What is Nanotechnology?

Nanotechnology is the creation of functional materials, devices, and systems through control of matter on the nanometer (1 to 100+ nm) length scale and the exploitation of novel properties and phenomena developed at that scale.
A scientific and technical revolution has begun that is based upon the ability to systematically organize and manipulate matter on the nanometer length scale.

Examples of nanotechnology applications:

- giant magnetoresistance in nanocrystalline materials
- nanolayers with selective optical barriers, hard coatings
- dispersions with optoelectronic properties, high reactivity
- chemical and bio-detectors
- advanced drug delivery systems
- chemical-mechanical polishing with nanoparticle slurries
- new generation of lasers
- nanostructured catalysts
- systems on a chip
- carbon nanotube products
- nanoparticle reinforced materials
- thermal barrier
- ink jet systems
- information recording layers
- molecular sieves
- high hardness cutting tools

What is a nanometer?

A nanometer is one billionth of a meter (10-9 m). This is roughly ten times the size of an individual atom. A cube 2.5 NM on a side would contain about a thousand atoms. The smallest feature in an integrated circuit of today is 250 NM on a side, and contains one million atoms in a layer of atomic height. Proteins, the molecules that catalyze chemical transformations in cells, are 1 to 20 NM in size. For comparison, 10 NM is 1000 times smaller than the diameter of a human hair. There are as many nanometers in an inch as there are inches in 400 miles.

Why is this length scale so important?

There are five reasons why this length scale is so important:
The wavelike properties of electrons inside matter are influenced by variations on the nanometer scale. By patterning matter on the nanometer length scale, it is possible to vary fundamental properties of materials (for instance, melting temperature, magnetization, charge capacity) without changing the chemical composition.

The systematic organization of matter on the nanometer length scale is a key feature of biological systems. Nanotechnology promises to allow us to place artificial components and assemblies inside cells, and to make new materials using the self-assembly methods of nature. This is a powerful new combination of materials science and biotechnology.

Nanoscale components have very high surface areas, making them ideal for use in composite materials, reacting systems, drug delivery, and energy storage.

The finite size of material entities, as compared to the molecular scale, determine an increase of the relative importance of surface tension and local electromagnetic effects, making nanostructured materials harder and less brittle.

The interaction wavelength scales of various external wave phenomena become comparable to the material entity size, making materials suitable for various opto-electronic applications.

Is this really new?

Many existing technologies depend crucially on processes that take place on the nanometer scale. Photography and catalysis are two examples of "old" nanotechnologies, which arose despite the limited ability of the times to probe and control matter (and which stand to be improved vastly as nanotechnology develops). What is new is the ability to specifically analyze, organize, and control matter on many length scales simultaneously. For over a century, chemists have developed the ability to control the arrangement of small numbers of atoms inside molecules (length scale of less than 1.5 NM), leading to revolutions in drug design, plastics, and many other areas.

Over the last several decades, photo-lithographic patterning of matter on the 1000 NM length scale has led to the revolution in microelectronics. With nanotechnology, it is possible to bridge this gap, and to control matter on every important length scale, enabling tremendous new power in materials design. (The most complex arrangements of matter we know of, living organisms, require specific patterns of matter on the molecular, nanometer, micron, millimeter, and meter scale, all at once.) Furthermore, by tailoring the structure of materials in the range about 10-9 to 10-7 m one can systematically and significantly change specific properties at larger scales: material behavior can be engineered. Larger systems constructed of nanometer-scale components can have entirely new properties that have never before been identified in nature. It is also possible to produce composites that combine the most desirable properties of very different materials to obtain characteristics that are greatly improved over those that nature supplies or that appears in combinations nature does not produce.

Thus, nanotechnology actually represents a revolutionary super-field that will eventually become a foundation for such currently disparate areas as inks and dyes, protective coatings, medicines, electronics, energy storage and usage, structural materials, and many others that we cannot even anticipate. Investigations at nanoscale were left behind as compared to molecular and bulk length scales because significant developments of the corresponding investigative tools have been made only recently.

How will the new technologies help solve society problems?

The new concepts of nanotechnology are so broad and pervasive, that they will influence every area of technology and science, in ways that are surely unpredictable. We are just now seeing the tip of the iceberg in terms of the benefits that nanostructuring can bring:

- wear-resistant tires made by combining nanometer-scale particles of inorganic clays with polymers
- medicines as nanoparticles with vastly improved delivery and control characteristics
- greatly improved printing brought about by nanometer-scale particles that have the best properties of both dyes and pigments, and
- vastly improved lasers and magnetic disk heads made by controlling layer thickness to better than a nanometer.

