

Resolution Optical Tomography for Imaging of Biological Tissues

Imaging of soft biological tissues using noninvasive techniques is of crucial interest in biomedicine as a satisfactory technique would greatly aid in detecting abnormalities and functions within such tissues. In the December 1, 2004, issue of *Optics Letters* (p. 2770), S. Sakadžić and L.V. Wang (Optical Imaging Laboratory at Texas A&M University) have reported the realization of high-resolution ultrasound-modulated optical tomography based on optical contrast for imaging soft biological tissues.

Ultrasound-modulated optical tomography is a hybrid technique that combines ultrasonic resolution with optical contrast. Ultrasound generates collective motions of the optical scatterers in a tissue and also leads to periodic changes in the optical index of refraction. This leads to fluctuations in the intensity of the speckles formed by multiple scattered light. Thus, the ultrasound-modulated component of light contains information about the tissue from the region of interaction between the optical and ultrasonic waves. Measurement techniques such as parallel speckle detection combined with ultrasound frequency sweep and computer tomography are commonly used to detect the modulated component of light produced by continuous-wave ultrasound. However, pulsed ultrasound provides direct resolution along the optical axis and is more compatible with conventional ultrasound imaging.

In Sakadžić and Wang's study, a long-cavity confocal Fabry-Perot interferometer (CFPI) is used to achieve high-resolution ultrasound-modulated optical imaging. A CFPI is advantageous due to its high *etendue*, which is defined as the geometric capability of an optical system to transmit radiation; more specifically, it is the product of the opening size and solid angle from which the system accepts light. The CFPI is able to detect the propagation of high-frequency ultrasound pulses in real time and tolerate speckle decorrelation. Ultrasound frequency of 15 MHz was used to detect ~100- μm -sized objects placed ~3 mm below the surface of chicken breast tissue samples. Two chicken breast tissue samples were investigated, each with a radius of curvature of ~3 mm. The 100- μm -thick black latex objects were placed in the centers of curvature of the samples, with their wide sides parallel to the ultrasound beam. As shown in Figure 1, estimated axial and lateral resolutions of 70 μm and 120 μm were measured, respectively. The researchers said this study demonstrates the feasibility of

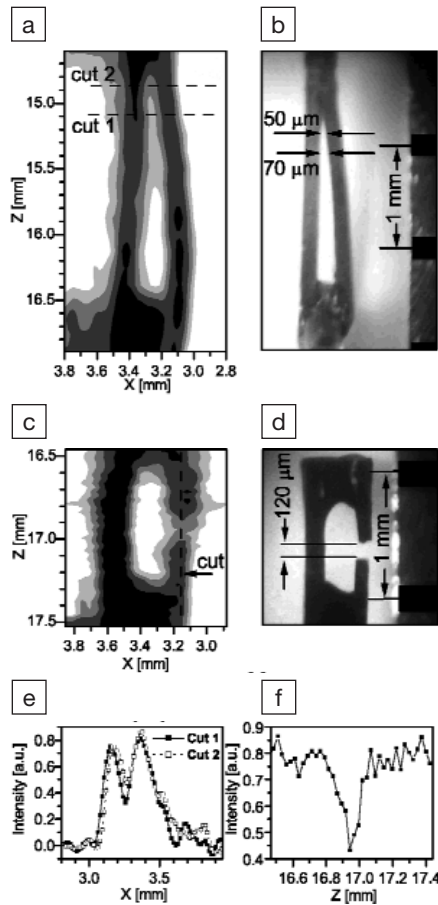


Figure 1. Measurement of the axial and lateral resolutions in breast tissue. (a) Measurement and (b) image of an object, showing the axial resolution. (c) Measurement and (d) image of an object, showing the lateral resolution. (e) One-dimensional (1D) axial profiles of intensity from the data in (a). (f) 1D lateral profile of intensity from the data in (c). Reproduced with permission from *Optics Letters* 29 (23) (December 1, 2004), p. 2772. © 2004 Optical Society of America.

high-resolution ultrasound-modulated optical tomography for imaging biological tissue to a depth of several millimeters. The researchers also said that the resolution can be improved upon by using higher ultrasound frequencies.

