IBM Research: Major Nanoscale Breakthroughs

More than twenty years ago, two IBM (NYSE: IBM) scientists won the Nobel Prize in Physics for their invention of the Scanning Tunneling Microscope (STM), which opened the world to the possibilities of nanotechnology. Shortly thereafter, in 1989, the letters IBM were spelled using individual atoms by an IBM scientist using a STM. Today, scientists and engineers from IBM Research continue to break new ground in nanotechnology – the science of the very, very small.

Highlights spanning more than a quarter century of nanotechnology innovations made in IBM labs include:

1981 - IBM scientists invent the Scanning Tunneling Microscope, giving ready access for the first time to the nanoscale world of individual atoms and molecules on electrically conducting substrates.

1986 -The Atomic Force Microscope is invented by IBM and Stanford University scientists, quickly becoming the workhorse of nanoscience, providing general purpose imaging and manipulation in the nanometer realm.

1986 - IBM scientists Gerd Binnig and Heinrich Rohrer win the Nobel Prize in Physics for the Scanning Tunneling Microscope.

1988 - IBM scientists observe photon emission from local nanometer-sizes areas stimulated by a scanning tunneling microscope, allowing phenomena such as luminescence and fluorescence to be studied on the nanometer scale.

1989 - IBM Fellow Don Eigler is the first to controllably manipulate individual atoms on a surface, using the STM to spell out "I-B-M" by positioning 35 xenon atoms, and in the process, perhaps creating the world's smallest corporate logo.

1991 -IBM scientists demonstrate an atomic switch, a significant milestone on the road to the eventual design of electronic devices of atomic dimensions.

1993 – Scientists at IBM and NEC independently discover single-wall carbon nanotubes and the methods to produce them using metal catalysts.

1996 - IBM scientists extend STM manipulation techniques to position individual molecules at room temperature for the first time.

1996 - The world's smallest abacus is created out of 10 atoms by scientists at IBM, another major milestone in engineering at the nanoscale.

1998 - IBM scientists and partners discover a molecular wheel, which shows promise for making nanoscale mechanical gears and motors.

2000 - IBM and university researchers develop nanomechanical sensors using tiny silicon fingers to detect minute quantities of biochemical substances and to recognize specific patterns of DNA.

2001 - IBM's "constructive destruction" method overcomes major hurdle for building computer chips beyond silicon with a method to separate semiconducting and metallic nanotubes to form a working transistor on the nanoscale

2001 - IBM scientists unveil the world's first single-molecule computer circuit, carbon nanotube transistors transformed into logic-performing integrated circuits, a major step toward molecular computers.

2002 - IBM researchers build world's smallest operating computing circuits using a molecule cascade, wherein molecules move in a manner analogous to falling dominos.

2003 -- Scientists from IBM, Columbia University and the University of New Orleans demonstrate the first three-dimensional self assembly of magnetic and semiconducting nanoparticles, a modular assembly method that enables scientists to bring almost any materials together.

2003 - IBM scientists demonstrate the world's smallest solid-state light emitter, suggesting that carbon nanotubes may be suitable for optoelectroinics.

2004 -- IBM scientists develop a new technique called “spin-flip spectroscopy” to study the properties of atomic-scale magnetic structures. They use this technique to measure a fundamental magnetic property of a single atom -- the energy required to flip its magnetic orientation.

2004 – IBM scientists measure the tiny magnetic force from a single electron spin using an ultra sensitive magnetic resonance force microscope, showing the potential of vastly extending the sensitivity of magnetic resonance imaging (MRI).

2004 -- IBM scientists manipulate and control the charge state of individual atoms. This ability to add or remove an electron charge to or from an individual atom can help expand the scope of atom-scale research. Switching between different charge states of an individual atom could enable unprecedented control in the study of chemical reactivity, optical properties, or magnetic moment.

2004 -- IBM scientists make breakthrough in nanoscale imaging -- the ability to detect the faint magnetic signal from a single electron buried inside a solid sample is a major milestone toward creating a microscope that can make three-dimensional images of molecules with atomic resolution.

2005 -- Using nanoelectronic fabrication technologies, IBM researchers create a tiny device that slows the speed of light, representing a big advance toward the eventual use

of light in place of electricity in the connection of electronic components, potentially leading to vast improvements in the performance of computers and other electronic systems.

2006 -- IBM researchers build the first complete electronic integrated circuit around a single "carbon nanotube" molecule, a new material that shows promise for providing enhanced performance over today's standard silicon semiconductors. The achievement is significant because the circuit was built using standard semiconductor processes and used a single molecule as the base for all components in the circuit, rather than linking together individually-constructed components. This can simplify manufacturing and provide the consistency needed to more thoroughly test and adjust the material for use in these applications.

2006 -- IBM scientists develop a powerful new technique for exploring and controlling atomic magnetism, an important tool in the quest not only to understand the operation of future computer circuit and data-storage elements as they shrink toward atomic dimensions, but also to lay the foundation for new materials and computing devices that leverage atom-scale magnetic phenomena.

2006 – In a study investigating the fundamentals of molecular electronics, the quantum mechanical effects of attaching gold atoms to a molecule were elucidated. The work demonstrated that it is not only possible to control the atomic-scale geometry of a metal-molecule contact, but also its coupling strength and the phase of the orbital wave function at the contact point.

2007 -- IBM demonstrates the first-ever manufacturing application of "self assembly" used to create a vacuum -- the ultimate insulator -- around nanowires for next-generation microprocessors for its airgap chip technique.

2007 - IBM researchers in collaboration with scientists from the ETH Zurich demonstrate a new, efficient and precise technique to "print" at the nanoscale.

2007 - IBM unveils two nanotechnology breakthroughs as building blocks for atomic structures and devices: Magnetic atom milestone brings single-atom data storage closer to reality; single-molecule switching could lead to molecular computers.

2007 - IBM researchers develop magnetic resonance imaging (MRI) techniques to visualize nanoscale objects. This technique brings MRI capability to the nanoscale level for the first time.

2008 - IBM scientists, in collaboration with the University of Regensburg in Germany, are the first ever to measure the force it takes to move individual atoms on a surface.

2009 – IBM Research builds microscope with 100 million times finer resolution than current MRI, extending three-dimensional MRI to the nanoscale.

2009 - IBM scientists reach a landmark in the field of nanoelectronics: the development and demonstration of novel techniques to measure the distribution of energy and heat in powered carbon nanotube devices. By employing these techniques, IBM researchers have determined how the energy of electrical currents running through nanotubes is converted into heat and dissipated into collective vibrations of the nanotube's atoms, as well as surface vibrations of the substrate beneath it.

2009 - IBM scientists in collaboration with the University of Regensburg, Germany, and Utrecht University, Netherlands, for the first time demonstrate the ability to measure the charge state of individual atoms using non contact atomic force microscopy.

2009 - In an effort to achieve energy-aware computing, the Swiss Federal Institute of Technology Zurich (ETH) and IBM plan to build a first-of-a-kind water-cooled supercomputer that will directly repurpose excess heat for the university buildings. The system is expected to save up to 30 tons of CO2 per year, compared to a similar system using today's cooling technologies.

2009 – IBM launches new research effort for next generation electric energy storage, exploring battery technologies to drive electric vehicle adoption and make energy grids more efficient.

2009 – IBM scientists first to image the "anatomy" of a molecule.

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