way of injecting light locally into a nanoscale photonic circuit.

The research team showed that the nanowires could even be successfully assembled into crossed and complex structures while still providing efficient waveguiding properties. These wires may thus become practical for usage in photonic elements with complex topology.

The research helps to resolve the fundamental problem of how to manipulate light in increasingly complex ways at very small scales, the researchers said. Their studies should have significant input on the development of novel computing technologies.

"However," Lieber said, "there are still remaining issues related to techniques to actually assemble such nanostructures efficiently and accurately."

If nanoscale assembling techniques are advanced further, CdS nanowire-based photonic elements may soon become reality in tomorrow's photonic circuits.

MARKUS J. BUEHLER

Silica-Based Nanocomposite Turns Cotton into Superhydrophobic Fabric

Surfaces with water contact angles larger than 90° are deemed superhydrophobic. A superhydrophobic cotton fabric would have a myriad of commercial and industrial applications; however, cotton fabric has a highly hydrophilic surface with a water contact angle of 0°. Widely studied sol-gel methods for coating fibers to provide hydrophobic properties are based on fluoroalkyl compounds. These are expensive processes that carry byproducts, which could potentially damage the environment if fluorine compounds were dispersed or endanger human health after skin contact. W.A. Daoud, J.H. Xin, and X. Tao from the Hong Kong Polytechnic University have now presented an alternative coating method based on a silica nanocomposite. Among other advantages of using this silica-based nanocomposite are its transparency and the capability to be processed at a low temperature compatible with cotton and other fabrics.

As reported in the September issue of the *Journal of the American Ceramic Society* (p. 1782), the researchers mixed tetraethoxyorthosilicate (TEOS), 3-glycidyloxypropyltrimethoxysilane (GPTMS), and HCl in the optimal ratio of 1:0.118:0.008, respectively. They added hexadecyltrimethoxysilane (HDTMS) in 10 wt% of TEOS, obtaining a modified silica sol. The cotton fabric samples were first cleaned with a non-ionic detergent at 80°C for 30 min, then dipped in the modified silica sol for a minute, padded, air-dried for 2 h and cured at 120°C for 1 h.

Measurements of the water contact angle were taken 1 min after placing a drop on the fabric, reporting 141°. Absorbency in uncoated cotton fabric was reported as 170% by volume of water sprayed, and after coating the absorbency decreased to 3%. The researchers conducted a standardized accelerated laundry test to simulate the effect of five consecutive wash cycles. After each wash cycle, the low level of absorbency increased and the water contact angle decreased continuously. After 30 wash cycles, the absorbency was up 17% and the water contact angle was 105°, still representing a highly hydrophobic fabric. Most of the increase in absorbency occurred after the first few wash cycles, and the hydrophobic properties reached a plateau after 15 cycles. The researchers attribute this high level of adherence to the addition of GPTMS to the modified silica sol.

The research team also studied the effect of the nanocomposite coating on the integrity of cotton fabric. Tearing strength did not change significantly, and tensile strength decreased less than 5%. When the investigators measured the permeability of the fabric (i.e., the ability of air to penetrate with a constant airflow), they reported a small increase after coating. This increase in permeability is an effect of the coating structure, they said, which deposits as round drops adhering to the fabric fibers. Therefore, they said, the nanocomposite coating enables cotton fabric to achieve consistent levels of water impermeability without losing its original properties.

SIARI SOSA

Structurally Ordered Polymer Electrolytes Prepared by Casting under Magnetic Field

Despite efforts in the past 20 years to improve the conductivity of polymer electrolytes (PEs), the maximum conductivity of solid PEs remains around 10^{-5} S/cm at room temperature. The problem is that in such semicrystalline materials commonly derived from the archetypal helical poly(ethylene oxide) (PEO), most of the helices lie parallel to the film plane, leading to low conductivity in the perpendicular direction where it is most important for electrochemical cells. Based on the idea that ionic conduction could be created by the movement of cations inside the helix and anions outside the chain, a group of researchers had recently used a stretching procedure to make a new group of structural ordering PEs from the archetypal helical PEO. In more recent work, the researchers pursued the use of magnetic field—a non-mechanical means—to achieve orientation of the PEO helices perpendicular to the plane of the film. D. Golodnitsky of Tel Aviv University in Israel, S.H. Chung of William Paterson University in New Jersey, S. Suarez of Hunter College of the City University of New York, and their colleagues have found that the ionic conduction of their PEs could be increased in one direction by a longitudinal alignment of the helices. The researchers published their studies in the November issue of *Electrochemical and Solid-State Letters* (p. A412).

