THE NANOTECH REVOLUTION (SCIENTIFIC AMERICAN CUTTING-EDGE SCIENCE) pdf

1: How to build a better battery through nanotechnology | Science | AAAS

Updated Article, Coming Soon The rising capabilities of nanotech are already taking effect on our world. Further advances will go on to revolutionise every aspect of our lives; beginning within just a decade. Nanotechnology nanotech is technology based on materials, the single units of which, are smaller than nanometers, but usually smaller than nm. When materials have been manipulated to have one or more of their dimensions under nanometres, they take on different properties â€” breaking their usual physical and chemical rules. For example, their strength, ability to conduct electricity and rate of reactivity increase massively; solids such as gold turn into liquids at room temperature, silver shows increased antimicrobial properties, inert materials like platinum and gold become catalysts, and stable materials like aluminium become combustible. The result is that we are given access to a more advanced level of construction materials. Chemistry, biology, physics, materials science, and engineering. Treat this page as an introduction. The issues surrounding this introduction will have impacts on our world, greater than the impacts of all humanities past revolutions combined. Please comment at the bottom of the page with anything you think should be included. Click to read more When the Revolution will Begin The revolutionary effects of nanotechnology are set to occur in phases. Phase 1 will feature the structures that are relatively easy to create. Examples of these structures include, graphene, carbon nanotubes, and super-hydrophobic coatings. If passive nanostructures were the materials needed to make the bicycle, then active nanostructures would be the bicycle itself. The active structures are defined as able to change their state during operation â€” examples include new nanoscale transistors, amplifiers, actuators, plasmonics, fluidics, molecular machines, light-driven molecular motors, and laser-emitting devices. The components can be used in nanoelectromechanical systems, which will enable the next phases of the revolution. If the current exponential rate of our technological advance continues, then within the next decade, the revolution will move progressively into both its 2nd and 3rd phases. Phase 3 devices are already in the design phase , and so once it is possible to create phase 2 structures, it will be possible to begin creating the phase 3 devices. It can be described as bringing the structures to life: Phase 4 of the nanotechnology revolution, could begin in as little as 30 years. The nanobots will be capable of gaining electrical power from their environment eg. These types of devices will have an incomprehensible effect on the way we live. What Nanotechnology will Revolutionise It is hard to think of anything that nanotechnology will not revolutionise; so the answer for now is â€” everything; the future it offers is incomprehensible. To give you an idea of the world we are moving into, listed below are some key examples of upcoming nanotechnology revolutions. Renewable Clean Energy The future will be powered by the sun, via nanotechnology. Energy will be collected decentrally, at our homes, and our local solar power stations. Battery technology must also be improved for this future â€” and this upgrade will also be supplied by nanotechnology. Clearly revolutionary; your car will run efficiently on a battery and solar panel; long distance power lines can be torn down; no more need for oil, or old hazardous versions of nuclear power; scrap the wind turbines. Sounds quite incredible right? Something to keep in mind as we run through these revolutions, is the massive reductions in the cost of living. For more information about the future of solar power, I recommend this article from the National Geographic. For more information about upcoming improvements in battery power, I have an article, here , and there is an overview over at the Battery University. More information about the new water purification system can be found at the Scientific American. Radically Improving Health and Longevity To the point: There is much that needs to be done before we all get ourselves our own forever young body. But exponential growth could see it happen in as little as 30 years. Learn more about the process on our central immortality information page. Immortality could first be achieved through biological means, as explained by Aubrey de Grey. But immortal, disease and damage resistant bodies will eventually be perfected through nanotechnology enhancements. Nanobots will be used to perfect the functions of our bodies. Already, microbivore nanobots are being developed to replace antibiotics: They will be able to search and destroy harmful bacteria in our bodies. Similar nanobots could be used to destroy viruses. They will be able to repair damaged tissue, as explained here. Not only can they be used to maintain our bodies â€" they could enhance us: Radically Enhancing Computing Power Quantum computing a nanotechnology is predicted to replace the traditional computer chip as the spearhead of computing power, within a decade â€" becoming billions of times more powerful than our current computers, within only 30 years. Find out what quantum computing is, at How Stuff Works. Therefore, the technology will be a complete game changer for the internet. The benefits of the technology though are also immense, with it likely being the foundation for sentient artificial intelligence , laying the road to the technological singularity. For now though, we only have the basics; so I will go on now to run through the main topics, to give you a base for expanding your research. More Breakthroughs Listed below are websites and articles which display nanotech breakthroughs and more examples of upcoming revolutions.

