

Theory Indicates How to Boost Speed of Robotic Muscles

Currently, robotic muscles move 100 times slower than the human equivalent. Now, researchers at the Massachusetts Institute of Technology, led by Sidney Yip, have proposed a theory that indicates how to boost those speeds—making robotic muscles a thousand times faster than human muscles—with virtually no extra energy demands and the added bonus of a simpler design. This study appears in the November 4, 2005, issue of *Physical Review Letters* (198303; DOI: 10.1103/PhysRevLett.95.198303).

In this case, a robotic “muscle” is a device that can be activated to perform a task, like a sprinkler that is activated by pulling a fire alarm lever, said Yip, a professor of nuclear engineering and materials science and engineering. In the past few years, engineers have made artificial muscles from conjugated polymers.

“Conjugated polymers are also called conducting polymers because they can carry an electric current, just like a metal wire,” said Xi Lin, a postdoctoral associate in Yip’s laboratory. Conjugated polymers can actuate on command if charge can be sent to specific locations in the polymer chain in the form of solitons (charge density waves). Solitons are highly mobile charge carriers that exist because of the special one-dimensional chain character of the polymer.

Scientists already knew that solitons enabled conjugated polymers to conduct electricity. Lin’s work attempts to explain how these materials can activate devices. This study is useful because scientists have until now been making conducting poly-

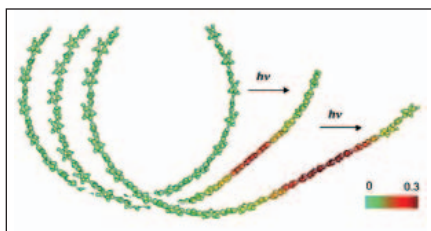


Figure 1. Theoretically, a conducting polymer can be actuated by shining a light of a specific wavelength ($h\nu$) on it. The polymer in this image is a chain (neutral charge, green) that is naturally curved before exposure. The effect of light ($h\nu$ wavelength) is to create positive charges (red) in a localized area. The positive charges enhance the chemical bonding between the polymer units and straighten out the curved chain in that area. Following the charges, this localized straightening can move along the polymer chain rapidly.

mers in a roundabout way by doping the materials with ions that expand the volume of the polymer. That expansion was thought to give the polymers their strength, but it also makes them heavy and slow. Lin discovered that adding the ions is unnecessary, because theoretically, shining a light of a particular wavelength on the conducting polymer can activate the soliton (see Figure 1). Without the extra weight of the added ions, the polymers can bend and flex much more quickly. That

rapid-fire motion enables the high-speed actuation of a device.

Temperature Measured with a Nanoscale Sensor

Nanoparticle (NP) superstructures are important for the creation of smart materials, but most current examples of NP systems show limited response to environmental parameters and do not exhibit transitions of their three-dimensional structures in response to external stimuli.

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Two-Stage Spinning

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Spin-up and flatten during Stage 2

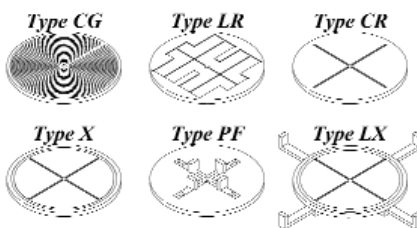
Adjustable Speed

Stage 1

500 to 2500 rpm
2 to 18 seconds

Stage 2

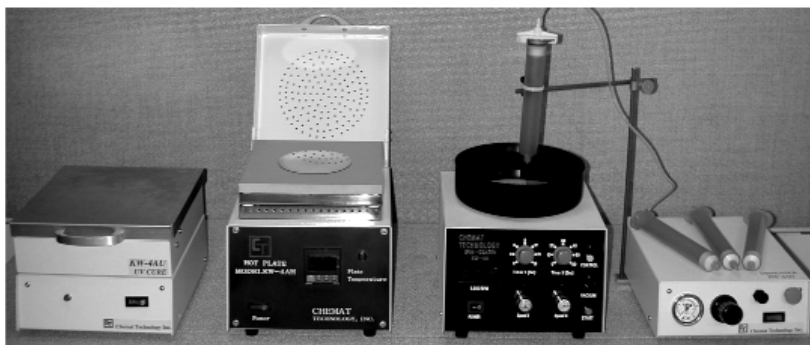
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3 to 60 seconds



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As reported in the November 18, 2005, issue of *Angewandte Chemie International Edition* (p. 7439; DOI: 10.1002/anie.200501264), J. Lee and N. Kotov from the University of Michigan and A. Govorov

from Ohio University created a reversible nanothermometer built from two types of NPs connected by a polymer that acts as a molecular spring. The superstructure is based upon a layer of poly(ethylene gly-

col) (PEG) derivatives with *tert*-butoxycarbonyl (Boc) and *N*-hydroxysulfosuccinimide (NHS) groups at the terminal ends of the linear molecules. Au NPs of 20-nm diameter are attached to the Boc ends and 3.7-nm diameter CdTe NPs are attached to the NHS ends. The superstructure coils into a corona-like structure, with the gold core surrounded by the PEG derivatives and the CdTe NPs.

Exciting the superstructure with the He:Ne laser at 633 nm excited the CdTe NPs. The similarity of the energies of the Au NP plasmon (2.26 eV) and the CdTe NP exciton (2.18 eV) results in resonance conditions in the superstructure that have two effects on the emission of CdTe: an enhancement of the luminescence intensity of the NPs and a strong dependence of the intensity on interparticle distance. The temperature of the CdTe-PEG-Au dispersion was varied between 20°C and 60°C, and it resulted in a swelling of the PEG molecule and an increase in its diameter with increasing temperature. This alters the distance between Au and CdTe NPs and, as a consequence, changes the luminescence output. The process is reversible, with less than 10% photodegradation in each temperature cycle. The researchers applied a simplified mathematical model to perform calculations that demonstrated that the change in the PEG-controlled distance is the cause of the variation in emission intensity.