As reported, while casting LiI:P(EO)$_n$ PEs (n = 3, 7, and 20), a strong magnetic field (0.8 T) produced from samarium-cobalt permanent magnets in the standard dipole arrangement was applied. Two different field configurations were used during the casting procedure: One was homogeneous and the other was highly inhomogeneous. After the solvent evaporation, a 100-μm-thick film was formed. In order to promote reorientation of the PE chains, diamagnetic alumina and ferromagnetic iron oxide were used as the additives. The incorporation of these nanosized inorganic fillers made a significant contribution to the magnetic field in PEs, the researchers said.

The orthogonally oriented macro- and microstructural changes of polymer segments and chains were studied from scanning electron microscopy and ^{7}Li-nuclear magnetic resonance spectroscopy. The PE's conductivity and PE/electrode interphase resistance were studied by a computer-interfaced frequency-response analyzer with a frequency range of 1 MHz to 0.1 Hz. Because the magnetic field was applied during the whole film casting process, both intra- and interchain ion mobilities were promoted by one order of magnitude. The researchers found that the lithium transference number increased from 0.2 to 0.6 in the magnetic-field-oriented PEs, which is important in battery applications; the resistance of the solid electrolyte interphase generated on the lithium electrode decreased by more than one order of magnitude. Due to the ability to make anisotropic, shape-persistent but flexible materials with preferred orientation, the researchers said this technique may enhance power in lithium batteries and possibly be applied in nanoscale technology.

LUCY YUE HU

Spin Separation Achieved in GaAs Heterostructure

L.P. Rokhinson of Purdue University, Y.B. Lyanda-Geller of the Naval Research

https://doi.org/10.1557/mrs2004.255 Published online by Cambridge University Press

Laboratory, L.N. Pfeiffer of Bell Laboratories/Lucent Technologies, and their colleagues have created a device that effectively splits a stream of quantum objects such as electrons into two streams according to the spin of each, herding those with "up" spin in one direction and corralling those that spin "down" in another (see Figure 1). By producing such spin-polarized streams, the device could become a key component in quantum computers, which have not yet left the drawing boards of the computer industry but are highly sought after for their purported facility at cracking codes and searching large databases.

"We have achieved spatial spin separation of the holes in gallium arsenide, the spaces that electrons leave behind as they travel through this semiconductor," said Rokhinson, who is an assistant professor of physics in the School of Science. "These holes also have spin characteristics, just as particles do, and separating them according to their spin has been a great challenge. Producing this effect will be critical for the success of any spin-based electronic device, and this separation method could be one of the missing links necessary for the development of quantum computers and nonvolatile memory devices."

Two particles' respective spins, which are opposite but inextricably linked, allow them to form a quantum bit, or qubit, that can actually be in a superposition state that simultaneously represents the possibility of "on" and "off" states, or function as both a one and a zero during digital calculations. This ability to represent two conditions at once, multiplied many times over within a computer chip

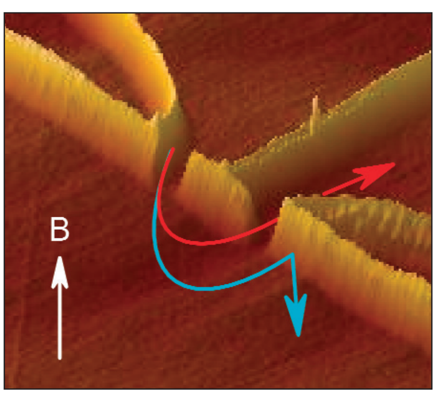

Figure 1. Atomic force micrograph of a device used to separate quantum objects according to their spin. The light-colored lines are oxide separating different regions of two-dimensional "hole gas" beneath the surface. (Graphic courtesy of Purdue University.)

that uses a large number of qubits, could be a powerful tool for sifting through information.

