Professor Yoshikazu Nakayama

Professor at Osaka Prefecture University Graduate School of Engineering, special professorship at Osaka University Graduate School of Engineering, Frontier Research Center, and Doctor of Engineering. Graduated 1972 from Osaka Prefecture University College of Engineering. After working for Matsushita Electronic Industries Co., Ltd., moved to Osaka Prefecture University College of Engineering in 1979. Has held current position since 2000. Awarded the 2003 "Nano Probe Technology Award" from the Japan Society for the Promotion of Science.

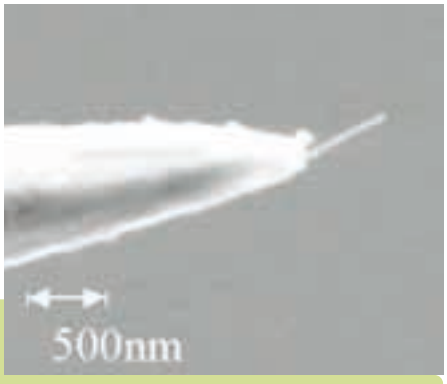
The Fruit of Collaboration between Academia and Industry

An "Ultra-Small Electron Microscope" Born from Carbon Nanotubes

The relationship between industry and academia is becoming more active in recent years. Shimadzu has long held a close relationship with the academic community through development of various products for researchers and is continuing its joint development programs enthusiastically. One of those joint development projects has born fruit with great potential. A single nanotube, developed in partnership with Professor Yoshikazu Nakayama of Osaka Prefecture University, has given birth to technology for making the key component of an electron microscope.

The World of Billionths of a Meter

Consider vinyl records making a noticeable comeback recently among young people. A record player produces sound by rubbing a stylus made of diamond or ruby along a bumpy groove cut into a polyvinyl chloride disk. A coil converts the resulting vibration into an electric signal, which the amplifier amplifies. The grooves on a LP record are about 0.05 millimeters wide and the needle thickness is about 0.026 millimeters, or 26 microns. In contrast, the world of carbon nanotubes is at a scale one thousand times smaller.



A carbon nanotube attached to the tip of a tungsten needle

In the U.S., a music critic once became a topic of conversation in the 1980's by identifying song titles from looking only at the record grooves. However, the nano-world cannot be seen with the naked eye. At the nano-level, one is able to see DNA, molecules and even individual atoms. Now carbon nanotubes are trying to provide a clear view into that smallest of worlds.

The Hardest and Most Flexible of Materials

Carbon nanotubes are a mesh of carbon atoms connected together like a beehive that forms a tube. The tube is a mere one to a dozen or more nanometers in diameter. Claimed to be the lightest and strongest material on earth, a 0.3 millimeter thick tube would have the strength to lift an automobile weighing a ton. These amazing properties have attracted the attention of researchers and companies around the world.

Sumio Iijima discovered carbon nanotubes in 1991. He announced his discovery in the science magazine "Nature." Mr. Iijima currently heads the Research Center for Advanced Carbon Materials at the National Institute of Advanced Industrial Science and Technology. Carbon nanotubes have caused quite a reaction. "To be honest, I thought this could be a winner," recalls Yoshikazu Nakayama, of Osaka Prefecture University, Graduate School of Engineering. At the time, Prof. Nakayama was studying in the United

States. As soon as he saw the news he immediately realized the potential and began research. That research resulted in the probe used in scanning probe microscopes (SPMs).

That probe consists of a plate spring, called a cantilever, that is fixed on one end and has a carbon nanotube attached to the free end. By drawing the probe across the sample surface, the contour of the sample surface can be measured. A typical application of the SPM technology is the atomic force microscope (AFM), which detects the atomic forces (the attractive forces generated between atoms) acting between the probe tip atoms and the sample atoms. The obtained data is processed into a three dimensional image by a computer.

"Carbon nanotubes have five to ten times the hardness of steel, yet are very flexible and won't break easily even if they are bent over. That's why I thought they were worth pursuing," explains Prof. Nakayama. Two years later, a scanning probe microscope containing a carbon nanotube was sent out into the world via a joint venture with a commercial company. Prof. Nakayama has also developed other products that employ carbon nanotubes, such as tweezers. "They're the perfect size for gripping DNA. I'd be happy if they are used as a set," Prof. Nakayama stated laughingly.

Shigeki Hayashi
Senior Researcher at Shimadzu Corporation's Technology Research Laboratory

Potential Electron Source

Carbon nanotubes also have another property that is worth pointing out. That is their high electrical current capacity, said to be more than ten times greater than copper, and their high aspect ratio. When a high voltage is applied to a carbon nanotube, an electric field builds up at its tip. Based on this fact, electrons can be discharged from a very narrow range on its tip. Shimadzu is working on applying this property to emit electrons or x-ray radiation for next-generation electron microscopes.

Carbon nanotube development is a cutting-edge field attracting considerable attention from around the world.

"It would allow us to easily focus a microscope, so in the future perhaps we can make electron microscopes the size of a magnifying glass." That's how Shigeki Hayashi, senior researcher at Shimadzu's Technology Research Laboratory promotes the idea. "In order to make this electron microscope a reality, we must first attach a carbon nanotube to the tip of a tungsten needle that has a radius of only 100 nanometers and to do that Prof. Nakayama's help is essential."

That is how Shimadzu began researching the use of carbon nanotubes as micro field electron emitters. The results were extremely promising. Compared to previous electron emitters, electrons discharged from the newly developed emitter fell within a range that was about one tenth as broad. "That means we can increase resolution that much more and increase accuracy. Once we obtain stable results then we should be able to make electron microscopes that are dramatically smaller than current systems," Mr. Hayashi stated.

Furthermore, standard electron emitters require use in an ultrahigh vacuum environment to prevent reactions with impurities in the air. However, carbon nanotubes do not react easily with impurities, so they are able to operate in vacuum levels that are one hundredth lower than the vacuum level required for standard emitters. "Electron microscopes can be used without installing an expensive vacuum pump system. That should increase their usage to a new level," predicts Hayashi.

Sending Them Out into the World As Soon As Possible

Shimadzu is already looking ahead and considering applying the technology to x-ray emission. The idea is to look inside objects using a nano-sized x-ray beam. For example, it would make it possible to check the internal circuits inside finished semiconductors.

Prof. Nakayama stated, "It's fun working with Shimadzu. The researchers are passionate and always pursuing their dreams. This is the result of taking full advantage of the properties of carbon nanotube, like its application in SPM probes. I want to send them out into the world as soon as possible." This new fruit born of a collaboration between industry and academia is about to be sent into the world soon.