Many further and greater advances resulting from nanotechnology are inevitable. Within a few decades, healthcare will be revolutionized by combining nanotechnology with biotechnology to produce ingestable systems that will be harmlessly flushed from the body if the patient is healthy but will notify a physician of the type and location of diseased cells and organs if there are problems.
Nanometer-scale traps will be constructed that will be able to remove pollutants from the environment and deactivate chemical warfare agents. Computers with the capabilities of current workstations will be the size of a grain of sand and will be able to operate for decades with the equivalent of a single wristwatch battery. Robotic spacecraft that weigh only a few pounds will be sent out to explore the solar system, and perhaps even the nearest stars.

What will government do for nanotechnology?

Government will play the key role in assuring that the enormous benefits of nanotechnology will be realized quickly and the U.S. will share the global benefits. The goals of nanotechnology are too long term (greater than ten years) for industry to take an immediate leadership role, although the high level of industry interest and concern for the field is almost unprecedented. Because of its interdisciplinary nature, the development of nanotechnology requires creating teams of physicists, chemists, biologists, and engineers to tackle the problems, and the funding agencies will need to be organized to foster this teamwork. The enabling infrastructure and technologies must be in place for industry to take advantage of nanotechnology innovations and discoveries. Industry is frequently reluctant to invest in risky research that takes many years to develop into a product. In the US the university and government research system fills this gap. The increasing pace of technological commercialization requires a compression of past time scales and parallel development of research and commercial products and a synergy among industry, university, and government partners. New infrastructure at the universities and national labs is required for the field to grow. A worldwide competition is underway, and the US response is fragmented in comparison to the approach of European and Asian countries. For all of these reasons, this is a moment of opportunity to create an inter-agency initiative in nanotechnology to catalyze academe, industry, health, business, and national security efforts.

Looking to the future

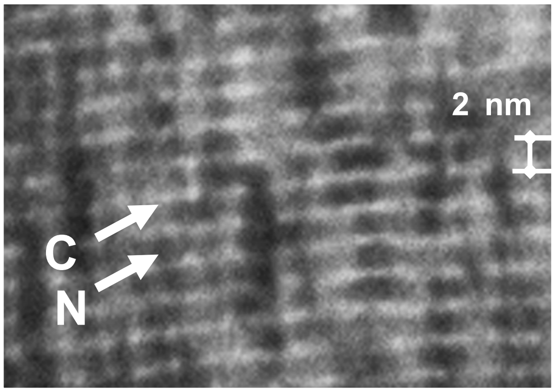
The total societal impact of nanotechnology is expected to be greater than the combined influences that the silicon integrated circuit, medical imaging, computer-aided engineering, and man-made polymers have had in this century. Significant improvements in performance and changes of manufacturing paradigms will lead to several industrial revolutions in the 21st century. Nanotechnology will change the nature of almost every human-made object. The major questions now are how soon will these revolutions arrive, who will benefit the most, and who will be in position to control or counter their negative aspects? How can we embrace and facilitate the new industrial revolution to maximize the benefit to US citizens? We believe that a national initiative is required to advance this goal because the needs for and from nanotechnology transcend anything that can be supplied by traditional academic disciplines, national laboratories, or even entire industries.

The text of the previous sections is taken from the introduction to "Vision for Nanotechnology R&D in the Next Decade" prepared by the workshop organizing committee of the Interagency Working Group on Nano Science, Engineering and Technology (IWGN) Workshop held January 27-29, 2001.

Nanotechnology Research

- Materials and chemistry
  - Nanomechanics
  - Nanofibers
  - Bulk materials
  - Nanocrystalline metals and alloys
  - Namopowders
  - Nanolayers
  - Self-assembled materials
  - Nanoporous materials
  - Nanostructured membranes
  - Nanofunctional polymers
- Devices and sensors
  - Quantum computing
  - Quantum dots
  - Organic electronics
  - Robots
- Synthesis and fabrication
- Bioscience
- Theory, modeling, and simulation
  - Quantum cryptography
  - Molecular dynamics
  - Electronic structure

