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Interview with Dr. Alain Kaloyeros

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Alain is also Professor of Nanoscience at the College of Nanoscale Science and Engineering (CNSE), University at Albany-State University of New York (SUNY). The world's first college dedicated to nanotechnology, CNSE was ranked in May 2007 by *Small Times* magazine as the nation's number one college for nanotechnology and microtechnology. A global resource for nanotechnology education, R&D, and commercialization, CNSE has generated over $4.2B in public and private investment at its world-class Albany NanoTech complex, which houses R&D centers for major corporations including IBM, AMD and SONY, involving nearly 2,000 personnel. Alain has authored and co-authored over 150 articles and contributed to 7 books. He holds 13 U.S. patents. He is a past recipient of the NSF Presidential Young Investigator Award, SUNY Outstanding Inventor Award and R&D 100 Award. Alain can be reached at akaloyeros@uamail.albany.edu.

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Doug: The term Nanotechnology is used in many ways. How do you define nanotechnology?

Alain: The widespread use of the word "nanotechnology" is giving the public at large the impression that it's a particular product or a specific application. In fact, nanotechnology is the science and engineering know-how that enables innovation at the atomic level. It is the knowledge base that allows for the management and control of individual atoms and molecules, and the subsequent ability to assemble them into real-life, functional systems.

If you look at the history of science and engineering you'll find that each time we were able to develop a new tool that allowed us to see deeper into matter, we were able to advance the state of science and engineering. The naked eye was the only optical instrument until 400 years ago when the optical microscope was invented. Approximately 60 years ago, we went from the optical microscope to the electron microscope, which uses electrons as opposed to light to enlarge and view matter. That development has driven the last 50 years of semiconductor electronics, which began with transistors and has evolved to systems on a chip. Now, as technology has evolved further, the development of scanning microscopes has given us the ability to see individual atoms and molecules. Enter the world of *nanotechnology* – a word that comes from nanometer, which is the scale we use to measure atoms and molecules.

With the world of nanotechnology, we are now able to achieve something never before achievable in the history of science. We are now able to engage individual atoms, manage them, and move them around. We can build objects one atom at a time, which is truly the dawn of a new era for science and engineering.

Doug: What were the first commercial applications for nanotechnology and when did they occur?

Alain: Commercial products in nanotechnology have been on the market for five to seven years. I would classify them in two areas, the first being those things that we use in everyday life, such as cosmetics, suntan lotion or car wax. Mercedes-Benz, for example, has been applying a special protective coating that uses nanoparticles on all of its cars since December 2004. There are now more than 500 such products on the market, according to the Project on Emerging Nanotechnologies. People are using and not even realizing that they are using nanotechnology every day. The everyday market itself has entered nanotechnology in a big way without anybody actually announcing, "Hey everybody, we're now into nanotechnology."

The second application, and the biggest driver for nanotechnology, is high-tech products. The computer chip is the entity that is leading the way, but I include nanobiology and nanomedicine, and health applications, along with renewable and sustainable energy, as some of the leading emerging applications.

Doug: If we start with a time perspective of five years ago, it seems that the early commercial applications for nanotechnology were "technology replacements." They were applications that were already being done in some way and nano-sized particles offered an opportunity for better performance along certain dimensions - coatings on automobiles, paints for stain resistance, material for antibacterial, for example.

What are other areas in the commercial marketplace that nanotechnology was a replacement for the way things were already being done?

Alain: Can you imagine not having constant, uninterrupted access to your computer, cell phone and BlackBerry? That's a relatively new phenomenon made possible by the development of more advanced computer chips that allow for increased functionality and performance. In order to go from having ten million transistors on a chip to having 100 million or a billion - and next we're looking at a trillion – we had to make transistors that were literally in the nanometer range. So, nanotechnology became the factor, the driver, for science and engineering in the chip.

We are now seeing commercial applications of what has become known as a laboratory on a chip. To develop this new know-how, we had to make chips that are not only faster, but also able to perform many more functions beyond that of computation. For example, the smart sensors that control the airbags in cars – these can detect the weight and height of the passenger and then control the force by which the airbag is deployed. This is all driven by nanotechnology in the chip. We now have nanotechnology sensors for the environment, DNA sequencing and blood testing.

Doug: The first stage of nanotechnology was nano-sized particles. Being able to sense aspects of the environment and integrate the microelectronics came second. What is the third stage?

Alain: Nanotechnology has provided the ability to make new materials so that you can manufacture cars that are more robust, yet lighter. I don't know this for a fact, but I suspect that nano-based materials went into the skins of the Boeing 787 Dreamliner.

Doug: We're in such a rapidly changing field that a number of our readers may have a dated view of nanotechnology and be unaware that their view is dated. What is now becoming practical and commercializable in the next two to three years?

