Photorefractive Polymer Device Records High-Resolution 3D Holographic Images

Holograms hold a special place in the popular imagination, from the cover of *National Geographic* to episodes of *Star Trek*. But three-dimensional holography is fast becoming a reality for high-value applications, including biomedical imaging of living tissue. Devices for such 3D holographic imaging have so far been limited by either slow response times or low sensitivity. Now, in an article in the August 1 issue of *Optics Letters* (p. 1914), a group from the University of Manchester in the United Kingdom has introduced holographic imaging with a photorefractive polymer device that is both fast and has high 3D resolution, even through a scattering medium similar to organic tissue.

A hologram is formed by creating ("writing") a pattern of refractive-index contrast inside a material. When the material is later illuminated with a "read" laser, this pattern diffracts the coherent laser light and creates the hologram. A common technique for recording refractive-index patterns is to use a photorefractive material in which incident light from the object being holographed liberates charge carriers in the material, which get trapped at points of low- or high-incident intensity. The electric field of these trapped charge carriers then modifies the local index of refraction through the electro-optic effect.

The Manchester group—P. Dean, M.R. Dickinson, and D.P. West—used as their holographic medium a photorefractive polymer host poly(*N*-vinylcarbazole) and doped it with 50 wt% of the electro-optic chromophore 1-(2′-ethylhexyloxy)-2,5-dimethyl-4–(4″-nitrophenylazo) benzene and 2 wt% of the sensitizer 2,4,7-trinitro-9-fluorenone dimalenitrile to enhance the photorefractive effect. The holographic reference beam intensity was 161 mW/cm^2, while the object beam intensity was 0.7 mW/cm^2, and the reading beam intensity was 0.5 mW/cm^2. With an exposure time of only a few seconds, they were able to record a high-resolution hologram of an object with transverse details as small as 42 μm and a depth resolution of 15 μm over an object area of 0.42 mm^2. Then, to demonstrate the usefulness of this technique for biomedical imaging, the researchers placed a suspension of polystyrene microspheres between the holographed object and the recording laser, which simulated the optical scattering effects of an intervening layer of biological tissue. The optical depth of the microspheres corresponded to seven scattering mean free paths (round-trip). With this layer present, the required recording time increased to 20 s, but the hologram resolution remained very high.

What makes the group's technique particularly noteworthy is that it operates at a near-infrared wavelength of 794 nm, which is only weakly absorbed by biological tissue. This, combined with the technique's relatively fast time scale and high spatial resolution at low optical intensity, make it an especially promising advance toward the clinical goal of holographic biomedical imaging.

COLIN MCCORMICK

Self-Assembled InAs/InP Quantum Dots Transform into Quantum Rings without Capping

Quantum rings—ring-shaped solid pipes with nanometer diameters—have recently been under intense investigation. In some quantum dot (QD) fabrication efforts, capping self-organized InAs QDs by a thin GaAs layer followed by a growth interruption results in a change of shape from a dot to a ring. Two competing models, thermodynamic and kinetic, have been proposed to explain the growth phenomena of these quantum rings. In the August 10 issue of *NanoLetters* (p. 1541; DOI: 10.1021/nl050646v), J. Sormunen and colleagues from Helsinki University of Technology, Finland, have reported their fabrication of InAs/InP rings. They have debated that a third mechanism, a Group V exchange reaction, is responsible for such growth.

The samples in their experiment were prepared by metalorganic vapor-phase epitaxy (MOVPE) under atmospheric pressure. Hydrogen was used as a carrier gas, with trimethylindium (TMI), tertiarybutylphosphine (TBP), and tertiarybutylarsine (TBA) as precursors. The growth process is explained in Figure 1. The substrate was first annealed at 650°C, then a 100 nm InP buffer layer was grown at 640°C. Next, the temperature was reduced to 560°C and 0.6–1.0 monolayers of InAs was deposited, followed by the self-organized growth of an InAs quantum dot. Following the formation of the InAs QDs, a flush was performed in TBA, after which the Group V precursor was switched to TBP. Figure 1 shows the proposed quantum-ring formation process. When TBA is switched to TBP, As/P exchange releases In atoms from the InAs lattice (Figure 1a). The In adatoms migrate toward the base of the InAs island, where the lateral lattice constant is closer to that of InP (Figure 1b), and are reincorporated at an energetically more favorable site. Material redistribution continues (Figure 1c) until the initial InAs island has vanished.