Nanomechanics

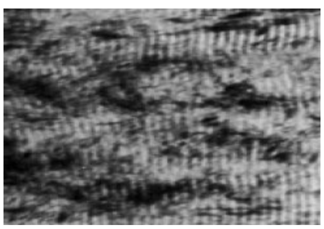


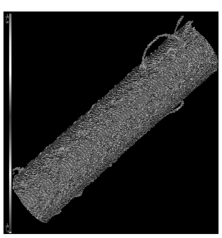
Atom-by-atom deposition of different metals into many very thin layers opens the door to the creation of a new
realm of composite materials with incomparable levels of strength and toughness. Very high strength derives from fine scale.
Composites of nanolayered metals can achieve strength levels that are 100 to 1000 times greater than the conventional strength of the individual components. Nano-scale design shows promise of synthesizing the strongest metals ever known to mankind.

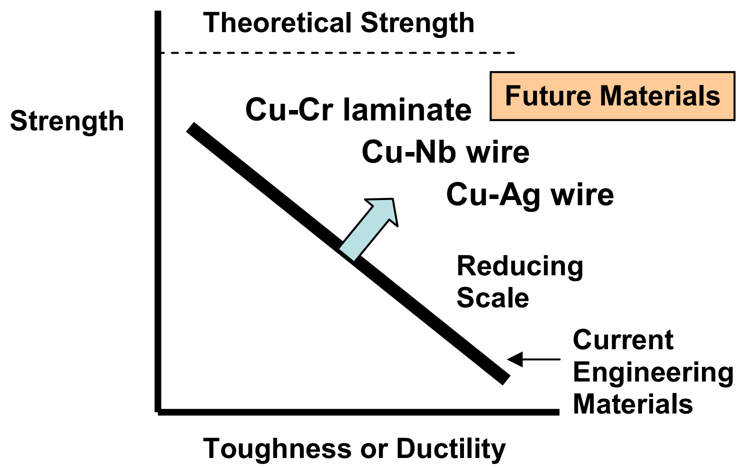
Nanofibers

Designing and Developing Structural Materials of the Future

Cu/Cr Nanolayers







Nanostructured materials can transcend the limits of strength and ductility of current engineering materials.

Nanomaterials laboratories at world leading research centers

A. National Institute for Materials Science (NIMS), Japan

The Nanomaterials Laboratories (NML) have been establishing throughout the world with the objective of making a major contribution to nanotechnology or a key technology in the 21st century from the viewpoint of materials.
Nanotechnology is an underlying technology that will produce breakthroughs in various fields ranging from practical engineering such as information technology, biotechnology and energy and medical engineering to basic sciences including physics, chemistry, biology and

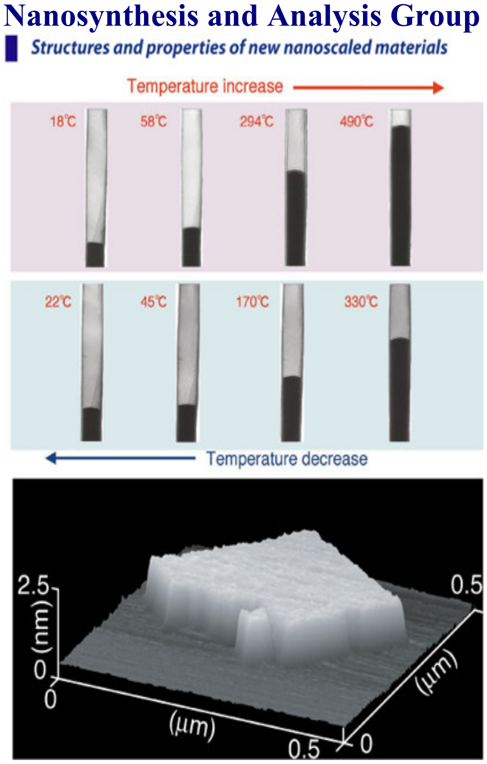
medicine. In order to make a unique contribution to nano-technology, the NML main objective is the development of novel nanoelectronic devices for next-generation information technology with the aim of establishing a highly information-oriented society.
To accomplish this mission, for instance, the NML in Japan has recently been restructured to consist of 16 research groups. These groups not only carry out their own research, such as the synthesis and characterization of novel nanomaterials, the fabrication and patterning of designed nano-structures and the development of new methods for nanoscale analysis and measurement, but also cooperate among themselves through common research projects.
NML goal is to develop advanced nanodevices including molecular and atomic devices for data processing and storage with much higher speed and capacity and lower power consumption, novel nanodevices and their systems for new computational algorithms with flexibility such as error tolerance, and highly controlled atomic and molecular nanosystems for quantum information processing.

