The Nanoscale Frontier

TECHNOLOGY THAT'S TOO SMALL TO SEE AND TOO BIG TO IGNORE

RICHARD FEYNMAN, THE NEW YORK-BORN THEORETICAL physicist, gave a lecture in 1959 where he speculated on the potential of radically miniaturized technology. It was possible to write the entire text of the *Encyclopaedia Brittanica* onto the head of a pin, he suggested, if we could shrink each pixel to just 1,000 atoms. Feynman proposed that, in time, miniature factories could be built and microscopic medical devices might transform healthcare.

"It would be interesting in surgery if you could swallow the surgeon," Feynman said. "You put the mechanical surgeon inside the blood vessel and it goes into the heart and 'looks' around."

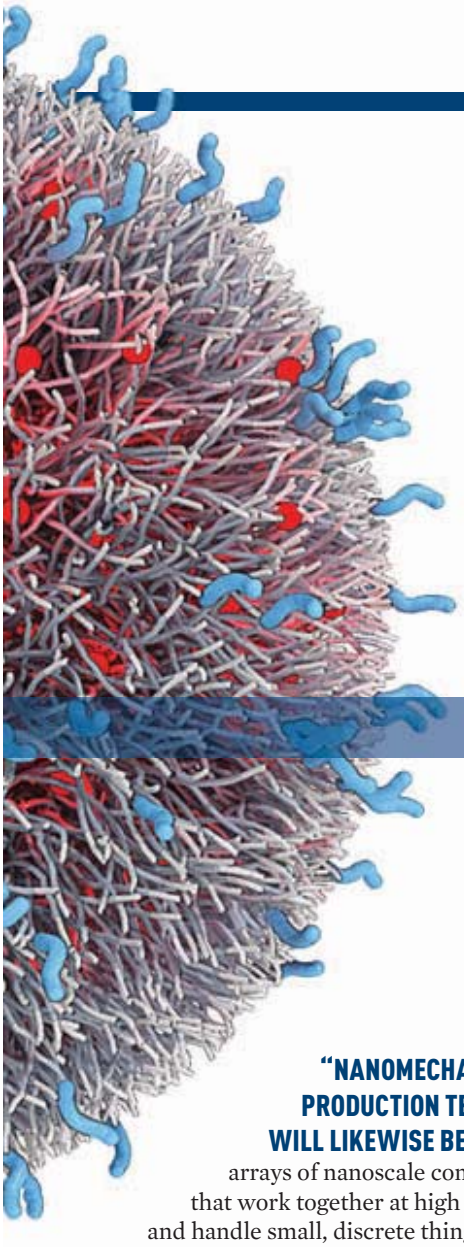
Feynman never used the term, but he was describing what we now call "nanotechnology."

The vision of powerful machines manufactured on molecular scales has intrigued technologists ever since. But in recent years, nanotechnology has left the domain of fancy and started to enter the real world. In the pages of *Mechanical Engineering*, we have featured the work of leading researchers describing their breakthroughs as well as the engineers who are bringing nanoscale products to market. To paraphrase Feynman, there's plenty of opportunity at the bottom, and these stories about nanoscale engineering have been some of our most provocative—and popular—articles.

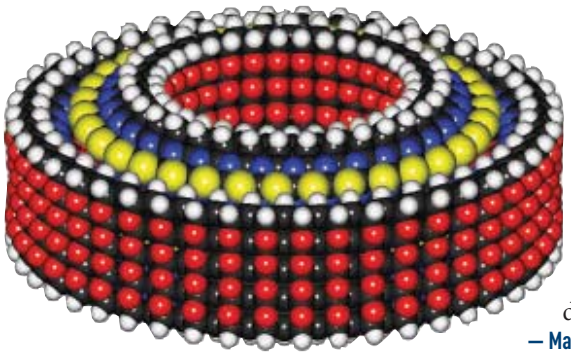
In October, as part of the celebration of National Nanotechnology Day, an event sponsored by the federal government's National Nanotechnology Coordination Office to raise awareness of the field, *Mechanical Engineering* magazine and ASME.org published a page with links to 15 of our best nanotechnology feature articles since 2010. Over the next four pages, we provide some excerpts from those articles, which hint at the excitement these technologists feel about nanotechnology's potential. The research and breakthroughs they describe could lead to new ways to store energy, probe the human brain, or even cure cancer.

And we extend our invitation to check out **http://www.asme.org/events/celebrating-national-nanotechnology-day/the-nanoscale-frontier**, which has links to PDFs of the feature articles we've curated.

JEFFREY WINTERS is a senior editor at *Mechanical Engineering* magazine.



This illustration of a nanoparticle encapsulating time-released drugs accompanied "Rebuilding Ourselves," February 2013.



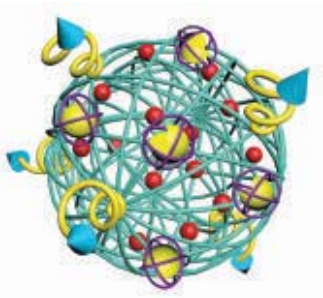
"NANOMECHANICAL PRODUCTION TECHNOLOGY WILL LIKEWISE BE BASED on arrays of nanoscale components that work together at high frequencies and handle small, discrete things. But in the nanomachine world the things aren't bits packaged in bytes, they're atoms packaged in molecules."
— K. Eric Drexler,
"Nothing Small About Nanotechnology,"
August 2014

"MECHANICAL ENGINEERING AT THE NANOSCALE IS AIDING cutting-edge applications in oncological diagnosis and treatment."
— Mauro Ferrari,
"Infernal Mechanism,"
March 2010