The researchers concluded the CdTe-PEG-Au system constitutes a nanoscale superstructure that undergoes a reversible structural change in response to a change in environmental conditions, with very high sensitivity of the output to the distance between CdTe NPs and Au NPs. The researchers said that these nanocolloids represent the foundation of a new family of sensing and optoelectronic devices.

MARÍA MARTA FIDALGO

Hot-Drawing Process Aligns and Toughens Carbon Nanotube Fibers

The abundance of commercial applications for high-performance textiles and cables has driven a great deal of materials research. In the November 2005 issue of *Nano Letters* (p. 2212; DOI: 10.1021/nl051419w), P. Miaudet from the National Center for Scientific Research (Pessac, France), V. Pichot from Paris University South (Orsay, France), and their colleagues report how they wet-spun multiwalled carbon nanotubes (MWNTs) with poly(vinyl alcohol) (PVA) to form super-tough composite fibers. The researchers demonstrated that a post-synthesis, hot-drawing treatment dramatically enhanced the composite fiber's mechanical properties. The

Metal-Oxide-Metal Heterojunction Nanowires Formed

Oxide nanowires are currently being developed and investigated for a variety of nanoelectronics applications because of their unique properties and potential opportunities for "bottom-up" assembly. Going a step further, if metal-oxide-metal (MOM) heterojunctions could be formed, sandwiching a functional oxide between two noble-metal nanowires, they could have distinct advantages over all-oxide nanowires. The synthesis of MOM nanowires using a template-based method has now been reported by J.S. Tresbeck and A.L. Vasiliev of the University of Connecticut and N.P. Padture of the Ohio State University.

As reported in the October 2005 issue of the *Journal of Materials Research* (p. 2613; DOI: 10.1557/jmr.2005.0347), the researchers examined Au-SnO₂-Au systems and Au-NiO-Au systems (see Figure 1 for Au-SnO₂-Au nanowires). Au-Sn-Au and Au-Ni-Au nanowires were formed inside anodic aluminum oxide (AAO) templates with 60-nm and 220-nm diameter nanoholes, respectively. First, one side of the template was sealed using 0.5- μ m-thick Ag thin film. A small 0.5- μ m Ag segment was electroplated within the nanoholes. Au was then electroplated inside the nanoholes. This was followed by Sn or Ni electroplating. Au was then again electroplated on top of the Sn or Ni. The Ag and the AAO template were then dissolved using nitric acid and NaOH, respectively, yielding Au-Sn-Au or Au-Ni-Au nanowires, which were centrifuged and rinsed. These nanowires were subjected to heat treatment to yield Au-SnO₂-Au (through oxidation of Sn to SnO and then SnO to SnO₂) or Au-NiO-Au nanowires, through oxidation of Ni to NiO. The nanowires were then dispersed in deionized water or ethanol. These MOM nanowires were examined in both a scanning and a transmission electron microscope.

The overall length of Au-SnO₂-Au nanowires in one case was more than 2 μ m. The Au diameter was \sim 60 nm, and the SnO₂ segment was \sim 60 nm in diameter and \sim 70 nm in length. Grain size in the SnO₂ ranged from 5–10 nm. Similarly, the overall length of a Au-NiO-Au nanowire was more than 7 μ m, with a Au diameter of \sim 270 nm, a NiO diameter of \sim 300 nm, and \sim 200 nm length. These dimensions varied for different templates used.

The study has demonstrated the feasibility of synthesizing MOM nanowires in the Au-SnO₂-Au and the Au-NiO-Au systems. This synthesis method appears to be applicable to a wide variety of metal-oxide combinations. Also, there are several potential unique advantages of this architecture. The dimensions of the functional oxide segment in the nanowires can be controlled by varying the electroplating conditions. The synthesis method described here also offers the possibility of better control over the structure and characteristics of the oxide segments. Site-specific assembly of the MOM nanowires into nanoscale circuits is a possibility. The structure of the nanowires may also enable the direct measurement of the functional properties of the oxides at the nanoscale.

GOPAL RAO

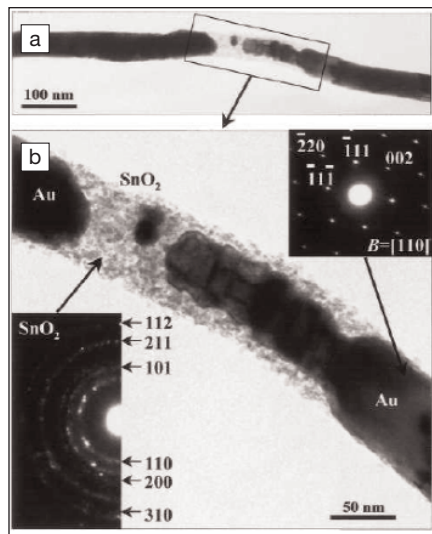


Figure 1. Transmission electron micrographs show an isolated Au-SnO₂-Au nanowire synthesized inside an anodic aluminum oxide template, at (a) low and (b) high magnifications. The dark regions are Au, and the light region is SnO₂. Reprinted with permission from the *Journal of Materials Research* **20** (10) (October 2005) p. 2613; © 2005 Materials Research Society.