NANOTECHNOLOGY: FACTS AND FIGURES

ILLINOIS SCIENCE & TECHNOLOGY COALITION

- Nanotechnology is the engineering of functional systems at the molecular scale.
- Nanotechnology has the potential to impact every sector of our economy and nano-enabled products are projected to be a $2.6 trillion global industry by 2014, increasing from $60 billion in manufactured goods in 2008. *Sources: The Guardian (London), March 26, 2009 and Drug Week, August 10, 2007*
- Nanotechnology is a building block for high-growth economic sectors including next generation materials, biotechnology, electronics, energy, homeland security, medical devices, among others.
- The application of nanotechnologies presents groundbreaking opportunities. U.S. companies engaged in nanotechnology development are already working to deliver innovations that may prevent disease and improve medical treatments, advance the delivery of renewable energy technologies and options for clean water and provide life-changing products in computing and electronics.
- The nation's coordinated federal program charged with organizing nanotechnology efforts across all agencies – the National Nanotechnology Initiative (NNI) – aims to catapult nanotechnology innovations and position America as the world leader in this industry. Specifically, the NNI aims to:
  - Advance a world-class nanotechnology research and development program.
  - Foster the transfer of new technologies into products for commercial and public benefit.
  - Develop and sustain educational resources, a skilled workforce, and the supporting infrastructure and tools to advance nanotechnology.
  - Support responsible development of nanotechnology.
- Illinois is a center for nanotechnology research and development and ranks highly among US states:
  - According to a May 2007 survey by *Small Times* magazine, Illinois ranks eighth on its list of leading nanotechnology states and fourth specifically for research and education in nanotechnology.
- Given these building blocks, further investment in Illinois-based nanotechnology research and development could lead to substantial job growth and strengthen state and regional economies.

ILLINOIS: A CENTER FOR NANOTECHNOLOGY

- Investment in nanotechnology in Illinois is not a new phenomenon, which is demonstrated in the diversity and scope of research and development activities in the state. The May 2007 *Small Times* magazine survey noted:
  - Illinois' strength in nanotechnology is derived from the numerous research centers and laboratories in the state, making Illinois an "unparalleled multi-disciplinary environment for cutting-edge basic and translational research."
  - Illinois is also ranked seventh in microtechnology research, and ninth in microtechnology commercialization.
- Illinois is already a leader for high-tech jobs.
  - According to TechAmerica and the U.S. Bureau of Labor Statistics, Illinois ranks No. 7 in high-tech employment. Forty-two of every 1,000 private sector workers in Illinois are employed by high-tech firms.
- Several leading research institutes operating in Illinois focus on areas of nanotechnology, ranging from nanomanufacturing and nanobiosystems to molecular and electronic nanostructures, for example: (*Source: Illinois.gov*)
  - Center for Nanoscale Materials - Argonne National Laboratory
  - Nano-CEMMS (Center for Nanoscale Chemical-Electrical-Mechanical Manufacturing Systems) - University of Illinois, Northwestern University and other university partners
  - International Institute for Nanotechnology - Northwestern University
  - Institute for Bionanotechnology in Medicine - Northwestern University
  - Center for Nanoscale Science and Technology - University of Illinois
  - The Beckman Institute for Advanced Science and Technology - University of Illinois
  - Micro and Nanotechnology Laboratory - University of Illinois
  - The James Franck Institute - University of Chicago

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EXAMPLES OF NANOTECHNOLOGY RESEARCH IN ILLINOIS

- Nanotechnology R&D in Illinois is diverse in purpose and application. While there are numerous real-time examples of groundbreaking work, here are four that provide a snapshot of the reach and scope of nano-activities in Illinois:

Nanotube technology maximizes power usage: By using thousands of perfectly aligned, single-walled carbon nanotubes as a type of semiconductor thin film, **University of Illinois** researchers in partnership with private industry researchers have become the first to successfully bring together all of the pieces required for building real radio frequency analog electronics, including amplifiers, mixers, and resonant antennae. Since carbon nanotube transistors use less power, the implications for battery operated radio frequency electronics is dramatic. Instead of a battery lasting two days, the same battery providing power to sensor systems built with carbon nanotube transistors may last up to two weeks.

Gold nanoparticles detect mercury: With gold nanoparticles, DNA and some smart chemistry as their tools, scientists at **Northwestern University** have developed a simple "litmus test" for mercury that eventually could be used for on-the-spot environmental monitoring of bodies of water, such as rivers, streams, lakes and oceans, to evaluate their safety as food and drinking water sources. The Northwestern method takes advantage of gold's intense color when the metal is measured on the scale of atoms. The researchers started with gold nanoparticles held together by complementary strands of DNA that are specifically designed with a single mismatch; if mercury is present, it bonds tightly with the mismatch causing a subsequent color change. Most existing detection methods require expensive complicated equipment forcing tests to take place in a lab. This method is simpler, faster and more convenient than conventional methods, and results can be read with the naked eye at the point of use.

"Electronic glue" promises less expensive semiconductors: Researchers at the **University of Chicago** and Lawrence Berkeley National Laboratory have developed an "electronic glue" that could accelerate advances in semiconductor-based technologies, including solar cells and thermoelectric devices that convert sun light and waste heat, respectively, into useful electrical energy. Engineers see great potential in semiconductor nanocrystals, sometimes just a few hundred atoms each. Nanocrystals can be readily mass-produced and used for device manufacturing via inkjet printing and other solution-based processes. But a problem remains: The crystals are unable to efficiently transfer their electric charges to one another due to surface ligands—bulky, insulating organic molecules that cap nanocrystals. The "electronic glue" developed in Dmitri Talapin's laboratory at the University of Chicago solves the ligand problem. The team describes in the journal *Science* how substituting the insulating organic molecules with novel inorganic molecules dramatically increases the electronic coupling between nanocrystals. The University of Chicago licensed the underlying technology for thermoelectric applications to a private firm in February 2009.

Hard x-ray nanoprobe assists researchers: To enrich our understanding of the nanoscale properties of complex systems, materials and devices, scientists come to **Argonne National Laboratory** to employ the laboratory's new hard X-ray nanoprobe, which is jointly operated by Argonne's Center for Nanoscale Materials and Advanced Photon Source. This system can currently resolve structures as small as 30 nanometers – a distance roughly equivalent to the width of 100 atoms and less than 1/1000th the diameter of an average human hair, and received one of the 2009 *R&D* 100 awards, which recognize the top 100 inventions of the previous year. While other forms of imaging – electron microscopy, for example – can reveal even smaller details close to a sample's surface, the high-energy X-rays generated by the APS can penetrate into a material's bulk to reveal buried structures and interfaces. "X-ray imaging gives scientists a unique window into complex systems, allowing us to see their structure, composition and dynamics," said Argonne nanoscientist Jörg Maser, who runs the nanoprobe.