"DESIGN ENGINEERS WILL BE ABLE TO CUSTOMIZE MATERIALS to their design in much the same way they select and change part geometries today. ... What we're envisioning is to allow engineers to define their own materials rather than use those already discovered."
— Yan Wang,
"CAD at the Nano Scale,"
August 2014

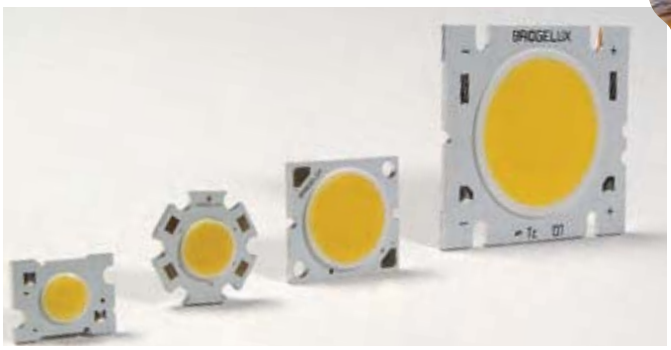
"OVER THE PAST DECADE, BIOENGINEERS HAVE TRANSFORMED the design of DNA scaffold origami from art to engineering."
— Hai-Jun Su and Carlos E. Castro,
"The Rise of the DNA Nanorobots,"
August 2016

TO PARAPHRASE FEYNMAN, THERE'S PLENTY OF OPPORTUNITY AT THE BOTTOM.



"YOU CAN HAVE THE FANCIEST IDEAS AND MOLECULES. But if you can't get them into the cell, they are of no use."
— Matthew Porteus, quoted in "Neat Little Packages," February 2016

"A NANOSTRUCTURED ENGINEERED MATERIAL BASED on gecko-foot reusable adhesive would have a wide range of applications, from everyday objects such as adhesive tapes and fasteners to exotic items such as wall-climbing robots. But engineering such a material isn't straightforward."
— Bharat Bhushan, "Nature's Nanotechnology," December 2012

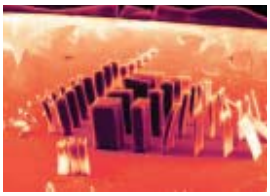


"WE'RE AT THE BEGINNING STAGES OF EXPONENTIAL GROWTH of nano-enabled product innovation.... That's where innovation is going to occur, at the molecular level."
— Steve Waite, quoted in "Nanotech Unbound," November 2012

"WHILE THE PROSPECT OF AUTOMATONS PATROLLING our capillaries is still far away, much more exquisite control of nanoparticles is already under development."
— Guy M. Genin and Ram V. Devireddy, "MEs in Nanomedicine," June 2012

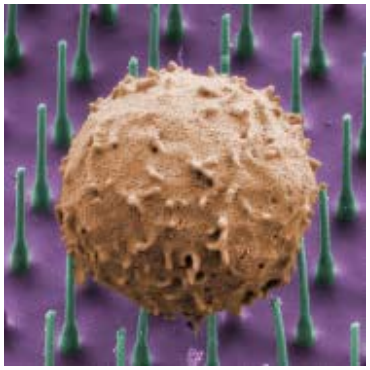
"ONCE CANCERS METASTASIZE, THEY ARE ALMOST ALWAYS FATAL. Researchers are looking at the nanoscale mechanics of tumors to discover means to attack—and kill—all kinds of cancer cells. If successful, this will be a cure for even metastatic cancer."
— Mauro Ferrari, "Slaying the Dragon," April 2015

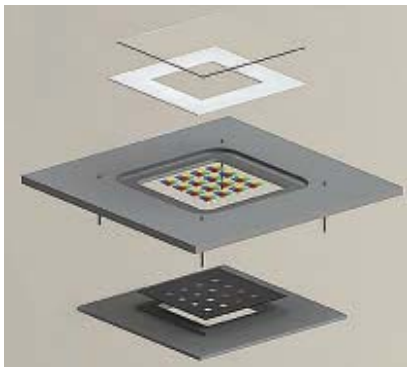
"CARBON NANOTUBES LET US USE 30 PERCENT LESS CARBON FIBER. We get the same results as a conventional composite, but the part is lighter and we don't have the brittleness."
— Roberto Velozzi, quoted in "Positive Reinforcement," March 2010



"TO STORE MACROSCOPICALLY SIGNIFICANT AMOUNTS OF ENERGY, you need to deform large numbers of carbon nanotubes. It is more challenging still to deform them in a way that maintains high energy density of the overall system."
— Carol Livermore, "Carbon Super-Springs," March 2010

"WOULDN'T IT BE COOL TO MAKE A MORE POWERFUL PROBE that was so small, it would cause little damage when it was implanted? There would be a good chance of implanting it in paraplegic patients, and using it to control devices that help them get around and take care of themselves."
— Sotiris Masmanidis, quoted in "Nanotechnology for the Brain," February 2014





"MICRO- AND NANOSCALE STRUCTURES HAVE GIVEN us capabilities to interact with cells and pathogens at their level as never before and helped us understand how they live, grow, multiply, differentiate, and die."
— Yunus Alapan, Ismail Sayin, and Umut Atakan Gurkan, "Making the Smallest Medical Devices," February 2014

"NANOTECHNOLOGY CAN ALSO HELP US ALTER NATURAL DESIGNS. Carbon nanotubes act like a reinforcement to give synthetic tissue the strength, stiffness, and viscoelastic performance of natural membranes."
— Rohit Karnik and Robert S. Langer, "Rebuilding Ourselves," February 2013

"AS OPPOSED TO THE MACROSCALE, WHERE WATER molecules next to a pipe wall have zero velocity, in nanochannels fluid molecules slip at the channel surface, experiencing an enhanced convective transport."
— Alessandro Grattoni, Scott Parazynski, and Fazle Hussain, "Building Nanoglands," February 2011