QNERC
Quantum Nanoelectronics Research Center

QNERC NEWS

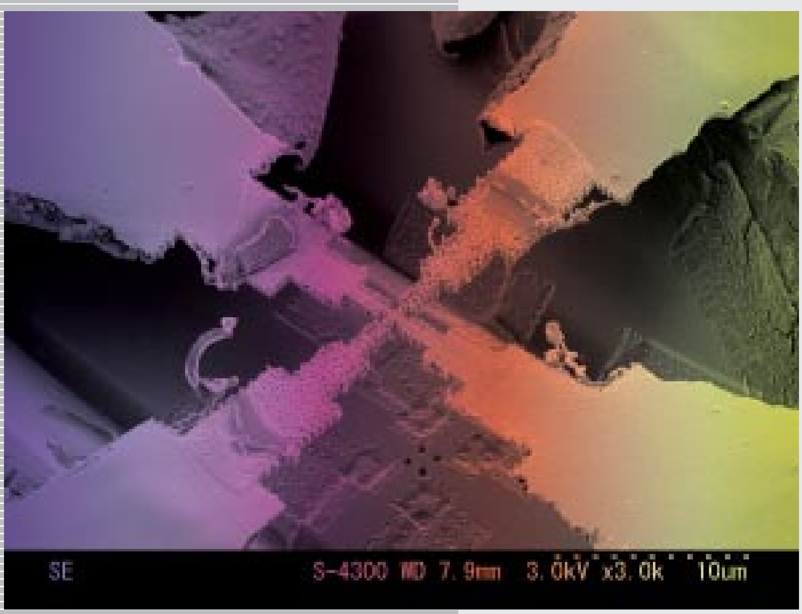
Real-World Nanotechnology

"Can you make it work?" That's a challenge that researchers face repeatedly from Dr. Shigehisa Arai, a member of Tokyo Tech's Quantum Nanoelectronics Research Center (QNERC). Renowned for his contributions to optical-fiber communications, Arai epitomizes QNERC's emphasis on—and success in—putting quantum physics and nanoscience to work in the real world. "We are here to blaze new trails in physics," declares QNERC director Dr. Kazuhito Furuya. "Nanotechnology is our highway."

"I spent 10 years in industry before coming to Tokyo Tech," explains QNERC colleague Dr. Adarsh Sandhu. "That has shaped my commitment to finding real-world solutions.""Ideas are international," notes another QNERC member, Dr. Shunri Oda, "and so are we. Our center attracts a global cast of researchers. We welcome the dynamism that results from multicultural cross-pollination."

"Practical electronic devices are the main theme of our research," adds QNERC's Dr. Akira Yamada, a leading researcher in silicon carbide nanoelectronics. "We are achieving some extremely interesting results with devices that no one else is studying yet."

The Tokyo Institute of Technology (Tokyo Tech), Japan's foremost university devoted to technological disciplines, established QNERC in April 2004. QNERC inherits the R&D portfolio of its predecessor, Tokyo Tech's Research Center for Quantum Effect Electronics. It translates advances in nanoscience into practical suggestions for industrial applications.



Finding real-world solutions

Hot Electrons

Dr. Kazuhito Furuya
Director, QNERC; Professor, Tokyo Tech
www.pe.titech.ac.jp/Furuya-MiyamotoLab/e-index.htm

Furuya's team is exploring applications for "hot electrons" in ultrahigh-speed functional devices where the electron wave properties determine the device performance. That work has resulted in important patents for ultrafast logic devices and other related technologies.

Scientists have achieved conditions in which the electrons in a semiconductor become substantially hotter than the crystal lattice that they occupy. That suspends Ohm's law and disrupts the linear correlation between current and voltage.

Furuya and colleagues published a paper in 2005 that describes the first definite observation of the double-slit interference of a hot electron in a solid. They achieved that observation by fabricating a double slit that had a 12-nanometer opening and a center-to-center distance of 25 nanometers. Their detection electrode was 40 nanometers wide. Furuya expects applications for the team's findings in new kinds of multifunctional devices based on the wave properties of electrons.

State-of-the-art equipment supports the development of innovative nanotechnology for fulfilling contemporary needs in science and industry.

Cross-fertilization among scientific disciplines nurtures important advances at QNERC that lead research in sometimes surprising directions.