2: Nanotechnology's Future - Scientific American

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How Things Work Introduction From the touch screens we use at ATMs to the treatments that keep our canine companions flea-free, we often take for granted the science behind everyday technologies. In this exclusive online issue, Scientific American editor Mark Fischetti explains the inner workings of 20 commonly used technologies. Learn how noise-cancelling headphones silence unwanted background noise and how digital cameras overcome shaky hands. Discover how crude oil is refined and how cochlear implants enable hearing. Steady Cam Image stabilization in digital cameras originally published October Carbon Hooch The sophisticated chemistry of refining crude originally published June Cutting Work How a robot can mow your lawn originally published May Into the Breach How levees hold back rivers originally published February Case Cracked Nuts to you! Rapid prototyping originally published July Reducing a Roar How new headphones cancel out unwanted background noise originally published February Crowded Skies How new headphones cancel out unwanted background noise originally published December Keep the Beat How pacemakers keep the beat originally published November Shock Absorbed Making cities earthquake-proof originally published October Clear Favorite Lasik and other laser eye surgeries originally published May Staying Power Seriously, how do nails hold things together? Uncommon Genius Introduction Millions of years of evolution have endowed Homo sapiens with remarkable intellect. But not all human brains are created equal. From the great powers of memory seen in savants to the skills of chess grandmasters, unusual talents can offer a unique window on how the mind works. This exclusive online issue examines genius in some of its most intriguing forms. Other savants have musical or artistic talents. Less well known than savant syndrome is Williams syndrome, a disorder in which affected individuals generally score below average on standard IQ tests, but often possess startling language and music skills, as another article in this issue describes. Mood disorders, too, have been linked to genius: Other articles focus on gifted children. These youngsters fascinate with their precocious intellect, but they often suffer ridicule and neglect. They also tend to be keenly aware of the potential risk of failure, which can prove emotionally paralyzing for them. Studies of such children have provided key insights into brain development--and revealed how best to nurture their extraordinary minds. Our final article in the issue considers whether some geniuses are made, not born. Dissections of the mental processes of chess grandmasters have shown that their skills arise from years of "effortful study"--continually tackling challenges that lie just beyond their competence. Could comparable training turn any one of us into such an expert? Islands of Genius Artistic brilliance and a dazzling memory can sometimes accompany autism and other developmental disorders originally published in Scientific American Mind, January Inside the Mind of a Savant Kim Peek possesses one of the most extraordinary memories ever recorded. Until we can explain his abilities, we cannot pretend to understand human cognition originally published December Williams Syndrome and the Brain To gain fresh insights into how the brain is organized, investigators are turning to a little known disorder originally published December Manic-Depressive Illness and Creativity Does some fine madness plague great artists? Several studies now show that creativity and mood disorders are linked originally published in Mysteries of the Mind Uncommon Talents: Gifted Children, Prodigies and Savants Possessing abilities well beyond their years, gifted children inspire admiration, but they also suffer ridicule, neglect and misunderstanding originally published in Exploring Intelligence Watching Prodigies for the Dark Side Gifted children who are not challenged can quickly grow bored with school, but a hidden fear of failure can lead to far greater problems originally published Scientific American Mind, April The Expert Mind The mental processes of chess grandmasters are unlike those of novices, a fact that illuminates the development of expertise in other fields originally published August 21st Century Medicine Introduction The 18th century witnessed the birth of a vaccine for smallpox; the 19th century ushered in the advent of aspirin; penicillin and the pill transformed the medical landscape of the 20th century. What will the history books regard as the medical milestones of the 21st century? But already a number of potentially revolutionary treatments have emerged. In this exclusive online issue, leading experts describe cutting-edge approaches to combating our collective ills. Learn about the gains being made on malaria, advances in pain control and efforts to construct a patch for human hearts. Other articles examine the road to real stem cell therapies, the promise of truly personalized medicine and the use of suspended animation to buy crucial time for patients in need. Tackling Malaria Interventions available today could lead to decisive gains in prevention and treatment--if only the world would apply them originally published December Virtual-Reality Therapy Patients can get relief from pain or overcome their phobias by immersing themselves in computer-generated worlds originally published August Rebuilding Broken Hearts Biologists and engineers working together in the fledgling field of tissue engineering are within reach of one of their greatest goals: Their potential to revolutionize research and bring about the era of truly personalized medicine means the time to start preparing is now originally published January Buying Time in Suspended Animation An ability to put the human body on hold could safeguard the critically injured or preserve donor organs for transport. Does the power to reversibly stop our biological clocks already