

# TOSHIBA REVIEW

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## Special Reports

### Nanoelectronics for Innovation

#### Nanotechnology Making Dreams Come True

ARINOBU Mutsuhiro

#### Expectations for Nanoelectronics Technologies toward Ubiquitous Network Society

ISHIKAWA Masayuki / HIRAOKA Toshiro

Performance improvement along a road map is driving the development of electronics technologies. However, it is predicted that the road map of electronics technologies will encounter technological limits. New developments in electronics technologies due to the limits of the road map and the wide array of needs in the ubiquitous network society are therefore expected. Electronics technologies will develop in two directions in this context: toward surpassing the limits of the road map on the one hand, and toward adding or changing the value axis on the other. A wide diversity of innovations by revolutionary nanotechnologies will appear due to these developments around 2010-2020.

#### New Batteries Using Nanomaterial Electrodes

TAKAMI Norio / INAGAKI Hiroki / MORITA Tomokazu

Lithium-ion batteries have been developed to enhance capacity, power, cycle life, and fast-charging performance for many applications such as mobile devices, automobiles, and various industrial sectors. New materials for lithium-ion batteries have been researched to achieve the high performance required for new applications.

Toshiba has developed new types of lithium-ion batteries using nanomaterials as the negative electrode. The use of nano silicon and carbon composites as a high-capacity negative electrode resulted in double the discharge capacity compared to conventional carbon electrodes and good cyclability, indicating the possibility of realizing lithium-ion batteries with higher capacity. For the development of fast-charging batteries, a new negative electrode consisting of a nanoparticle material exhibited the rapid insertion of lithium ions without decomposition of the electrolyte. A prototype fast-charging battery demonstrated 60 times faster charging than conventional lithium-ion batteries. This fast-charging battery technology not only offers the advantage of rapid charging, but also effective saving and reuse of energy.

#### MOSFETs Fabricated on Ultrathin Silicon-on-Insulator Film

UCHIDA Ken / KOGA Junji

Metal-oxide-semiconductor field-effect transistors (MOSFETs) fabricated on ultrathin silicon-on-insulator (SOI) films show promise as transistors in future large-scale integrated circuits (LSIs).

Toshiba has successfully fabricated and operated ultrathin SOI MOSFETs with an SOI film thickness of less than 1 nm, for the first time. In addition, we have found that quantum mechanical effects have a significant impact on transistor operations.

#### Ultrasmall Random Number Generator

TANAMOTO Tetsufumi / OHBA Ryuji / FUJITA Shinobu

As the demand for information security becomes increasingly severe, higher level random number generators, which are one of the fundamental information technologies, are also required every year. Because the unpredictability of a random number is closely relevant to the basis of information security, significantly stricter statistical tests of commercial random numbers have been adopted in recent years.

Toshiba has developed an ultrasmall random number generation circuit that can generate high-quality and high-speed random numbers. This was achieved by the development of nano-scale Si devices.

#### CPP Spin-Valve Films with Current-Confined-Path Nano-oxide Layer

FUKUZAWA Hideaki / YUASA Hiromi / IWASAKI Hitoshi

Demand has recently arisen for new reader heads with high sensitivity for use in hard disk drives (HDDs), in order to realize high-areal-density recording. Since such high-density recording cannot be achieved by improvement of the conventional technology, spin-valve films with high sensitivity and new functionality are required.

Toshiba has successfully developed new spin-valve films having a special nanostructure. A significant increase in sensitivity has been achieved by inserting a nano-oxide layer (NOL) in the spin-valve film, with the NOL being mainly composed of an insulator material having nano-size current-confined paths that punch through the insulator layer.

#### Nanopatterned Media

SAKURAI Masatoshi / KIMURA Kaori / HIEDA Hiroyuki

The areal recording density of hard disk drives (HDDs) has increased over the years and reached a very high level today. In order to maintain this high growth in recording density in the future, it is necessary to overcome the media noise problem.

Toshiba has developed nanopatterned media with uniform magnetic dot size, the areal recording density of which can exceed a terabit (10<sup>12</sup> bits) per square inch. All magnetic dots in the nanopatterned media are accurately placed in position by an artificially assisted self-assembly method.

