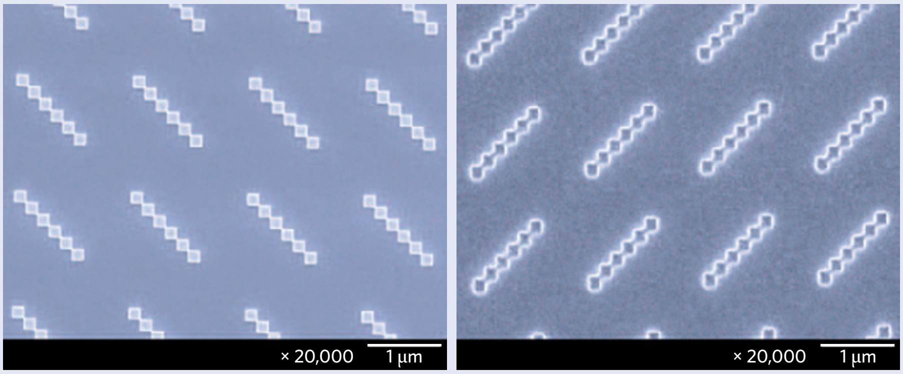
NANOLITHOGRAPHY

Exploiting propagation and evanescence

Lithography of sharp-edged features with nanoscale precision remains a challenging task. Several approaches have been proposed and experimentally tested, but the problem is not yet solved. According to recent progress (*Appl. Phys. Lett.* **99,** 011107; 2011) reported by Kosei Ueno and colleagues from Hokkaido University and the Japan Science and Technology Agency, plasmon-assisted lithography aided by two-photon chemical reactions of photoresists may be a useful tool.



Nanostructure photomasks (pictured left) were fabricated by electron-beam lithography and coated with a 10-nm-thick gold film. The masks were then brought into direct contact with a positive photoresist. The photomask had a complex electromagnetic response resulting from its rich structure. This included a resonance at a wavelength of 780 nm, for which the team illuminated the sample with a femtosecond laser centred at 800 nm.

Plasmon lithography has been in use for a while, but Ueno says that the experiment stands out through its careful use of the directional scattering components of light from a higher-order multipole plasmon resonance, and not only localized evanescent fields, as an exposure source. Ueno explained that in previous plasmonic lithography systems, near-field light generated by dipole plasmon resonances of metallic nanostructures could be used to make nanoscale pits on the photoresist film, but that only shallow nanopatterns could be produced on the resist film because the nanopatterning depth is strongly dependent on the localized profile of the near-field light. He also emphasized that the patterns did not always directly reflect the photomask.

"These drawbacks are problematic to the construction of a practical plasmonic lithography system. To overcome these limitations, a new plasmon-assisted lithography technique is proposed," said Ueno. "In this work, because the directional scattering components of light coupled with the radiation mode of a multipole plasmon resonance were used (this is not near-field light), relatively deep nanopatterning of the photoresist film (penetrating the resist layer) could be achieved."

The team notes that the resist patterns are particularly similar to the photomask designs and that even 10-nm-wide features were patterned (pictured right). 'Bottleneck' features 10 nm wide were formed in nanochains in a relatively large exposure area of 30 μm × 30 μm. Fluctuation of the structural size is estimated to be of the order of 4 nm. From a practical point of view, one of the main disadvantages, however, is the direct contact exposure scheme (although this is common to many plasmon lithography schemes at this stage), and the team aims to develop their photolithography system to do away with contact exposure.

DAVID PILE

OPTICAL ISOLATION

A non-magnetic approach

Going beyond the conventional approach based on the Faraday effect, scientists have now used acoustic modes optically excited in the core of a photonic crystal fibre to realize a reconfigurable all-optical isolator.

Zongfu Yu and Shanhui Fan

Optical isolators — devices that allow light to pass in one direction and block light in the opposite direction — are essential to prevent interference caused by reflections between different parts of optical networks. For instance, they are routinely used in combination with lasers to stop reflected light being fed back to the lasers, thus avoiding any fluctuations of laser frequency and output power due to undesirable interference in the laser cavity.

They are non-reciprocal optical devices, and to achieve a non-reciprocal response, the device cannot have time-reversal symmetry. The conventional approach to breaking time-reversal symmetry is based on external magnetic fields or the spontaneous magnetization of the device materials, and is used in all commercially available isolators. All isolators of this type require the use of either magneto-optical materials such as yttrium iron garnet or strong external magnetic fields. Writing in *Nature Photonics*[1], Kang, Butsch and Russell now report the demonstration of an optical isolator based on dynamic photonic structures. Using optically excited acoustic waves, they turn a photonic crystal fibre into a one-way light valve, creating an in-fibre optical isolator.