Optoelectronics Nanomaterials Group

Instruments :
cathodoluminescence (Upper Left)
MOCVD and MBE(Upper Right)
UHV-SEM, SNOM, PL, FTIR and DLTS(Down Right)

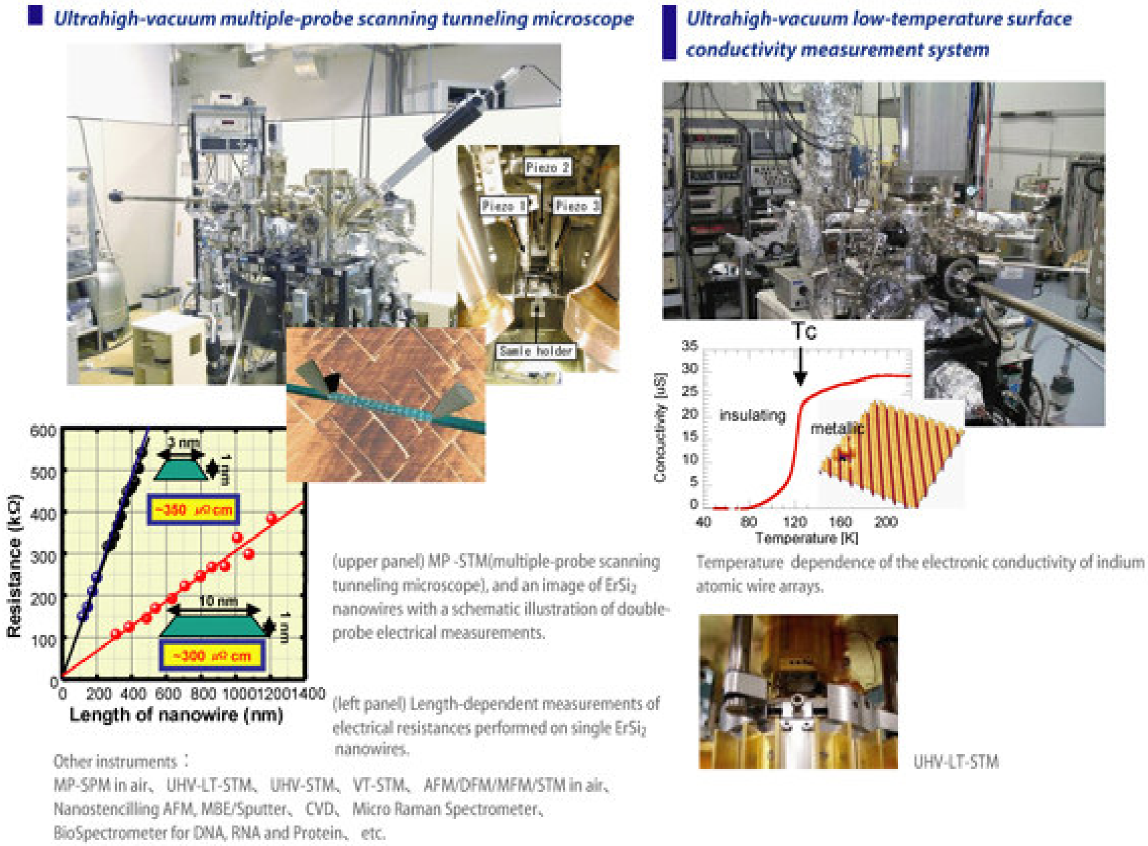
This group characterizes the light emitting properties of various semiconductors and ceramics by using nanoscale excitation from an electron beam or light. They are developing quantitative measurement techniques of cathodoluminescence (CL) and near-field scanning optical microscopy. Also they measure the emission spectra from semiconductor nanostructures and nanoparticles with spatial resolution of c.a. 50 nm. Group fabricates semiconductor quantum dots and core-shell type organic nanocrystals. By characterizing the optical property of each quantum dot or nanocrystal, the parameters which govern the optical properties were found. Optimizing such parameters, scientists are looking for novel characteristics of nanomaterials.

