beams. They also found that control of the intensity of the optical beams was critical to observing transistor-like action in the single molecule.

Sandoghdar said, "Many more years of research will still be needed before photons replace electrons in transistors. In the meantime, scientists will learn to manipulate and control quantum systems in a targeted way, moving them closer to the dream of a quantum computer." Thus component parts such as the new single molecule optical transistor may also pave the way for a quantum computer.

Mechanical Stress Leads to Self-Sensing in Solid Polymers

Parachute cords, climbing ropes, and smart coatings for bridges that change color when overstressed are several possible uses for force-sensitive polymers being developed by N. Sottos, D. Davis, and colleagues at the University of Illinois—Urbana-Champaign (UIUC). The polymers contain mechanically active molecules called mechanophores. When pushed or pulled with a certain force, specific chemical reactions are triggered in the mechanophores.

"This offers a new way to build function directly into synthetic materials," said Sottos, a Willett Professor of materials science and engineering at UIUC. "And it opens the door to creating mechanophores that can perform different responsive functions, including self-sensing and self-reinforcing, when stressed."

In previous work, Sottos and collaborators showed they could use mechanical force to induce a reaction in mechanophore-linked polymers that were in solution. Now, as reported in the May 7 issue of *Nature* (DOI: 10.1038/nature07970; p. 68), the researchers show they can perform a similar feat in a solid polymer.

The researchers used molecules called spiropyrans, a class of molecular probes that serve as color-generating mechanophores, capable of vivid color changes when they undergo mechanochemical change. Normally colorless, the spiropyran used in the experiments turns red or purple when exposed to certain levels of mechanical stress.

"Mechanical stress induces a ring-opening reaction of the spiropyran that changes the color of the material," said D. Davis, a graduate research assistant and the article's lead author. "The reaction is reversible, so we can repeat the opening and closing of the mechanophore."

To demonstrate the mechanochemical response, the researchers prepared two different mechanophore-linked polymers and subjected them to different levels of mechanical stress. In one polymer, an elastomeric mechanophore-linked poly(methyl acrylate) (PMA), the material was stretched until it broke in two. A vivid color change in the polymer occurred just before it snapped. The second polymer, a glassy mechanophore cross-linked poly(methyl methacrylate) (PMMA), was formed into rigid beads 100–500 μm in diameter. When the beads were squeezed, they changed from colorless to purple. The color change that took place within both polymers could serve as a good indicator of how much stress a mechanical part or structural component made of the material had undergone.

"We've moved very seamlessly from chemistry to materials, and from materials we are now moving into engineering applications," Sottos said. "With a deeper understanding of mechanophore design rules and efficient chemical response pathways, we envision new classes of dynamically responsive polymers that locally remodel, reorganize or even regenerate via mechanical regulation."

Working Model of a Two-Qubit Electronic Quantum Processor Developed

L. DiCarlo, J.M. Chow, L.S. Bishop, B.R. Johnson, D.I. Schuster, L. Frunzio, S.M. Girvin, and R.J. Schoelkopf of Yale University, J.M. Gambetta of the University of Waterloo, J. Majer of Vienna University of Technology, and A. Blais of the Université de Sherbrooke have implemented simple algorithms using a quantum processor based on microwave solid-state technology—similar to that found in computers and cell phones. The new processor is far from conventional, however, in that it uses the potent power of quantum mechanics to bring the dream of quantum computing a small but significant step closer to reality.

"Our experiment can only perform a few very simple quantum tasks, which have been demonstrated before using other systems such as photons, trapped ions, and nuclear magnetic resonance," said Robert Schoelkopf, a principal investigator and professor of applied physics and physics at Yale. "But this is the first time it has been done in an all-electronic device, which looks and feels much more like a regular microprocessor."

As reported in the June 28 online issue of *Nature* (DOI: 10.1038/nature08121), the research team used artificial atoms as quantum bits, or qubits. Although made from over a billion aluminum atoms in a superconducting electronic circuit, these qubits behave as single atoms. The difference is that the manufactured atoms are much larger and therefore easier to control than single atoms or other types of qubits.

The devices were fabricated on an *R*-plane α Al_2O_3 wafer with 180-nm thick Nb coplanar waveguides. The artificial atoms (qubit structures), based upon interdigitated capacitors and split-junction structures, were fabricated using double-angle evaporation of Al (20/90 nm) with intermediate oxidation.

Just like a single atom, an artificial atom can be stimulated into different energy states, akin to the "on" and "off" states of the bits in conventional computers. But following the counterintuitive laws of quantum mechanics, the scientists can also place these artificial atoms in "superpositions" of quantum states—both "off" and "on" at the same time. This wider variety of possible states allows for greater information storage and processing power.

"The success of the experiment relied on integrating three previously demonstrated capabilities," said Leonardo DiCarlo, lead author of the article. According to DiCarlo, the key building blocks included local tuning of qubits on nanosecond timescales, which enabled the researchers to switch the interaction between the qubits "on" and "off" abruptly; a joint readout scheme that efficiently reveals two-qubit correlations; and state-of-the-art coherence times of about 1 μs for both qubits.

"There have been several earlier instances of two-qubit logic gates, but to do a quantum computation, you need to be able to control single qubits, and you

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