lie within us? And they are just some of the cutting edge ideas that leading authorities explore in this, our second exclusive online issue on extreme physics. The First Few Microseconds In recent experiments, physicists have replicated conditions of the infant universe--with startling results originally published May An Echo of Black Holes Sound waves in a fluid behave uncannily like light waves in space. Black holes even have acoustic counterparts. Could spacetime literally be a kind of fluid, like the ether of pre-Einsteinian physics? Finding that Higgs field will give us a more complete understanding about how the universe works originally published July Inconstant Constants Do the inner workings of nature change with time? Yet in school districts across the U. Spurred by this worrying state of affairs, we have put together a collection of some of our favorite articles concerning the history of life, starting with a firm refutation of creationist arguments by Scientific American editor-in-chief John Rennie. Learn how four-legged land animals evolved from fish, how birds descended from dinosaurs and where whales come from. Explore the origins of early animals, and retrace the steps of paleontologists hot on the fossil trail of the earliest human ancestor. Also, discover how the application of evolutionary biology to medicine is informing medical research. Parents, of course, play a critical role in this aspect of development. Psychologists, neurobiologists and other scientists can help fill in the blanks, however. In this exclusive online issue, leading authorities share their insights into the minds of the young. Learn how children develop morals, why they talk to themselves, and what happens to brain development and function in the face of abuse at an early age. Other articles explore how reading should be taught, how attention-deficit hyperactivity disorder arises and what unique challenges gifted children face. The Moral Development of Children It is not enough for kids to tell right from wrong. They must develop a commitment to acting on their ideals. Educators have long argued over the best way to teach reading to children. The research, however, indicates that a highly popular method is inadequate on its own originally published March Uncommon Talents: Gifted Children, Prodigies and Savants Possessing abilities well beyond their years, gifted children inspire admiration, but they also suffer ridicule, neglect and misunderstanding originally published in Scientific American Presents; Exploring Intelligence Attention-Deficit Hyperactivity Disorder A new theory suggests the disorder results from a failure in self-control. ADHD may arise when key brain circuits do not develop properly, perhaps because of an altered gene or genes originally published September The Nanotech Revolution Introduction Good things come in small packages. What on earth is nanotech, you ask? In this compilation of articles published over the past five years, leading authorities trace the steps scientists have taken in ushering us into the nano age--and make predictions about what is to come. Michael Roukes describes the unique mesoscale realm in which nanotechnological devices exist and contends that engineers will not be able to make reliable nanodevices until they understand the physical principles that govern matter there. Peter Vettiger and Gerd Binnig recount their efforts to build the first "nanodrive"--a micromechanical digital storage device with nano-size components. Seeman explains how DNA is an ideal molecule for building nano-scale structures that hold molecule-size electronic devices, or guest molecules for crystallography. But first, scientists have to understand the unique physics that governs matter there originally published in The Edge of Physics The Nanodrive Project Inventing a nanotechnology device for mass production and consumer use is trickier than it sounds originally published January Innovations: Over the years, we have invited readers to submit their queries to us. This compilation brings together the most fascinating of these exchanges to date. Learn how caffeine is removed from coffee, what causes hiccups, why bees buzz and why life expectancy is longer for women than it is for men. Find out how long a person can survive without food, how the abbreviations of the periodic table were determined--or even what would happen if you fell through a hypothetical hole in the earth. If so, just drop us a line at experts sciam. What is the origin of zero? What happens when an aircraft breaks the sound barrier? When Tyrannosaurus rex fell, how did it get up, given its tiny arms? What is a blue moon? How can graphite and diamond be so different if they are both composed of pure carbon? Why is spider silk so strong? And why does it seem to be contagious? Why do stars twinkle? How do rewritable CDs work? Why are snowflakes symmetrical? How long can the average person survive without water? Why does shaking a can of coffee cause the larger grains to move to the surface? How long do stars usually live? How do manufacturers calculate calories for packages foods? Am I still protected? Why is the South Pole colder than the North Pole? Why is the sky blue? Are humans the only primates that cry? Why do we get goose bumps? What causes a mirage? How can deleted computer files be retrieved at a later date? How does club soda remove red wine stains? How can the weight of Earth be determined? How do sunless tanners work? Why does a shaken soda fizz more than an unshaken one? How does decanting red wine affect its taste? And why not decant white? Why do traffic jams sometimes seem to appear out of nowhere? How are the abbreviations of the periodic table determined? How do scientists detect new elements that last only milliseconds? Why do people have different blood types? How are tattoos removed? How can a poll of only 1, Americans represent million people? What causes feedback in a guitar or microphone? But the serene beauty of the night sky belies the tumultuous nature of the cosmos.