Nanosynthesis and Analysis Group



This group intends to explore and synthesize new nanoscaled materials such as nanotubes, nanowires, nanocones and nanosheets and to characterize their specific structures by using electron microscopy and related surface analytical tools. Special attention will be paid to the production of boron nitride nanotubes and nanocables in large quantity and to clarify their thermal, electrical and mechanical properties. Nano-sized particles and lamellar crystallites of various materials such as semiconductors or solid state electrolytes will be also synthesized by a soft chemical route. These nano-scale materials are then self-assembld into a larger nanostructured system, by which a new solar cell is planned to be designed.

Electro-Nano Characterization Group



The electro-nanocharacterization group is exploring novel methodologies to characterize nanoscale properties of individual nanostructures, and is aiming to contribute to the development of nanomaterials science which is key to future nano-technology and electronics. For example, to measure the electrical properties of individual nanostructures, group has developed multiple-probe scanning tunneling microscopes (MP-STM) which independently-driven two, three, and four STM tips. Their MP-STM's have successfully been used to measure the electrical resistivities of ErSi2 nanowires and fullerene nanofilms. Group is further pursuing potential new methodologies for revealing useful functionality of nanostructures. They also devote ourselves to creating nanostructures to confirm the versatility nanostructures to confirm the versatility of the novel techniques and the nanostructures group has created.

B. Nanotechnology at IBM

IBM Unveils Two Major Nanotechnology Breakthroughs as Building Blocks for Atomic Structures and Devices that could one day lead to new kinds of devices and structures built from a few atoms or molecules:

- Magnetic Atom Milestone Brings Single-Atom Data Storage Closer to Reality;
- Single-Molecule Switching Could Lead to Molecular Computers

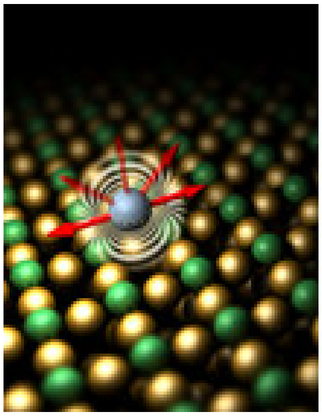
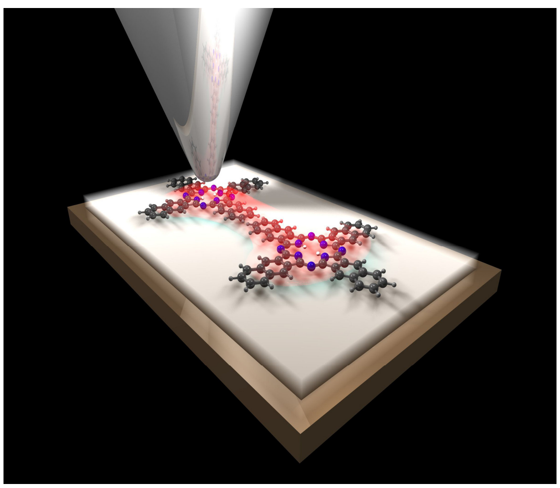


Illustration of the preferred magnetic orientation of an iron atom on a specially prepared copper surface. The ability of an atom to maintain its magnetic orientation can help determine that atom's suitability for storing data. As the atom's magnetic spin points in one direction, it can represent a "1", and in the other direction a "0", telling scientists that single-atoms may be suitable for storing the 1s and 0s known as bits, that enable information storage in computing devices. This represents a potential building block for atomic storage.



IBM's Single-Molecule Logic Switch
Schematic three-dimensional image of a molecular "logic gate" of two naphthalocyanine molecules, which are probed by the tip of the low-temperature scanning tunneling microscope. By inducing a voltage pulse through the tip to the molecule underneath the tip (shown in the back), the two hydrogen atoms in the adjacent molecule (in white at the center of the molecule in front) change position and electrically switch the entire molecule from "on" to "off". This represents a rudimentary logic-gate, an essential component of computer chips and could be the building block for computers built from molecular components.

Although still far from making their way into products, these breakthroughs will enable scientists at IBM and elsewhere to continue driving the field of nanotechnology, the exploration of building structures and devices out of ultra-tiny, atomic-scale components. Such devices might be used as future computer chips, storage devices, sensors and for applications nobody has imagined yet.

In the first report, IBM scientists describe major progress in probing a property called magnetic anisotropy in individual atoms. This fundamental measurement has important technological consequences because it determines an atom’s ability to store information. Previously, nobody had been able to measure the magnetic anisotropy of a single atom.