Quantum-Wire Lasers

Dr. Shigehisa Arai
Professor, Tokyo Tech
www.pe.titech.ac.jp/AraiLab/index-e.html

Arai participated in developing the world's first laser of 1.5-micrometer wavelength in the 1970s. That development was instrumental in making long-distance optical-fiber communications possible.

More recently, low-damage fabrication technology pioneered by Arai has resulted in quantum-wire lasers that provide room-temperature continuous-wave (RT-CW) operation well in excess of 10,000 hours (24,000 hours and counting as of December 26, 2005). His team has achieved the lowest threshold current ever documented, 0.7 microamperes, with distributed feedback (DFB) lasers. QNERC's electron beam (EB) lithography system enables Arai's team to achieve dot sizes of 5 nanometers in fabricating quantum-wire and DFB lasers.

Third-party recognition of Arai's work has included the Michael Lunn Memorial Award from the 2000 Indium Phosphide and Related Materials Conference, sponsored by the Institute of Electrical and Electronics Engineers.

Hall Sensors

Dr. Adarsh Sandhu

Associate Professor, Tokyo Tech

spirit.pe.titech.ac.jp/index-e.html

Sandhu has assembled a multidisciplinary team to develop and refine applications for Hall sensors in evaluating magnetic materials and in conducting biochemical screening. Hall sensors provide noninvasive means of detecting the distribution of magnetism on the surfaces of recording media, and advances by Sandhu in minimizing noise and maximizing sensor accuracy have proved invaluable in commercializing ultrahigh-density media.

Recently, the Sandhu Laboratory has captured attention with its work in biosensors based on ferromagnetic labeling. That labeling could support improved drug delivery systems, as well as advances in diagnostics.

Sandhu and his researchers also contribute to continuing advances in Hall-effect technology. They create original Hall sensors for different applications, and they can fabricate sensors as small as 50 nanometers.

QNERC lends a full range of technical and instructional support to researchers for nanotechnology projects that comply with its acceptance guidelines.

Tokyo Tech's expansive O-okayama campus provides a setting conducive to research and study for QNERC faculty and students.

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The QNERC laboratories and classrooms occupy 10 floors in a dedicated building. Their facilities include a 132-square-meter class-five clean room and 409 square meters of special-gas clean rooms, along with vibration-resistant rooms for scanning electron microscopy (SEM) and atomic force microscopy (AFM).

Finding real-world solutions

Single-Electron Devices

Dr. Shunri Oda
Professor, Tokyo Tech
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Researchers in QNERC's Oda Laboratory are laying the groundwork for practical single-electron devices. Those devices promise to support advanced functionality and minimal power consumption in future electronic devices. Oda and his team combine the "top-down" methodology of semiconductor design with the "bottom-up" methodology of materials research. They use plasma processes to fabricate monodispersed nanocrystalline silicon quantum dots, and they use electron-beam lithography to position the dots precisely.

The Oda team has verified single-electron tunneling and memory effects in silicon nanodevices, even at room temperature, with 8-nanometer quantum dots. It has also observed high-efficiency visible photoluminescence due to quasi-direct transition in surface-oxidized nanocrystalline silicon.

Achieving reliable quantum transport at room temperature will depend on reducing the size of the quantum dots to 3 nanometers, and Oda and his team are exploring self-limiting oxidation as a means of achieving that size reduction.

QNERC researchers look beyond the established wisdom in exploring possibilities across a broad range of scientific disciplines.

A whole world of research talent converges at QNERC to transform promising nanoscience into useful nanotechnology.

Strained Layers of Silicon Carbide on Silicon

Dr. Akira Yamada
Associate Professor, Tokyo Tech
tkhshi.pe.titech.ac.jp/index_e.html

Silicon carbide materials developed originally by Yamada and his colleagues for photovoltaic cells have exhibited exciting promise in semiconductor devices. Researchers around the world continue to explore different compounds of silicon as candidate semiconductors for future-generation devices, and Yamada's team has led the way in silicon carbide.

Low-field electron mobility is theoretically higher in silicon carbide than in pure silicon, which suggests possible applications in high-performance metal oxide semiconductor (MOS) field-effect transistors (FETs). The Yamada team has focused on compounds of $Si_{0.99}C_{0.01}$ and has confirmed MOS FET functionality with strained silicon carbide grown on silicon. It uses atomic force microscopic (AFM) mechanical lithography to fabricate nanoscale structures in semiconductors, and it uses QNERC's systems for chemical-vapor deposition (CVD) to grow epitaxial films of silicon carbide.