3: The Scientific Revolution (www.enganchecubano.come) - PDF Free Download

The Nanotech Revolution (Scientific American Cutting-Edge Science) Library Binding - Bargain Price, June 30, by Rosen Pub.

The term "nano-technology" was first used by Norio Taniguchi in , though it was not widely known. Eric Drexler used the term "nanotechnology" in his book Engines of Creation: The Coming Era of Nanotechnology , which proposed the idea of a nanoscale "assembler" which would be able to build a copy of itself and of other items of arbitrary complexity with atomic control. Also in , Drexler co-founded The Foresight Institute with which he is no longer affiliated to help increase public awareness and understanding of nanotechnology concepts and implications. Since the popularity spike in the s, most of nanotechnology has involved investigation of several approaches to making mechanical devices out of a small number of atoms. First, the invention of the scanning tunneling microscope in which provided unprecedented visualization of individual atoms and bonds, and was successfully used to manipulate individual atoms in Buckminsterfullerene C60, also known as the buckyball , is a representative member of the carbon structures known as fullerenes. Members of the fullerene family are a major subject of research falling under the nanotechnology umbrella. In the early s, the field garnered increased scientific, political, and commercial attention that led to both controversy and progress. These products are limited to bulk applications of nanomaterials and do not involve atomic control of matter. Some examples include the Silver Nano platform for using silver nanoparticles as an antibacterial agent, nanoparticle -based transparent sunscreens, carbon fiber strengthening using silica nanoparticles, and carbon nanotubes for stain-resistant textiles. By the mids new and serious scientific attention began to flourish. Projects emerged to produce nanotechnology roadmaps [19] [20] which center on atomically precise manipulation of matter and discuss existing and projected capabilities, goals, and applications. Fundamental concepts Nanotechnology is the engineering of functional systems at the molecular scale. This covers both current work and concepts that are more advanced. In its original sense, nanotechnology refers to the projected ability to construct items from the bottom up, using techniques and tools being developed today to make complete, high performance products. By comparison, typical carbon-carbon bond lengths , or the spacing between these atoms in a molecule , are in the range 0. By convention, nanotechnology is taken as the scale range 1 to nm following the definition used by the National Nanotechnology Initiative in the US. The lower limit is set by the size of atoms hydrogen has the smallest atoms, which are approximately a quarter of a nm kinetic diameter since nanotechnology must build its devices from atoms and molecules. The upper limit is more or less arbitrary but is around the size below which phenomena not observed in larger structures start to become apparent and can be made use of in the nano device. In the "bottom-up" approach, materials and devices are built from molecular components which assemble themselves chemically by principles of molecular recognition. The positions of the individual atoms composing the surface are visible. Nanomaterials Several phenomena become pronounced as the size of the system decreases. These include statistical mechanical effects, as well as quantum mechanical effects, for example the " quantum size effect" where the electronic properties of solids are altered with great reductions in particle size. This effect does not come into play by going from macro to micro dimensions. However, quantum effects can become significant when the nanometer size range is reached, typically at distances of nanometers or less, the so-called quantum realm. Additionally, a number of physical mechanical, electrical, optical, etc. One example is the increase in surface area to volume ratio altering mechanical, thermal and catalytic properties of materials. Diffusion and reactions at nanoscale, nanostructures materials and nanodevices with fast ion transport are generally referred to nanoionics. Mechanical properties of nanosystems are of interest in the nanomechanics research. The catalytic activity of nanomaterials also opens potential risks in their interaction with biomaterials. Materials reduced to the nanoscale can show different properties compared to what they exhibit on a macroscale, enabling unique applications. For instance, opaque substances can become transparent copper ; stable materials can turn combustible aluminium ; insoluble materials may become soluble gold. A material such as gold, which is chemically inert at normal scales, can serve as a potent chemical catalyst at nanoscales. Much of the fascination with nanotechnology stems from these quantum and surface phenomena that matter exhibits at the nanoscale. Molecular self-assembly Modern synthetic chemistry has reached the point where it is possible to prepare small molecules to almost any structure. These methods are used today to manufacture a wide variety of useful chemicals such as pharmaceuticals or commercial polymers. This ability raises the question of extending this kind of control to the next-larger level, seeking methods to assemble these single molecules into supramolecular assemblies consisting of many molecules arranged in a well defined manner. The concept of molecular recognition is especially important: The Watsonâ€"Crick basepairing rules are a direct result of this, as is the specificity of an enzyme being targeted to a single substrate , or the specific folding of the protein itself. Thus, two or more components can be designed to be complementary and mutually attractive so that they make a more complex and useful whole. Such bottom-up approaches should be capable of producing devices in parallel and be much cheaper than top-down methods, but could potentially be overwhelmed as the size and complexity of the desired assembly increases. Most useful structures require complex and thermodynamically unlikely arrangements of atoms. Nevertheless, there are many examples of self-assembly based on molecular recognition in biology , most notably Watsonâ€"Crick basepairing and enzyme-substrate interactions. The challenge for nanotechnology is whether these principles can be used to engineer new constructs in addition to natural ones. Molecular nanotechnology Molecular nanotechnology, sometimes called molecular manufacturing, describes engineered nanosystems nanoscale machines operating on the molecular scale. Molecular nanotechnology is especially associated with the molecular assembler , a machine that can produce a desired structure or device atom-by-atom using the principles of mechanosynthesis. Manufacturing in the context of productive nanosystems is not related to, and should be clearly distinguished from, the conventional technologies used to manufacture nanomaterials such as carbon nanotubes and nanoparticles. When the term "nanotechnology" was independently coined and popularized by Eric Drexler who at the time was unaware of an earlier usage by Norio Taniguchi it referred to a future manufacturing technology based on molecular machine systems. The premise was that molecular scale biological analogies of traditional machine components demonstrated molecular machines were possible: It is hoped that developments in nanotechnology will make possible their construction by some other means, perhaps using biomimetic principles. However, Drexler and other researchers [27] have proposed that advanced nanotechnology, although perhaps initially implemented by biomimetic means, ultimately could be based on mechanical engineering principles, namely, a manufacturing technology based on the mechanical functionality of these components such as gears, bearings, motors, and structural members that would enable programmable, positional assembly to atomic specification. In general it is very difficult to assemble devices on the atomic scale, as one has to position atoms on other atoms of comparable size and stickiness. Another view, put forth by Carlo Montemagno, [29] is that future nanosystems will be hybrids of silicon technology and biological molecular machines. Richard Smalley argued that mechanosynthesis are impossible due to the difficulties in mechanically manipulating individual molecules. Leaders in research on non-biological molecular machines are Dr. An experiment indicating that positional molecular assembly is possible was performed by Ho and Lee at Cornell University in They used a scanning tunneling microscope to move an individual carbon monoxide molecule CO to an individual iron atom Fe sitting on a flat silver crystal, and chemically bound the CO to the Fe by applying a voltage. Current research Graphical representation of a rotaxane , useful as a molecular switch. This DNA tetrahedron [33] is an artificially designed nanostructure of the type made in the field of DNA nanotechnology. Each edge of the tetrahedron is a 20 base pair DNA double helix , and each vertex is a three-arm junction. Rotating view of C60, one kind of fullerene. This device transfers energy from nano-thin layers of quantum wells to nanocrystals above them, causing the nanocrystals to emit visible