With further work it may be possible to build structures consisting of small clusters of atoms, or even individual atoms, that could reliably store magnetic information. Such a storage capability would enable nearly 30,000 feature length movies or the entire contents of YouTube – millions of videos estimated to be more than 1,000 trillion bits of data – to fit in a device the size of an iPod. Perhaps more importantly, the breakthrough could lead to new kinds of structures and devices that are so small they could be applied to entire new fields and disciplines beyond traditional computing.

In the second report, IBM researchers unveiled the first single-molecule switch that can operate flawlessly without disrupting the molecule's outer frame -- a significant step toward building computing elements at the molecular scale that are vastly smaller, faster and use less energy than today's computer chips and memory devices.

In addition to switching within a single molecule, the researchers also demonstrated that atoms inside one molecule can be used to switch atoms in an adjacent molecule, representing a rudimentary logic element. This is made possible partly because the molecular framework is not disturbed.

The Science of The Small: Understanding the Magnetic Properties of Atoms

In the paper titled "Large Magnetic Anisotropy of a Single Atomic Spin Embedded in a Surface Molecular Network," the researchers used IBM's special scanning tunneling microscope (STM) to manipulate individual iron atoms and arranged them with atomic precision on a specially prepared copper surface. They then determined the orientation and strength of the magnetic anisotropy of the individual iron atoms.

Anisotropy is an important property for data storage because it determines whether or not a magnet can maintain a specific orientation. This in turn allows the magnet to represent either a "1" or "0," which is the basis for storing data in computers.
"One of the major challenges for the IT industry today is shrinking the bit size used for data storage to the smallest possible features, while increasing the capacity," said Gian-Luca Bona, manager of science and technology at the IBM Almaden Research Center in San Jose, California. "We are working at the ultimate edge of what is possible – and we are now one step closer to figuring out how to store data at the atomic level. Understanding the specific magnetic properties of atoms is the cornerstone of progressing toward new, more efficient ways to store data."

Lilliputian Scale Devices: Single Molecule Logic Switching

In the paper titled "Current-Induced Hydrogen Tautomerization and Conductance Switching of Naphthalocyanine Molecules," IBM researchers describe the ability to switch a single molecule "on" and "off," a basic element of computer logic, using two hydrogen atoms within a naphthalocyanine organic molecule. Previously, researchers at IBM and elsewhere have demonstrated switching within single molecules, but the molecules would change their shape when switching, making them unsuitable for building logic gates for computer chips or memory elements.

Switches inside computer chips act like a light switch to turn the flow of electrons on and off and, when put together, make up the logic gates, which in turn make up electrical circuits. Having ever smaller switches allows the circuits to be shrunk to ever smaller sizes, making it possible to pack more circuits into a processor and boosting speed and performance.

These molecular switches could one day lead to computer chips with speeds as fast as today's fastest supercomputers, but much smaller in size; with some speculating even building computer chips so small they could be the size of a speck of dust or fit on the tip of a needle.

Development of conventional silicon-based CMOS chips is approaching its physical limits, and the IT industry is exploring new, truly disruptive technologies to achieve further increases in computer performance. Modular molecular logic is a possible candidate, though still several years from reality. The next step for the Research team is to build a series of these molecules into a circuit, then figure out how to network those together into a molecular chip.

The concept of using molecules as electronic components is still in its infancy. Only a few examples of individual molecules serving as switches or memory elements have been demonstrated to date. Most of these molecules are complex, three-dimensional structures and change their shape when switching. Placing them on a surface while maintaining their function is extremely difficult, making them unsuitable as building blocks for computer logic.

The switching within the molecule used by the IBM researchers is well-defined, highly-localized, reversible, intrinsic to the molecule, and does not involve changes in the molecular frame. Therefore, this molecule could be used as a building block for more complex molecular devices that serve as logic elements. As the shape of the molecule does not change during switching, single switches can be coupled in a controlled way. The switching process should also work with molecules embedded in more complex structures.

"Accidental" Science

Although the IBM Research team had been screening various molecules to discover if they would be suitable for molecular switches, in the case of naphthalocyanine, the tests being performed were not to observe switching but rather to examine molecular vibrations, since understanding vibrations of molecules is important for devices operating at the atomic level. During those tests, team members were surprised to observe results that were intriguing for switching at the molecular scale, and they shifted their focus from studying vibrations to studying switching, leading to this breakthrough.