Alain: I see several areas where nanotechnology will make a significant impact. In health care, we will be seeing nanoprobes being injected into the blood stream with programming to go after certain cancer cells, using heat to destroy them while leaving healthy cells intact. This is an application that we wouldn't have even dreamed of three or four years ago, but is now working on mice and is moving into clinical testing. We are also developing chips designed to replace optical nerves and address spinal cord injuries, by carrying the signal around the damaged area.

Portable energy sources, which are renewable and use nanobiological or nanochemical materials to produce heat or power, represent another emerging area. This technology will help address a growing need to power the electronic devices that are becoming ubiquitous, including cell phones and PDAs. The FAA recently announced that it is looking into new rules that might allow portable fuel cells on airplanes. Portable, renewable energy has the potential to reduce our utilization of fossil fuels.

The industry of transportation infrastructure has also found applications for nanotechnology, for instance, in the ways that bridges are built and inspected. Demonstration projects are embedding sensors into the structures of bridges as well as the construction materials for roads, using nanotechnology to alert structural engineers to potential safety concerns that effect the traveling public.

As ultra-fast, reliable, and secure transmission of data and information becomes increasingly important in the 21st century innovation economy – everything from text to voice to video – the development of nanotechnology-enabled optical fiber and wireless devices will play a critical role in improving both the efficiency and security of telecommunications.

And, our military personnel will realize perhaps some of the most important benefits of nanotechnology: lightweight nanomaterials embedded inside a soldier's uniform that will harden upon impact and protect against enemy fire; built-in sensors that detect biological and chemical threats; nano-camouflage that detects its surroundings and changes color to mimic the environment, making a soldier nearly invisible.

I would classify all of these areas as new opportunities, as opposed to a replacement of current technology.

Doug: These are new opportunities that are going to be commercially available and financially practical, as well as being in scale production, within the next two to three years?

Alain: Absolutely.

Doug: Our readers are familiar with open innovation and the idea of collaborative models. The work of your center involves collaborating with corporations. What do you see as the pillars of success in these collaborations?

Alain: The CEO of a company once said, "In order to be successful in this new era of nanotechnology, we have to go from being in the Kremlin to becoming the Acropolis." Meaning - collaborators need to see the value of sharing knowledge and know-how. They need to learn from what others are doing as opposed to protecting all of the intellectual property and owning all of the patents. Nanotechnology requires interdisciplinary know-how. No single entity can possibly possess it all. The companies and the universities need to have an open mind with regard to intellectual property (IP).

One of the biggest age-old debates occurs between companies and universities. The company's attitude is, "Look, we're paying for the research. We should own the title to

any patents." The universities' attitude is, "No, we're going to own the title, and we're willing to provide you with either a royalty-free, non-exclusive license or a royalty-bearing exclusive license." It is my view that both entities have to keep an open mind. The companies need to realize that they are coming to the universities not just to pay the money, but also to get a service in return. The faculty and the students are involved in the innovation and that is going to demand a certain piece of the prize of the patent.

Financial partnerships are another factor. Going from today's state-of-the-art semiconductor manufacturing plant to the next generation will quadruple capital spending from $2.5 billion to nearly $10 billion, with 20 percent of that cost in R&D. Private funding has become essential to success. One of the key pieces driving our success here at CNSE's Albany NanoTech, along with intellectual leverage, is financial leverage.

One principle that I have found to be an essential driver in success is the Darwin Principle: It is not the most intelligent or the strongest species that are apt to survive, but those who are most adaptable to change. One pillar is flexibility, the ability to be open-minded and to change one's ways to enter the nanotechnology era. Another pillar is to be open in terms of learning about the other entities involved in the potential collaboration – what they are about and how they do business. Many of our challenges early on centered around getting the corporate and government entities to learn about each other. This takes time and an open mind.

Doug: To conclude our interview, what else would you like to say to our readers?

Alain: Nanotechnology is here and it is now. It is not something that you are going to be seeing 10 or 20 years from now, and it is not a chemist with a beaker in the lab trying to come up with some crazy idea that you might or might not be able to use 20 years from now. I would say that 20 to 25 percent of what you use everyday has nanotechnology know-how in it, and that percentage will continue to evolve to 50 percent over the next three to five years.

It is also important to recognize that innovation is the strength of science and research in the United States. Quite simply, innovation is done better here than anywhere else in the world. As a result, the dawn of the nanotechnology era gives the U.S. an incredible opportunity to make exciting discoveries, create new economic growth and provide a chance for our children to build exciting and important careers.

Reference sources for further information

1. College of Nanoscale Science and Engineering, University of Albany, SUNY www.CNSE.Albany.edu

2. Alain Kaloyeros' presentation: Nanotechnology: Opportunities, Drivers and Outcomes (click to view)

3. Project on Emerging Nanotechnologies: news, information and an expanding inventory of nanotechnology applications. http://www.nanotechproject.org/