#### RF-MEMS Devices

ITAYA Kazuhiko / KAWAKUBO Takashi

Wireless communication systems have undergone a remarkable evolution to realize a comfortable ubiquitous society. With the constant demand for higher communication speeds and seamless connection, however, the increase of components in personal terminals, especially passive devices, is becoming a serious problem. In this situation, radio-frequency microelectromechanical systems (RF-MEMS) technology has recently been attracting considerable attention.

Toshiba has developed a technology for atomic-order control of orientation in thin-film piezoelectric materials, which has been adapted to RF-MEMS devices such as filters and tunable capacitors. This process technology is compatible with LSI processes, and both miniaturization and high performance have been realized. This technology will make possible the further miniaturization of next-generation wireless terminals with, for example, passive devices and an LSI in one chip.

#### Semiconductor Nanotechnology for Quantum Photonics

Andrew Shields

Toshiba is making progress toward developing a nanotechnology for the generation and detection of quantum light states using self-assembled semiconductor quantum dots. Previously we demonstrated that a single quantum dot placed within a conventional semiconductor light-emitting diode (LED) acts as a single photon source. It is shown here that the quantum dot growth can be manipulated to achieve an emission wavelength compatible with transmission over optical fiber. Incorporation of a cavity into the LED structure leads to a tenfold increase in the single photon generation efficiency, and electrical control of the carrier dynamics has been used to achieve repetition rates as high as 1 GHz. Quantum dot devices are also demonstrated to be efficient detectors of single photons.

#### Nanoarchitectures Based on Post-Silicon Devices

FUJITA Shinobu / NOMURA Kumiko / ABE Keiko

As silicon complementary metal-oxide semiconductor (Si-CMOS) technology reaches its limits in the coming 10 years, it is expected to be replaced by post-silicon devices such as transistors using carbon nanotubes or nanowires. To continue increasing the performance of integrated circuits, new architectures suitable for these post-silicon devices are necessary. Such "nanoarchitectures" must be constructed based on three-dimensional circuits, with both the device resources and bandwidth increased by means of three-dimensional stacking. Mechanical switching nanodevices are also a promising candidate for three-dimensionally fabricated post-silicon devices.

#### Spin-Electronics Devices and Magnetic Switching Technique

NAKAMURA Shiho / SAITO Yoshiaki / MORISE Hirofumi

Spin-electronics devices utilize the spin degree of freedom in addition to the charge degree of freedom and the nonvolatile property of magnetic materials.

To realize ultralow power consumption and new functions, Toshiba has developed a current-induced magnetic switching technique as a fundamental technique for such devices, and lowered the switching-current density to 1 x 10<sup>6</sup> A/cm<sup>2</sup> by introducing new device structures. This technique is expected to lead to the realization of new devices including spin memories and logic devices, which will form the basis of the advanced ubiquitous society.

## Feature Articles

#### Large-Scale Field Test of Residential Fuel Cell System and Microgrid Demonstration Test at Aichi Expo 2005

NAKAJIMA Ryo / SANAGI Yoshihisa / YABUKI Masanori

Fuel cells are expected to be widely used in a variety of applications, including both stationary and automotive systems, due to their high efficiency and environmental friendliness. Toshiba has been developing 1 kW-class residential fuel cell systems since FY2000 with the aim of improving their performance, durability, and reliability.

Toshiba Fuel Cell Power Systems Corporation (TFCP) has developed and deployed 40 residential polymer electrolyte fuel cell (PEFC) systems in various dwellings for a large-scale field test program and confirmed their excellent energy-saving capability in actual daily operating conditions. At Aichi Expo 2005, a microgrid system consisting of several new energy-distribution type power generation systems, including four 200 kW phosphoric acid fuel cell (PAFC) systems manufactured by TFCP, demonstrated stable controllability through grid independent operation.

#### Control System for Overseas Combined-Cycle Power Plants

SAITO Hiroyuki / DOZONO Takeshi / TAKASHIMA Michiharu

To meet the increasing and diversifying demand for both the new construction and rehabilitation of overseas combined-cycle power generation plants, Toshiba is adopting the state-of-the-art TOSMAP-DS<sub>TM</sub> as a distributed control system (DCS), which is the main control and monitoring equipment for the plant, as a part of our turnkey projects.

