nanoshell bioconjugates can be used to effectively target and image human epidermal growth factor receptor 2 (HER2—a relevant biomarker that is prevalent in human breast carcinoma cells). The researchers chose nanoshells composed of a dielectric silica core surrounded by a thin metallic shell composed of gold whose optical properties can be adjusted by controlling their dimensions. Nanoshells have a strong optical resonance that can be tuned in wavelength across the visible and infrared spectrum, allowing the relative contributions of scattering and absorption at a given wavelength to be tuned by controlling the dimensions of the core and the shell. In this study, nanoshells with a 240-nm-diameter silica core and a 35–nm-thick gold shell were used. By utilizing these nanoshells, it is possible to conjugate bio-relevant materials, in this case, proteins that facilitate *in vivo* imaging.

The researchers attached a linker complex—either anti-HER2 or anti-IgG antibodies–PEG (poly ethylene glycol)—to the nanoshell surface. These conjugated nanoshells where exposed to HER2 expressing SKBr3 cells and studied by dark-field microscopy. A significant increase in optical contrast was observed in the HER2 positive cells targeted with anti-HER2-labeled nanoshells as compared to anti-IgG-labeled nanoshells or cells not exposed to the nanoshell conjugates. The researchers said that nanoshell-based conjugates offer the next generation to *in vivo* imaging due to their near-infrared tunability, size flexibility, and systemic control of optical properties.

LARKEN E. EULISS

Hybrid Photoelectrodes for Solar Water Splitting

Efficient production of hydrogen from water using solar energy is a much-sought-after research goal that has eluded scientists for many years. The wide-bandgap materials that are used in single-junction electrochemical devices to carry out water splitting processes typically absorb sunlight poorly, resulting in low solar-to-hydrogen (STH) conversion efficiencies. Recently, E.L. Miller and colleagues from the Hawaii Natural Energy Institute at the University of Hawaii developed a prototype multijunction photoelectrode proposed to more effectively harness the sun's energy for hydrogen production than has been previously possible.

In the May issue of *Electrochemical and Solid-State Letters* (p. A247), the researchers reported on the performance characteristics of a prototype hybrid photoelectrode (HPE) device and discussed materials developments that will be necessary to improve the STH efficiency. An HPE is a monolithic thin-film device that integrates photoelectrochemical (PEC) and photovoltaic (PV) components in a multiple-junction arrangement. In such a device, the efficiency of hydrogen production is ideally proportional to the photocurrent in the PEC semiconductor, and thus optimum performance is achieved by maximizing this photocurrent.

The prototype HPE described and tested by the research group consists of an *a*-SiGe/*a*-SiGe tandem structure coated with a sputtered WO_3 thin film. This device operated at a hydrogen photocurrent level of 0.5 mA/cm^2 in outdoor sunlight conditions. This corresponds to an STH efficiency of 0.6%. The researchers estimated that peak photocurrents of 0.7 mA/cm^2 could be obtained from this device.

Although the results are promising, these materials clearly do not offer optimal device performance; novel materials must be developed for use as the PEC and PV components. One upgrade suggested by the researchers is the use of "improved" sputtered WO_3 coatings. These films offer peak photocurrents of 2.4 mA/cm^2, which represent a threefold increase in peak photocurrent and ideally a corresponding improvement in STH. The researchers predict that when integrated with a newly developed *a*-Si/*a*-Si tandem structure, an HPE with this improved coating layer would yield STH efficiencies exceeding 2.2%.

The chief limitation of HPE structures at the moment is the maximum photocurrent allowed by the top PEC semiconductor films. Doped TiO_2 or WO_3 films may offer a solution; these feature photocurrent values as high as 5 mA/cm^2. The researchers also suggest that appropriate combinations of PEC and PV materials may yield STH values in excess of 10%. Clearly, much development is necessary to attain such efficient hydrogen production in HPE devices, but these prototype results point to possible significant improvements in efficiency.

ANDY FRANCIS

Distribution of Nanoparticles in Photopolymer Controlled Holographically

Applications for holograms include three-dimensional displays, data storage, and photonics. In recent years, holographic gratings have been fabricated from two-component mixtures of organic photopolymers and from polymer-dispersed liquid crystals. The incorporation of materials that extend the range of the refraction index profile will result in more efficient holograms. For example, a system composed of organic photopolymers and inorganic nanoparticles, which, unlike organic compounds, display a wide range of refractive indices (n), were recently proposed by researchers from the Department of Electronics Engineering, University of Electro-Communications (UEC), Tokyo, although heretofore, the formation mechanism of such holographic gratings was not clearly understood.

As reported in the April 15 issue of *Optics Letters*, UEC researchers Y. Tomita and N. Suzuki and K. Chikama from Chemical Research Laboratories, Nissan Chemical Industries, demonstrated holographic control of morphology in nanoparticle-dispersed photopolymers and explained the formation of the holographic gratings in relatively simple terms of the chemical potential (μ) of non-interacting particles. The researchers combined either SiO_2 nanoparticles (n = 1.46, diameter = 13 nm) or TiO_2 nanoparticles (n = 2.55, diameter = 15 nm) at a volume fraction of 0.34 with methacrylate monomers (n = 1.55 in the liquid and 1.59 in the solid phase at a wavelength of 589 nm) and the initiator titanocene to cast films ~50 μm thick. Transmission-type holograms were then recorded at a grating spacing of 1 μm by exposing the films to two mutually coherent beams at a wavelength of 532 nm. The researchers used transmission electron microscopy to show that the nanoparticles followed the intensity interference fringe pattern at a grating spacing of 1 μm.

Tomita and his colleagues hypothesized a mutual diffusion model in which monomers polymerize in the bright regions, where their μ decreases, leading to the diffusion of monomers from dark to bright regions. The photoinsensitive inorganic nanoparticles, on the other hand, are not consumed during polymerization, and their μ increases in the bright regions, causing them to diffuse to the dark regions. The researchers reasoned that the phase shift (ϕ) between the intensity interference fringe pattern and the recorded holograms should be 0° for the SiO_2 hologram, that is, the change in n (Δn) is highest in the bright regions, because n for SiO_2 is less than n for the polymer. Similarly, ϕ for the TiO_2 hologram should be 180°, that is, Δn is highest in the dark regions, because n for TiO_2 is greater than n for the polymer. Both of these predictions were confirmed by the researchers.

Tomita and his colleagues said that their finding of all-optical control of nanoparticle distribution in photopolymers will facilitate the addition of new functionality to holographic applications, such as the fabrication of nonlinear periodic structures and nonlinear photonic

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