“One of the beauties of doing exploratory science is that by researching one area, you sometimes stumble upon other areas of major significance,” said Gerhard Meyer, senior researcher in the nanoscale science group at the IBM Zurich lab. “Although the discovery of this breakthrough was accidental, it may prove to be significant for building the computers of the future.”

Low-temperature scanning tunneling microscopy and atomic/molecular manipulation

IBM scientists investigate the fundamental properties of single atoms and molecules on solid surfaces. Within this field they are specifically interested in the growth of ultrathin insulating films, the manipulation and buildup of atomic-scale nanostructures, and the mechanical and electrical properties of individual molecules.

IBM’s experiments exploit the extreme versatility and sensitivity of a low-(variable)-temperature scanning tunneling microscope (STM). Such a machine is not only a nanoanalytical instrument to perform imaging and vibrational/electronic spectroscopy on the atomic scale, but can also be used as an atomic-scale tool to assemble atomic structures, manipulate molecules and their conformations, and induce chemical reactions including the synthesis and dissociation (forming and breaking bonds) of individual molecules.

Overview of basic manipulation processes that can be induced with an STM:
Lateral manipulation: The transfer of atoms/molecules along the surface employing for example attractive/repulsive forces between the tip and the adsorbate.
Vertical manipulation: The reversible transfer of atoms/molecules between the surface and the STM tip employing additionally electronic/vibrational excitation of the adsorbate by inelastic tunneling.
Desorption: Similar to vertical manipulation, but desorption of individual adsorbates directly into the surrounding gas phase.
Dissociation: Selective bond breaking within a molecule by means of inelastic tunneling processes.
Synthesis: Selective bond formation between two molecular units employing lateral manipulation followed by electronic/vibrational excitation.

The development of nanosciences and nanotechnologies is based on the use of new tools to fabricate and manipulate materials at the nanometer scale, to achieve miniaturisation through atomic and molecular manufacturing techniques. One major challenge is to be able to identify, to characterize, to manipulate and to get detailed information on nanoscale objects and devices. In this context, the electron transport through single molecules or semiconductor nanostructures receives an increasing interest from the researchers. Indeed, semiconductor nanostructures are often considered as artificial atoms or molecules, having in common with the molecules a discretization of their energy levels. The development of the Tunnelling Spectroscopy on single nanostructures allows now to determine the electron levels with a high accuracy and, very recently, to image the corresponding waves functions. As this field of science is emerging, with the main developments obtained within the last two or three years, there is a great need to share our theoretical and technical knowledges in order to improve the spectroscopic techniques and to explore a broad range of new properties. Thus, the aim of the network is to build collaborative projects in the field of "Tunnelling spectroscopy on single molecular and semiconducting nanostructures".

The nano-objects which will be studied in the project are semiconductor nanocrystals and quantum dots, and single molecules adsorbed on surfaces. Major breakthroughs are anticipated in several directions: knowledge of the electronic structure, inelastic tunnelling, imaging of electron and hole wave functions using Scanning Tunnelling Spectroscopy or Magneto-Tunnelling Spectroscopy, probing spin polarization using Spin Polarized Tunnelling Spectroscopy in magnetic field, and fabrication of nanodevices (molecules, semiconductor nanocrystals, quantum dots) with the desired electronic properties.

Investigating nanoscale objects is a hugely tricky process -- even with a scanning electron microscope -- and the research needs to be conducted in a special atmosphere. This particular work, conduced by Dr Walter Riess, the research manager for nanoscale structures and devices, is looking at ways of growing nanowires.

A nanowire is an extremely narrow object that has an aspect ratio (the ratio between length and width) of 1,000 to 1 or greater. At this time nanowires and their possible uses exist only in the realms of research, but Dr Riess and his team are investigating different elements for their suitability for "growing" nanowires, and trying to deduce the properties those wires will have. The aim is to use nanowires to manufacture microprocessors.

A microprocessor built from nanowires whould, in theory, be much more powerful than current processors since computers are based on electrical signals running through very narrow channels. Today's microprocessors are so small inside that signals leak and create interference, which is a problem that will only get bigger as the channels get smaller. Can nanowires conduct electrical signals in nanoscale structures? A lot of science needs to be done before we know the answer to that one.