"The trouble is, you have to find a way to measure the final quantum state of the qubit after the calculations have been made to extract useful information from them," Rokhinson said. "Only once you have separated them can you obtain the answer to your calculations. This measurement issue has been one of the big challenges of the field."

Part of the reason behind this difficulty lies in the very weak coupling of spin with the environment. In semiconductor materials, Rokhinson said, spin is coupled many trillions of times less than charge is, and spin experiences comparatively little influence from nearby matter.

"In practical terms, this means you can try to make a particle flip its spin from 'up' to 'down,' but it won't feel you pushing," he said. "Researchers have tried to polarize the particles using everything from light waves to strong magnetic fields, but nothing was working well enough to separate them."

However, Rokhinson's team discovered that semiconductors made of highly purified GaAs sandwiched between layers of AlGaAs possessed a natural property that when harnessed could push the holes into two different directions according to their spin state, as the researchers reported in the October 1 issue of *Physical Review Letters* (146601).

Using a so-called magnetic focusing technique, a small perpendicular magnetic field bends a beam of holes in a GaAs semiconductor along two different cyclotron trajectories, with the radius depending on the spin of the particles. Those holes with "up" spin curve in one direction, those with "down" spin in the other.

Rokhinson said, "The only reason I have used holes rather than electrons is a pure convenience: GaAs/AlGaAs heterostructures are the cleanest systems we can grow, and two-dimensional gases of this material have the highest mobility (the catch is that our particles should not experience any scattering while completing the half-a-circle, which is a few microns)." Spin-orbit interaction for electrons in GaAs is an order of magnitude weaker than for holes. "But the physics is the same," said Rokhinson. "As long as we deal with charged particle with spin-orbit coupling we can construct a 'spin spectrometer' of a 'spin filter.'"

Nanoporous Structures Formed by Electrodeposition Process

Existing techniques for producing functionally graded electrodes require the deposition of multiple layers of material, each with a different pore structure. Each layer must be thermally and chemically compatible and able to conduct electricity. M. Liu of the Georgia Institute of Technology and collaborators H.-C. Shin and J. Dong have found a simpler means of producing three-dimensional nanoporous electrodes that facilitate the movement of liquids and gases.

By generating hydrogen bubbles during the deposition of copper, tin, or a copper–tin alloy onto a copper substrate, the researchers create self-supported metallic foam electrodes that contain a complex network of interconnected pores. Because the bubbles expand as they move away from the substrate, they create passageways through the deposited metal that become wider the closer they get to the outside of the electrode.

The tapered passageways should allow gases and fluids to move more easily through these functionally graded electrodes, enhancing the performance of solid-oxide fuel cells, lithium batteries, and chemical sensors, for example. The nanoporous nature of the structures provides a large surface area on which electrochemical reactions can take place.

"By adjusting the properties of the electrolyte—the viscosity and chemical composition—we can change the size of the gas bubbles we generate," said Liu, a professor in the School of Materials Science and Engineering. "Getting the bubbles small enough allows us to produce three-dimensional nanostructures in which the pores are small on the inside but taper to larger pores on the outside."

Lui, who is also the co-director of Georgia Tech's Center for Innovative Fuel Cell and Battery Technologies, said, "In our electrode, the gradient is created naturally and is ideal for our needs.... You can avoid the complexity of creating multiple layers."

The researchers said that the production of hydrogen bubbles serves as the basic sculpting tool for creating the pore structure. The gas acts as a dynamic template for the formation of the structure and serves as a barrier for the diffusion of reactive ions from the electrolyte to regions around the branches that are depleted of ions, preventing overgrowth of passageways.

The new electrodes vary in thickness from a few microns up to 15 μm, depending on the materials used and the processing time. Liu expects that copper-based electrodes will be useful in solid-oxide fuel cells, while tin-based electrodes will be useful in lithium batteries.

Microscope study reveals subtle differ-

https://doi.org/10.1557/mrs2004.255 Published online by Cambridge University Press