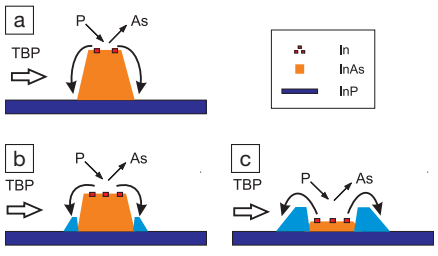

Figure 1. Schematic diagram of the dot-to-ring transformation of an InAs/InP quantum dot. (a) In atoms are released by As/P exchange and migrate outward from the InAs island. (b) In atoms are reincorporated at the interface of the quantum dot and the flat surface. (c) Material redistribution continues until the initial InAs island has disappeared. TBP is tertiarybutylphosphine. Reprinted with permission from NanoLetters ***5****(8)(2005) p. 1541; DOI: 10.1021/nl050646v. © 2005 American Chemical Society.*

The researchers conclude that because the quantum rings were fabricated uncapped, As/P exchange plays an important role, in contrast to the thermodynamic and kinetic models. Because of Group V exchange reactions, the uncapped rings were assumed to consist of $InAs_yP_{1-y}$.

VIVEK RANJAN

Gradient Chemical Micropatterning Enables Fabrication of Reference Substrates for Calibration of Scanning Surface Nanometrology

Scanning probe microscopy (SPM) techniques (e.g., atomic force microscopy, friction force microscopy, chemical force microscopy, and atomic force acoustic microscopy) are important tools for surface nanometrology. However, their use as tools for examining surface chemistry, particularly for materials processing and technologies including nanolithography masks, micro- and nanoelectromechanical systems, microfluidics, and tissue scaffolds, requires detailed knowledge of surface energy variations across the nanostructures. Accurate measurement of surface energy is critically affected by the condition of probe tips and their possible chemical contamination, which cannot always be easily determined. Consequently, the accuracy of such scanning probe measurements would be greatly facilitated by the existence of a reference substrate with surface energy gradients spanning the values of interest that could be used as a calibration tool.

Most current methods to impart substrates with tailored surface energy and chemical patterns involve only "single

case" conditions, where the surface exhibits uniform chemistry. In this respect, a few published works investigate the ability to create continuous surface energy gradients to study the effect of surface energy on phenomena such as wetting and self-assembly in one single sample surface. Now, a team led by Michael J. Fasolka at the National Institute of Standards and Technology (NIST) in Gaithersburg has reported a unique fabrication of a new class of substrates that combine a micrometer-scale chemical pattern with a surface energy gradient.

As reported in the August 10 issue of *NanoLetters* (p. 1535; DOI: 10.1021/nl050612n), Fasolka and co-workers fabricated a micropatterned sample with a gradual and systematic change of chemical contrast, that is, surface energy differences between surface domains. To achieve fabrication of this specimen, they developed a method for patterning monochlorosilane (MCS) self-assembled monolayers (SAMs) which combines microcontact printing and vapor deposition. This approach provides reproducible microscale SAM patterns on a Si substrate with the ability for multisample batch processing. The process starts with a composite elastomer stamp containing both flat and corrugated regions, allowing the deposition of a SAM strip adjacent to a calibration strip.

The gradient of the surface chemistry in the sample was acquired by exposing the surface to ultraviolet ozonolysis in a graded manner. This model specimen, which presents a multitude of patterned chemical conditions in a single substrate, can be used as a reference substrate for the development and calibration of surface-chemistry-sensitive measurements such as the SPM techniques listed earlier. The researchers demonstrated this by using the graded specimen to correlate friction SPM image contrast with surface energy differences over a number of SPM probe functionalities. These experiments illuminated the full spectrum of contrast/surface energy relationships, including the ultimate sensitivity of the probes, by using a single specimen. In addition, the researchers demonstrated the potential of this new specimen for the high-throughput analysis of thin-film stability by studying the wetting behavior of polystyrene over the gradient micropatterns with a custom-made automated optical microscope.

FENGTING XU

MWNTs Follow in Geckos' Footsteps

The physical properties of the gecko lizard's foot anatomy allow the animal to climb any vertical surface and to hang upside down by a single toe. Covering each five-toed foot are microscopic elastic hairs called setae, whose ends split into "spatulas" that adhere to surfaces by van der Waals forces. The aspect ratio and stiffness of gecko foot hairs allow them to deform at different length scales so that they can come into close contact with surfaces of any type and shape at sufficient density to bring about high adhesive forces. Recently, researchers from the Department of Polymer Science at the University of Akron, Ohio, and the Department of Materials Science and Engineering at Rensselaer Polytechnic Institute in Troy, New York, used multiwalled carbon nanotubes (MWNTs) to fabricate a gecko foot-hair mimic that displays strong nanometer-level adhesion forces 200 times greater than those observed for gecko foot hairs.

As reported in *Chemical Communications* (issue 30; p. 3799; DOI: 10.1039/b506047h), University of Akron researcher A. Dhinojwala and co-researchers grew 10–20-nm-diameter, 50–100-μm-long, vertically aligned MWNTs on silicon substrates through chemical vapor deposition. After embedding the free ends of the MWNTs in a poly(methyl methacrylate) (PMMA) matrix, the PMMA–MWNT sheets were peeled off the silicon substrate, thereby forming a very smooth surface. This surface was then etched with either acetone or toluene. Not only can the researchers control the length of exposed MWNTs by varying the etching time, but also the solvent-

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