C. Nanostructured Materials Characterization at Los Alamos National Laboratory.

The **Electron Microscopy Laboratory** (EML) is part of the Structure/Property Relations Group (MST-8) in the Materials Science and Technology Division of LANL

The laboratory contains:

- two scanning electron microscopes
- two analytical transmission electron microscopes
- high-resolution transmission electron microscope
- specimen preparation equipment
- optical microscopes
- digital imaging and analysis work area and a photographic darkroom

Philips CM-30 Analytical Electron Microscope
General purpose TEM/STEM equipped for x-ray microanalysis, electron diffraction and conventional imaging.

- High-brightness LaB6 filament.
- +/- 45' of specimen tilt.
- Energy-dispersive x-ray analysis. PGT Avalon 4000 System.
- Point to point resolution of 0.23 nm.

FEI Tecnai F30 Analytical TEM/STEM

This is a very flexible TEM/STEM equipped with an energy-dispersive x-ray spectrometer and an electron energy-loss Gatan Imaging Filter. Images can be recorded using two different CCD cameras or film in TEM. This microscope is used primarily for studying the structure and chemistry of materials at high spatial-resolution.

- Field-emission electron source.
- Operation at accelerating voltages of up to 300 kV.
- Point to point resolution of 0.21 nm. 0.14 nm. resolution can be extracted by computer processing.
- 0.34 nm. electron probe in STEM mode.
- Gatan Ultrascan 4000 4k x 4k CCD camera.
- High angle dark field STEM Z-contrast imaging.
- Gatan Imaging Filter with 2k x 2k CCD for electron energy loss spectrometry, energy-filtered imaging and STEM spectrum imaging.
- Energy-dispersive x-ray microanalysis using EDAX detector and embedded software. Spectra, line scans, maps, and spectrum images can be collected and analyzed.
- TSL/EDAX Automated Crystallography for the TEM (ACT) and Tools for Orientation and Crystallographic Analysis (TOCA).

JEOL 6300FXV High-Resolution SEM

- High-resolution TEM equipped with an electron energy-loss spectrometer and a CCD camera for digital image acquisition. This microscope is used primarily for imaging the atomic structure of defects and interfaces in materials.
- Field-emission electron source. Coherent source with an energy spread of 0.8 eV.
- Operation at accelerating voltages of up to 300 kV.
- +/- 10? of eucentric specimen tilt.
- Point to point resolution of 0.17 nm. 0.10 nm. resolution can be extracted by computer processing.
- Gatan Multiscan CCD Camera for digital image acquisition.
- Automated microscope alignment: defocus calibration/adjustment, astigmatism correction and beam-tilt correction (automatic coma-free alignment).
- Gatan Digi-PEELS System for elemental microanalysis.

Philips XL-30 F Orientation Imaging Microscopy System

This is a dedicated system equipped for orientation imaging using backscattered electron patterns.

- Small, stable, high-brightness Schottky-based field-emission electron source provides 1 nm. resolution at 30 kV.
- Capable of operating from 1-30 kV.
- Large specimen chamber.
- Digital image acquisition.
- TSL/EDAX orientation imaging CCD camera system for collecting and analyzing BSE patterns to determine sample phases, orientation distributions, textures, twins and grain boundaries, grain size distributions, etc.

Specimen Preparation Facility

This part of the facility contains equipment for TEM and SEM sample preparation, including the following.

- Mechanical Thinning of Materials
- Buehler Isomet and South Bay Technology Model 660 Low Speed Diamond Saws for cutting hard materials.
- Gatan Model 601 Ultrasonic disc cutter and South Bay Technology Model 360 Abrasive Slurry disc cutter cut 3 mm diameter discs from bulk material. Other diameters and cross-sections can be cut with special tooling
- Gatan, tripod and other polishers are utilized for grinding and polishing TEM specimens. SiC paper and/or diamond lapping films of successively finer grade typically are utilized to mechanically thin specimens to thicknesses of about 100 microns down to just a few microns.
- VCR Model D500 and Gatan Model 656 Dimplers are utilized to mechanically thin specimen centers to less than 10 microns. A dimpler is a precision tool that creates a dimple or small depression in a specimen. The specimens will generally need to be thinned further with ion beam techniques as described below.
- Ion-Beam Thinning of Materials
- Gatan Duomill Model 690 is a conventional Argon ion miller capable of operating at liquid Nitrogen temperatures to minimize ion beam heating and damage of the specimen.
- Gatan Precision Ion Polishing System (PIPS) Model 691 is utilized for ion thinning samples at low incident angles. Low-angle milling can reduce the preferential removal of soft materials adjacent to harder materials. Additionally, PIPS units allow for sector milling for the preparation of cross-section specimens.