light. Nanomaterials with fast ion transport are related also to nanoionics and nanoelectronics. Nanoscale materials can also be used for bulk applications; most present commercial applications of nanotechnology are of this flavor. Progress has been made in using these materials for medical applications; see Nanomedicine. Nanoscale materials such as nanopillars are sometimes used in solar cells which combats the cost of traditional silicon solar cells. Development of applications incorporating semiconductor nanoparticles to be used in the next generation of products, such as display technology, lighting, solar cells and biological imaging; see quantum dots. Recent application of nanomaterials include a range of biomedical applications, such as tissue engineering , drug delivery , and biosensors. DNA nanotechnology utilizes the specificity of Watsonâ€"Crick basepairing to construct well-defined structures out of DNA and other nucleic acids. Approaches from the field of "classical" chemical synthesis Inorganic and organic synthesis also aim at designing molecules with well-defined shape e. More generally, molecular self-assembly seeks to use concepts of supramolecular chemistry, and molecular recognition in particular, to cause single-molecule components to automatically arrange themselves into some useful conformation. Atomic force microscope tips can be used as a nanoscale "write head" to deposit a chemical upon a surface in a desired pattern in a process called dip pen nanolithography. This technique fits into the larger subfield of nanolithography. Molecular Beam Epitaxy allows for bottom up assemblies of materials, most notably semiconductor materials commonly used in chip and computing applications, stacks, gating, and nanowire lasers. Top-down approaches These seek to create smaller devices by using larger ones to direct their assembly. Giant magnetoresistance -based hard drives already on the market fit this description, [41] as do atomic layer deposition ALD techniques. Focused ion beams can directly remove material, or even deposit material when suitable precursor gasses are applied at the same time. Atomic force microscope tips can be used as a nanoscale "write head" to deposit a resist, which is then followed by an etching process to remove material in a top-down method. Functional approaches These seek to develop components of a desired functionality without regard to how they might be assembled. Magnetic assembly for the synthesis of anisotropic superparamagnetic materials such as recently presented magnetic nano chains. These could then be used as single-molecule components in a nanoelectronic device. Synthetic chemical methods can also be used to create synthetic molecular motors , such as in a so-called nanocar. Biomimetic approaches Bionics or biomimicry seeks to apply biological methods and systems found in nature, to the study and design of engineering systems and modern technology. Biomineralization is one example of the systems studied. Bionanotechnology is the use of biomolecules for applications in nanotechnology, including use of viruses and lipid assemblies. Speculative These subfields seek to anticipate what inventions nanotechnology might yield, or attempt to propose an agenda along which inquiry might progress. These often take a big-picture view of nanotechnology, with more emphasis on its societal implications than the details of how such inventions could actually be created. Molecular nanotechnology is a proposed approach which involves manipulating single molecules in finely controlled, deterministic ways. This is more theoretical than the other subfields, and many of its proposed techniques are beyond current capabilities. Nanorobotics centers on self-sufficient machines of some functionality operating at the nanoscale. There are hopes for applying nanorobots in medicine, [46] [47] [48] but it may not be easy to do such a thing because of several drawbacks of such devices. Because of the discrete i. Due to the popularity and media exposure of the term nanotechnology, the words picotechnology and femtotechnology have been coined in analogy to it, although these are only used rarely and informally. The dimensionality play a major role in determining the characteristic of nanomaterials including physical , chemical and biological characteristics. With the decrease in dimensionality, an increase in surface-to-volume ratio is observed. This indicate that smaller dimensional nanomaterials have higher surface area compared to 3D nanomaterials. Recently, two dimensional 2D nanomaterials are extensively investigated for electronic , biomedical , drug delivery and biosensor applications. Tools and techniques Typical AFM setup.