ADITI S. RISBUD

Direct Methanol-Air Fuel Cell with Nanoporous Proton-Conducting Membrane Reaches Cell Power of 0.5 W/cm²

Fuel cells are attracting considerable attention for possible applications in portable electronics, distributed energy, and transportation. Direct methanol fuel cells composed of nanoporous proton-

conducting membranes can be used for these applications because of their lower cost, higher conductivity, higher water permeation under hydraulic pressure, and lower fuel crossover as compared with a commercial counterpart, a Nafion membrane. In the December 2004 issue of *Electrochemical and Solid-State Letters* (p. A507), E. Peled (Tel-Aviv University), M. Rakhman (Israel Plastics and Rubber Center in Haifa), and their colleagues report on the performance of a nanoporous proton-conducting membrane (NP-PCM)-based direct methanol fuel cell (DMFC) operated with triflic acid instead of sulfuric acid. The composition of the NP-PCM was 28 vol% poly(vinylidene fluoride), 12 vol% SiO₂, and 60 vol% liquid (an acid-methanol mixture). It was hot-pressed at 100°C and 24 kg/cm² to a final thickness of 70–100 μm . The purpose of the triflic acid, in contrast to sulfuric acid, is that it does not adsorb on the platinum catalyst. In conjunction with a membrane with high water permeability and high conductivity, a fuel cell is produced that can increase power by up to 250%, as compared with sulfuric acid-based systems. In fuel cells in which sulfuric acid is used, a higher overpotential at both electrodes is observed, while switching to triflic acid decreases the overpotential at the anode from 0.47 V to 0.33 V, and the overpotential at the cathode drops from 0.44 V to 0.36 V. This decrease in overpotential leads to a rise in cell voltage, which produces a maximum power density (0.5 W/cm²) at 130°C. This particular fuel cell has shown an acceptable operating lifetime of 1000 h at room temperature and is efficient when compared with reformate-hydrogen fuel cells. The direct methanol fuel cell studied by Peled's group competes favorably with indirect methanol or gasoline fuel cells when size, weight, complexity, and efficiency are considered.

LARKEN E. EULISS

Copper Nanowires Broken into Nanospheres by Rayleigh Instability

Despite significant progress in understanding materials behavior at the macroscopic level, the behavior of small-scale nanomaterials under changing conditions remains largely unknown. However, this behavior must be addressed before new small-scale materials can be successfully used in technological applications. M.É. Toimil Molares (Gesellschaft für Schwerionenforschung, Darmstadt, Germany), A.G. Balogh (Technische Universität Darmstadt), and their colleagues have reported significant progress in understanding the behavior of small volumes of copper in the shape

of nanowires. As reported in the November 29, 2004, issue of *Applied Physics Letters* (p. 5337), the research team discovered that fragmentation of copper nanowires occurs as a function of temperature and is driven by the Rayleigh instability. The Rayleigh instability concept, introduced over a century ago to explain the instability of a liquid jet, is now being applied to describe the fragmentation of copper nanowires; it is driven by surface atomic diffusion in conjunction with any periodic variations in wire diameter. The researchers observed, by high-resolution scanning electron microscopy (HRSEM), different stages of fragmentation after annealing the nanowires at elevated temperatures and reported a clear dependence of the decay process on temperature. According to the researchers, the wires started to fragment at $\sim 400^\circ\text{C}$, form shorter segments with an increase to $\sim 500^\circ\text{C}$, and decayed into chains of nanospheres at 600°C . All of these processes occurred at temperatures far below the melting point of copper.

The nanowires employed by Toimil Molares and colleagues for the annealing experiments were fabricated by electrochemical deposition of copper into the pores of etched ion track membranes. The templates were created by irradiating thin polycarbonate foils with 2 GeV Au heavy ions. The damage zones produced by the ions along their paths were then dissolved in NaOH solution. The scientists were also able to show that these pores have a slightly biconical shape, with diameters varying between 30 nm at the center and 50 nm at the ends. These pores were subsequently filled with copper by electrochemical deposition, and the surrounding matrix was dissolved in dichloromethane for SEM investigations.

Toimil Molares said that the observed mechanism of the copper nanowire fragmentation agrees qualitatively with previous theoretical work, such as Monte Carlo calculations of fragmentation of Ge nanowires due to the Rayleigh instability. The resulting size and spacing of the nanospheres has also been linked to additional theoretical predictions.

"Our research clearly indicates that for nanoscale device applications, technological problems arising from the thermal instability of materials must be taken into account if reliable devices must be produced," said Toimil Molares. The observed phenomenon could also be used to develop new materials processing techniques, for example, to fabricate nanospheres of copper, silver, or gold.