This paper describes our commitment to fully satisfying the diverse needs of plant owners as a turnkey contractor using TOSMAP-DS<sub>TM</sub>, referring to recent achievements among the many projects we have participated in.

#### Low-Cost Brazing Metal for Vacuum Circuit Breakers

KUSANO Takashi / OSABE Kiyoshi / OKUTOMI Tsutomu

Vacuum circuit breakers have various advantages such as compactness and light weight, and they are also maintenance-free as well as environmentally friendly compared with other types of circuit breakers. As a result, their applications have rapidly expanded.

Brazing in a vacuum is a necessary process for manufacturing of the vacuum interrupter, which is the main component of a vacuum circuit breaker. The parts of vacuum interrupters are made from special materials of extremely low gas content, such as oxygen-free Cu or Cu-Cr alloys. Brazing processes in a vacuum are applied to weld the parts of vacuum interrupters. In these processes, first an expensive Pd-containing brazing material is applied followed by the commonly used Ag-Cu eutectic brazing material. These brazing materials are used according to the assembly temperature. The Pd-containing brazing material has a melting and welding performance suited to the existing manufacturing process for vacuum interrupters. However, it has prevented the cost reduction of vacuum interrupters because its price has risen with the rise in price of Pd, and also because an Ni-plating process is necessary on the surface of stainless steel to be brazed.

Toshiba has been making efforts to develop Pd-free brazing materials and to apply these materials to actual processes while enlarging the areas of application.

#### Practical Use of Construction Information Based on Life Cycle Data Management

KOZAI Toshihiro / MOCHIZUKI Yoshiaki / YANO Rei

The Japanese government is promoting the e-Japan Strategy Program, which includes the Electronic Government Deployment Program and the Local Government Deployment Program. In the construction field, although progress has been made in the introduction of information technology and standardization as shown by the application of continuous acquisition and life-cycle support/electronic commerce (CALS/EC) and the geographic information system (GIS), there are still some issues to be solved regarding the practical use of construction information.

Toshiba Solutions Corp. has been participating in the Life Cycle Data Management (LCDM) Forum and has been actively promoting the dissemination of LCDM activities to enable the effective practical use of construction information.

#### NEOSERA<sub>TM</sub> Lighting System Featuring High-Efficiency Ceramic Metal Halide Lamps with High Color-Rendering Index

TAKAYAMA Daisuke / TERASAKA Hiroshi / SUZUKI Norimasa

Toshiba has developed the innovative NEOSERA<sub>TM</sub> series ceramic metal halide lamp system (100 W, 250 W, and 400 W).

The system consists of new ceramic metal halide lamps, a new electronic ballast, and the new FLOOR MASTER<sub>TM</sub> luminaire, each possessing great advantages compared to conventional lamp systems. In particular, the NEOSERA<sub>TM</sub> 100 W model has a luminous efficacy of 115 lm/W and a color-rendering index of 90, which are world-leading performance levels realizing a new-generation ceramic metal halide lamp for energy-saving with higher color rendition. The NEOSERA<sub>TM</sub> 250 W and 400 W models can be operated without any restrictions on the burning position, making these the first such products to be marketed above the 200 W class.

#### GR-W45FB Refrigerator with High Capacity Efficiency

GONO Kazuaki / MASHIMO Takuya / NOGUCHI Yoshifumi

Since its development and manufacture of Japan's first electric refrigerator in 1930, Toshiba has been actively developing new refrigerator technologies aiming at the improvement of food storage performance and usability, reduction of energy consumption, environmentally conscious design, and so on.

In November 2005, we launched the GR-W45FB refrigerator on the market to mark the 75th anniversary of that achievement. The GR-W45FB has 38 liters greater capacity than the previous model despite having the same installation space. This was realized by slimmer design and better layout of the twin evaporator as well as downsizing of the heat radiation system. It also features the "Cool Purifier" cleaning function, which deodorizes, eliminates bacteria, and resolves ethylene gas in the cool air with "Nano-Optical Plasma." Furthermore, this model has additional functions for improved usability and food storage performance, including electrically operated automatic door opening and closing, and an ice tray that eliminates bacteria in the water.

## Frontiers of Research & Development

#### HD DVD-Recordable Dis

Application of Shape Optimization to Thermal Stress Analysis