THE NANOTECH REVOLUTION (SCIENTIFIC AMERICAN CUTTING-EDGE SCIENCE) pdf

4: Nanotechnology - Wikipedia

Yi Cui uses nanotechnology to control the way chemical reactions inside batteries proceed. Noah Berger By Robert F. Cui, a materials scientist at Stanford University here, is headed to visit Amprius, a battery company he founded 6 years ago. In a few years, he says, he plans to upgrade to a new model, with a crucial improvement: They have plenty of company. Massive corporations such as Panasonic, Samsung, LG Chem, Apple, and Tesla are vying to make batteries smaller, lighter, and more powerful. But among these power players, Cui remains a pioneering force. He is building intricately structured battery electrodes that can soak up and release charge-carrying ions in greater quantities, and faster, than standard electrodes can, without producing troublesome side reactions. Yi Cui, Stanford University In a series of lab demonstrations, Cui has shown how his architectural approach to electrodes can domesticate a host of battery chemistries that have long tantalized researchers but remained problematic. That could give modest-priced EVs the same range as gas-powered modelsâ€”a revolutionary advance that could help nations power their vehicle fleets with electricity provided by solar and wind power, dramatically reducing carbon emissions. His lab is exploring nanotech innovations that are spawning startup companies aiming to provide cheaper, more effective air and water purification systems. But so far Cui has made his clearest mark on batteries. In the past decade, the energy density of the best commercial batteries has doubled. Battery users want more. The rise in production of EVs by car companies that include Tesla, General Motors, and Nissan accounts for some of that surge. Yet they can take the car only about kilometers on a single charge, substantially less than the range of many conventional cars. But with a smaller battery pack, its range is only about one-third that of the Tesla. Improving batteries could make a major impact. Those were the early days of nanotechnology, when researchers were struggling to get a firm handle on how to create just the materials they wanted, and the world of applications was only beginning to take shape. But Chu and others impressed on him that nanotechnology could give batteries an edge. After moving to Stanford, Cui quickly gravitated to the nexus between nanotechnology and the electrochemistry that makes batteries workâ€”and accounts for their limitations. Take lithium-ion rechargeable batteries. In principle, these batteries are simple: When a battery is charging, lithium ions are released from the positive electrode, or cathode, which consists of a lithium alloy, commonly lithium cobalt oxide or lithium iron phosphate. They are drawn toward the negatively charged electrode, called the anode, which is usually made of graphite. Voltage from an external power source drives the whole ionic mass migration, storing power. When a deviceâ€”say, a power tool or a carâ€”is turned on and demands energy, the battery discharges: Lithium atoms in the graphite give up electrons, which travel through the external circuit to the cathode. Meanwhile, the lithium ions slip out of the graphite and zip through the electrolyte and the separator to the cathode, where they meet up with electrons that have made the journey through the circuit see diagram below. But graphite is only so-so at gathering lithium ions during charging. It takes six carbon atoms in graphite to hold on to a single lithium ion. That weak grip limits how much lithium the electrode can hold and thus how much power the battery can store. Silicon has the potential to do far better. Each silicon atom can bind to four lithium ions. In principle, that means a silicon-based anode can store 10 times as much energy as one made from graphite. After only a few cycles of such torture, silicon electrodes fracture and eventually split into tiny, isolated grains. The anodeâ€”and the batteryâ€”crumbles and dies. For starters, they have a much higher percentage of their atoms at their surface relative to the number in their interior. And because surface atoms have fewer atomic neighbors locking them in place, they can move more easily in response to stresses and strains. Other types of atomic movement explain why thin sheets of aluminum foil or paper can bend without breaking more easily than chunks of aluminum metal or wood can. Cui and colleagues started devising ways to make cheaper silicon anodes. Though potentially cheaper, these faced a second problem: The shell gave silicon atoms in the yolk ample room to swell and shrink, while protecting them from the electrolyteâ€”and the reactions that form an SEI layer. They did even better 2 years later. With his battery company up and running, Cui plans to launch startups that apply nanotech to air and water purification. Noah Berger Earlier this year, Cui and colleagues reported a solution that outdoes even their complex pomegranate assemblies. The hammered particles wound up larger than the silicon spheres in the pomegranatesâ€”so big that they fractured after a few charging cycles. It was also flexible enough to maintain contact with the fractured particles and thus carry their charges to the metal wires. And those, he says, still represent only the beginning of how good silicon anodes will eventually become. Now, Cui is looking beyond silicon. One focus is to make