together with the realization of high-energy particle beams. On the other hand, new coherent X-ray sources that employ acceleration technology, X-ray free-electron lasers (XFELs), have recently been established. Examples include FLASH at DESY (Germany), LCLS at SLAC (USA) and SACLA at SPring-8 (Japan). The use of these plasma-based and accelerator-based sources of high-intensity, coherent, ultrashort X-ray pulses has spawned a new scientific field known as coherent X-ray science, which has been applied in various fields, including solid-state physics, bioscience, high-energy-density physics and laboratory astrophysics.

In plasma-based soft-X-ray lasers, the lasing medium is a plasma consisting of multiply charged ions, and the population inversion between the excited levels of these ions is used for X-ray amplification. Various pumping schemes have been developed, including those based on plasma recombination, collisional excitation, optical field ionization and inner-shell excitation. Significant advances have been realized in the