INTERVIEW

Opening up New Possibilities in Communications using Nano-technology

Akira OTOMO
Director of Nano ICT Laboratory, Advanced ICT Research Institute

After completing a doctoral program, he joined the Communications Research Laboratory (currently NICT) in 1996. Engaged in research on applications of molecular photonics and nano-photonics for optical control technologies. Current position held since 2011. Ph.D.

Information and communications networks have become essential for our lives in society. However, as systems become faster and increase in capacity, we cannot ignore the increasing power consumption and heat generated, and new technical breakthroughs are needed urgently. A development promising for answers to these issues is the appearance of nano-technology materials and devices. We spoke with Dr. Akira OTOMO, Director of Nano ICT Laboratory, Advanced ICT Research Institute.

Nano-technology in information and communications

— We often hear about "nano-technology" as an advanced technology that gets a lot of attention, but beyond "the world of the extremely small," it is difficult to form an image of exactly what it is, or how it is related to information and communications technology.

OTOMO It's true, the word 'nano-scale' alone might not give a clear image of what we're talking about. A nanometer is a unit that is one billionth of a meter. If I say that one tenth of a nanometer is on the scale of atoms and several nanometers is on the scale of molecules, does that convey how tiny this is?

The Nano ICT Laboratory deals with applying materials and processing technologies at these scales in the field of information and communications technology. We are conducting R&D on innovative ICT hardware that would not be possible by only making small advances of existing technologies. Nano-technologies open up possibilities for devices that have much higher performance and efficiency, and are smaller than ever before. This has huge benefits for network infrastructure, which continues to grow in scale.

Two fields producing innovative hardware

— Can you describe specific examples of the research you are doing?

OTOMO We are working on two main research themes.

The first is organic materials. In organic materials, π electrons in the molecules are resonant with the optical electromagnetic fields, so they have faster, more efficient photoresponsivity than inorganic materials. However, this feature is affected by molecular structure and arrangement, so design, control and synthesis at the molecular level—of just a few nanometers—is necessary (Figure 1). Our Organic Nano-Device Group handles this area.

The other theme is superconducting materials. As you know, superconductivity is the phenomenon by which the electrical resistance of certain materials drops to zero be-

Figure 1 Synthesis of new organic molecular materials

low a particular temperature. There is great potential for devices that make use of unique properties, such as perfect conductivity and flux quantization, which occur in that state. To develop such superconducting devices, atoms must be deposited to thicknesses in the range of ten nanometers, requiring technologies for nano-processing and forming thin films. Our Superconductive Device Group handles this area.

Results coming into practical use

— Are there any technologies from your R&D that are at or near the stage of practical application?

OTOMO One device that is particularly oriented to practical use is our superconducting nanowire single photon detector (SSPD) (Figure 2), which was developed based on niobium nitride (NbN) thin film deposition and nanowire fabrication techniques from our superconducting device research. This photon detector has higher performance than the avalanche photodiodes (APD) that are currently in wide use and it is becoming a key device for quantum cryptography communication systems in the field of information and communications.

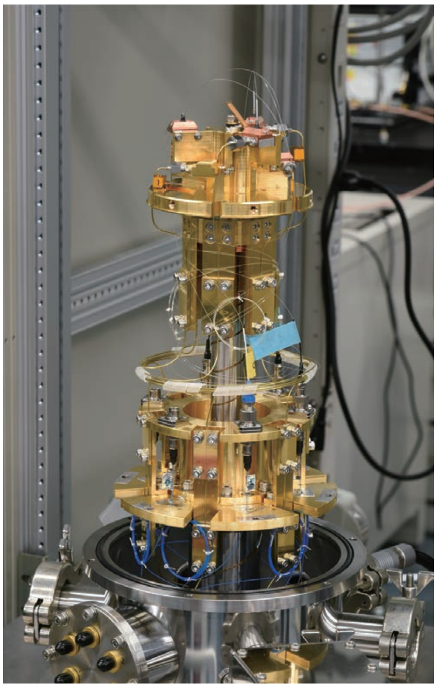

Figure 2 Inside of the superconducting nanowire single photon detector (SSPD) system

The SSPD also promises to have broad influence in fields other than information and communications. Dramatic improvement in performance and speed can be expected in fields such as fluorescence microscopes and laser ranging technologies, by replacing the current semiconductor devices with SSPDs.

We are also planning to make organic electro-optic (EO) polymers more practical. These are needed for optical modulators and other components in optical communications, which forms the foundation for information and communications technology. We can increase speed and save energy by using efficient organic materials. We have already achieved modulation at speeds exceeding 100 GHz.

Conventionally, organic materials have had the disadvantage of being susceptible to environment compared to inorganic materials, but we are developing technologies to make them more practical, such as developing heat-resistant EO polymers, and protecting materials from surrounding oxygen and water by covering the surface with a layer of atoms of an inorganic material.

NICT overall is also promoting research on terahertz (THz) technologies, and organic materials are having a great influence on this field as well. The frequencies are higher than the gigahertz (GHz) band, where modulators generally operate, but the interactions are basically the same. Thus, using the materials and devices we have created for ultra-high-speed optical modulators will enable us to implement THz generators that are more efficient and compact than before. This is another theme we are pursuing vigorously.

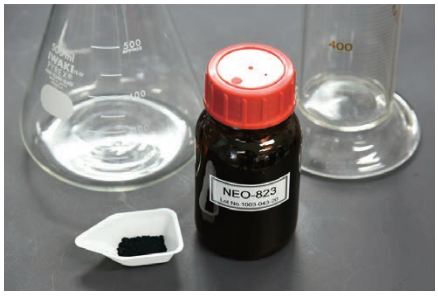

Figure 3 High-performance organic EO material to go on the market

Strength in an R&D system integrated from materials to devices

— It sounds like you will be producing some very interesting results in the future. What are your laboratory's particular features or strengths, in terms of research organization?

OTOMO Generally in materials research, devices are divided into their own specialties, and usually they don't cooperate well. But in our Nano ICT Laboratory, we synthesize our own materials, and have integrated development from instrumentation to design and device development. As such, we have a good understanding of the characteristics of the materials when we create a device, and we can go back to basic principles for ideas in finding solutions to whatever issues we meet. We are getting many inquiries about collaborative research and are planning to sell the materials themselves for an appropriate price, in order to expand the foundation for R&D (Figure 3).

Of course, the market for what we are working on will be small initially, and there are many issues, but considering the future of information and communications technology, there should be strong demand. We feel our responsibilities in this area strongly.