anodes out of pure lithium metal, which has long been viewed as the ultimate anode material, as it has the potential to store even more energy than silicon and is much lighter. But there have been major problems here, too. For starters, an SEI layer normally forms around the lithium metal electrode. Lithium ions can penetrate the layer, so the SEI acts as a protective film around the lithium anode. But as the battery cycles, the metal swells and shrinks just as silicon particles do, and the pulsing can break the SEI layer. Lithium ions can then pile up in the crack, causing a metal spike, known as a dendrite, to sprout from the electrode. Improving anodes is only half the battle in making better batteries. Like silicon on the anode side, sulfur has long been seen as a tantalizing option for the cathode. Perhaps equally important, sulfur is dirt cheap. But it, too, has problems. Sulfur is a relatively modest electrical conductor, and it reacts with common electrolytes to form chemicals that can kill the batteries after a few cycles of charging and discharging. Sulfur cathodes also tend to hoard charges instead of giving them up during discharge. Down the road, Cui says, he intends to put both of his key innovations together. By coupling silicon anodes with sulfur cathodes, he hopes to make cheap, high-capacity batteries that could change the way the world powers its devices. It just might help him change the world, and get rich on the side.

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5: Scientific American Online Article Index

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ROCO Advertisement Today nanotechnology is still in a formative phase--not unlike the condition of computer science in the s or biotechnology in the s. Yet it is maturing rapidly. About two million workers will be employed in nanotech industries, and three times that many will have supporting jobs. Descriptions of nanotech typically characterize it purely in terms of the minute size of the physical features with which it is concerned--assemblies between the size of an atom and about molecular diameters. That depiction makes it sound as though nanotech is merely looking to use infinitely smaller parts than conventional engineering. But at this scale, rearranging the atoms and molecules leads to new properties. One sees a transition between the fixed behavior of individual atoms and molecules and the adjustable behavior of collectives. Thus, nanotechnology might better be viewed as the application of quantum theory and other nano-specific phenomena to fundamentally control the properties and behavior of matter. Over the next couple of decades, nanotech will evolve through four overlapping stages of industrial prototyping and early commercialization. The first one, which began after , involves the development of passive nanostructures: These can be as modest as the particles of zinc oxide in sunscreens, but they can also be reinforcing fibers in new composites or carbon nanotube wires in ultraminiaturized electronics. Rearranging atoms leads to new properties. The second stage, which began in , focuses on active nanostructures that change their size, shape, conductivity or other properties during use. New drug-delivery particles could release therapeutic molecules in the body only after they reached their targeted diseased tissues. Electronic components such as transistors and amplifiers with adaptive functions could be reduced to single, complex molecules. Starting around , workers will cultivate expertise with systems of nanostructures, directing large numbers of intricate components to specified ends. One application could involve the guided self-assembly of nanoelectronic components into three-dimensional circuits and whole devices. Medicine could employ such systems to improve the tissue compatibility of implants, or to create scaffolds for tissue regeneration, or perhaps even to build artificial organs. After , the field will expand to include molecular nanosystems--heterogeneous networks in which molecules and supramolecular structures serve as distinct devices. The proteins inside cells work together this way, but whereas biological systems are water-based and markedly temperature-sensitive, these molecular nanosystems will be able to operate in a far wider range of environments and should be much faster. Computers and robots could be reduced to extraordinarily small sizes. Medical applications might be as ambitious as new types of genetic therapies and antiaging treatments. New interfaces linking people directly to electronics could change telecommunications. Over time, therefore, nanotechnology should benefit every industrial sector and health care field. It should also help the environment through more efficient use of resources and better methods of pollution control. Nanotech does, however, pose new challenges to risk governance as well. Internationally, more needs to be done to collect the scientific information needed to resolve the ambiguities and to install the proper regulatory oversight. Helping the public to perceive nanotech soberly in a big picture that retains human values and quality of life will also be essential for this powerful new discipline to live up to its astonishing potential. Roco is senior adviser for nanotechnology to the National Science Foundation and a key architect of the National Nanotechnology Initiative.

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