"This new kind of nanoscopic string of spheres could also find applications in

nanophotonics, since it may be used to guide light below the diffraction limit via coherent coupling of surface plasmon polaritons," Toimil Molares said.

This increased understanding of how copper nanowires behave as a function of temperature should have an impact on both fundamental sciences and technological applications, and it could lead to substantial future studies—for instance, *ab initio* atomistic simulations of the mechanism to reveal more of the underlying atomistic details of the processes.

MARKUS J. BUEHLER

Layer-by-Layer Growth of Multilayer Thin Films Containing Microgels Allows Controlled, Tunable Release of Medications

L. Andrew Lyon and colleagues at the Georgia Institute of Technology have developed a film for drug delivery with the goal of replacing daily injections and pills with microthin, implantable films that release medication according to changes in temperature (see Figure 1).

Lyon, associate professor at the School of Chemistry and Biochemistry, said, "We loaded insulin in layers of microgel films in the lab and released bursts of insulin by applying heat to the films. They were extremely stable and could continue to release the drug for more than one month at a time."

Films assembled from microparticles allow more control over drug release than films previously made in monolithic form. As reported in the September 13, 2004, issue of *Biomacromolecules* (p. 1940), the films release their cargo at 31°C , six degrees below human body temperature. Lyon's

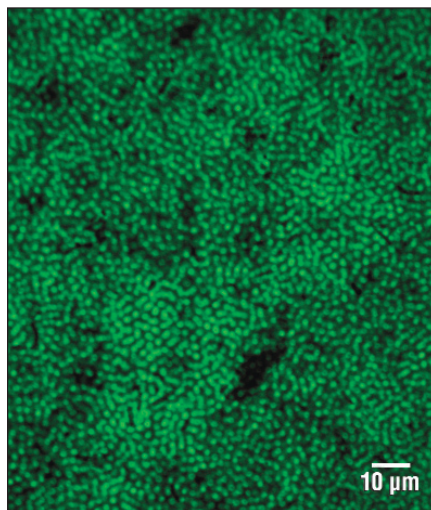


Figure 1. Fluorescently tagged insulin occupies a three-layer microgel thin film.

group is working on pushing the release point to a temperature slightly above that of the human body. Once implanted, the researchers said, the pharmaceutical-loaded films could be placed on chips with resistive heaters and designed to release drugs according to a time schedule or another trigger.

The microgels are composed of the thermoresponsive polymer poly(*N*-isopropylacrylamide) cross-linked with *N,N'*-methylenebisacrylamide. This polymer is highly water-swollen below its lower critical solution temperature of 31°C . Above that temperature, an entropically favored phase separation, or deswelling, event occurs as the hydrophobic interactions between the isopropyl groups are favored over polymer swelling.

The films were fabricated using a layer-by-layer process. Measurements demonstrated that the amount of insulin released during long-term cycling tests depended upon the number of film layers, indicating the potential for tunability of the amount of medication released.

Composite Cathode with Boroxine Ring Developed for All-Solid-Polymer Lithium Cell

The poly(ethylene oxide) (PEO)-based lithium polymer electrolyte has been regarded as the best electrolyte candidate in lithium secondary batteries since the late 1970s. However, due to the electrolyte's low conductivity, those solid-polymer lithium batteries have to be operated above a temperature of 60°C . Q. Li (Mie University, Japan), O. Yamamoto (Genesis Research Institute, Japan), and their colleagues are involved in the development of new electrolytes, especially focusing on electrical conductivity enhancement at lower temperature. In 2000, the group reported that the addition of BaTiO_3 to PEO-Li $(\text{CF}_3\text{SO}_2)_2\text{N}$ can increase the electrical conductivity at room temperature. In 2003, they combined a composite polymer, PEO-Li $(\text{CF}_3\text{SO}_2)_2\text{N}$ -BaTiO₃, with a hyperbranched polymer (HBP), poly[bis(triethylene glycol)benzoate] capped with the acetyl group, and found that the electrolyte's conductivity could reach 10^{-4} S/cm at room temperature and 10^{-3} S/cm at 60°C . However, there was still a rate capacity restriction by a high interface resistance at the cathode side at low temperature. To overcome it, the same group developed a novel composite cathode with the addition of a boroxine ring compound.

To prepare the solid-polymer electrolyte cell, the researchers sandwiched the composite polymer electrolyte (CPE)