

TOSHIBA REVIEW

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Special Reports I

Nanotechnology

*The Dominating Technology for Realizing a New IT

AZUMA Makoto

*Trends in and Prospects for Nanotechnology

TOYODA Nobuyuki FUJITA Shinobu KUROBE Atsushi ISHIKAWA Masayuki
Nanotechnology is expected to become a fundamental technology in the future. This paper describes the trends in nanotechnology and its future prospects. First, the history of nanotechnology is reviewed. Next, the definition of nanotechnology is reconsidered from the viewpoints of fabrication, size, materials, and morphology, leading to a simple classification of the wide range of varieties of nanotechnology. This is followed by the most important section of this paper, explaining the application of nanotechnology in the fields of electronics, bionics, mechatronics, energy, and environment. The emphasis in this section is on areas of application where Toshiba is making efforts to develop new technology.

*Single-Electron Device Technology for Ultralow-Power LSIs

KOGA Junji UCHIDA Ken OHBA Ryuji

The miniaturization of transistors is a powerful driving force for the rapid progress in silicon LSI technology. Transistors with a gate length of less than 50 nm have been reported. As the gate length is scaled down, however, it becomes increasingly difficult both to suppress the short channel effects and to reduce the power consumption. Recently, single-electron devices, which operate normally in the nanometer-scale region, have been identified as an attractive future ultralow-power LSI technology.

Toshiba has demonstrated a single-electron transistor (SET) and memory operating at room temperature by developing the process technology for precise control of silicon nanometer-scale structures. The concept of programmable SET logic was proposed and SET circuit operation was demonstrated at room temperature for the first time. Self-aligned double-stacked silicon dots were successfully fabricated, making the single-electron memory a possible candidate for a practical high-speed nonvolatile memory operating at a low voltage.

*New Nanopatterning Technique for High-Density Magnetic Recording Media

HIRAOKA Toshiro ASAKAWA Koji KIKITSU Akira

Toshiba has developed a new nanopatterning technique to obtain superfine patterns for high-density magnetic recording media. Self-assembling nanopatterns of polymers were generated and then transferred to substrates using the reactive-ion etching (RIE) method. The sizes and structures of the nanopatterns can be controlled by controlling the molecular structures of the polymers. This process is potentially inexpensive compared with the conventional lithography processes.

*Nanostructural Electrode Materials for High-Energy-Density Batteries

TAKAMI Norio YAMADA Shuji KOHNO Tatsuki

Higher energy density is required for lithium-ion batteries (LIBs) and nickel-metal hydride (Ni-MH) batteries used in portable electronic equipment.

Toshiba has developed new electrode materials using nanotechnology to enhance the capacities of these batteries. Boron-doped carbon fiber with a radial texture was developed to enhance the capacity of the negative electrode in LIBs. A lithium nickel-based oxide material ($\text{LiNi}_{0.8-x}\text{Co}_{0.2}\text{Al}_x\text{O}_2$) developed as a new positive electrode material for LIBs was synthesized by cobalt and aluminum substitution of nickel sites. Positive electrodes fabricated with $\text{LiNi}_{0.8-x}\text{Co}_{0.2}\text{Al}_x\text{O}_2$ showed a long cycle life and good thermal stability. Furthermore, by optimizing nanostacked layers in an La-Mg-Ni-based alloy for the negative electrode of Ni-MH batteries, a negative electrode with high capacity and a long cycle life was realized.

*Spin-Polarized Scanning Tunneling Microscopy for Magnetic Imaging with Nanometer Spatial Resolution

OKUNO Shiho KISHI Tatsuya TANAKA Kuniyoshi

Toshiba has developed spin-polarized scanning tunneling microscopy for magnetic imaging of magnetic storage materials. Magnetic information was obtained utilizing the bias-voltage dependence of the spin-polarization of the system. The magnetization direction of Co elements was displayed as two-dimensional images with a contrast ratio of 23 %. This analysis method can be used to reveal the magnetic structures of ultrafine magnetic materials of nanometer size.

*Single Photon Technology for Secure Optical Quantum Communications

Andrew Shields Mark Stevenson

This paper describes a hardware-based solution to network security issues which relies on communication using single photon signals. It allows, for instance, two parties on the network to form a shared cryptographic key, with a guarantee that the key cannot be known by anyone else. Crucial to the implementation and performance of such a secure optical communication system is the development of novel devices for the detection and generation of single photons. Using nanotechnology we have fashioned a new class of semiconductor optoelectronic device for this application. By integrating a layer of quantum dots inside a field-effect transistor we have realized a detector of single photons. We also show that the emission from a single quantum dot can be used as a source of single photons.

*DNA Chips for Diagnostic Applications

GEMMA Nobuhiro HASHIMOTO Kouji ISHIMORI Yoshio

DNA chips can easily evaluate responses to or side effects of drugs in individuals, and are therefore expected to become indispensable devices for tailor-made medical care. Compared with conventional DNA chips employing detection of fluorescence, the electrochemical DNA chip originally proposed by Toshiba has the advantages of both low cost and rapid detection, which will lead to further diagnostic applications. At present, we are developing an electrochemical DNA chip to predict response to interferon in patients with the hepatitis C virus (HCV).

*Microfluidic Techniques for Handling Micro- and Nanoscale Fluids

KAWANO Koichiro SEKIMURA Masayuki SUDO Hajime

The development of microelectromechanical system (MEMS) technology has made it possible to fabricate microscale fluid components (channels, pumps, valves, etc.) in silicon or glass chips. Microfluidics, which deals with microscale fluid components, is a field whose techniques promise to contribute to the development of nanotechnology.

This paper presents a high-performance microchannel heat exchanger and biosensor, which have been developed by Toshiba utilizing microfluidic techniques, to demonstrate the advantages of these techniques. Furthermore, nanofluidic techniques are beginning to be developed as the next stage of microfluidics to handle a few molecules in fluids.

Special Reports II

System LSI Technologies for Mobile and Digital Consumer Products

*System LSI Technologies for Advanced Digital Consumer Products

YOSHIMUCHI Shigeru

*Progress of Semiconductor Technology and System on Chip

SAITO Mitsuo

The relationship between system development and semiconductor technology from the historical point of view is described in this paper. The year 2000 marked a time of transition, especially from the perspective of technology drivers, toward the full-scale system on chip (SOC) era. This is explained in terms of the architecture of the Emotion Engine (EE) and the generational change in cellular phones. Semiconductor technology issues related to SOC are also discussed, and the directions for solutions are briefly mentioned.

*Challenges in System LSI Design Technologies and Evolution

AHARA Masami IGARASHI Mutsunori USAMI Kimiyoshi HIWATASHI Tamotsu

The design of system LSIs involves difficult challenges due to the very large scale of integration on a chip and device miniaturization. Design productivity, power consumption, and the impact of interconnect delay are the most critical issues.

This paper describes Toshiba's design technologies in this field, including hardware-software co-verification, low-power design methodology, and layout technology utilizing diagonal interconnect architecture.

*Single-Chip Digital TV LSI

KAI Naoyuki NAGOYA Tetsuo MANAKA Shigeyuki

Toshiba has developed a single-chip LSI for high-definition digital TV. The new LSI integrates MPEG-2 transport stream processing, video and audio decoding, and graphics processing functions, and also has an on-chip 64-bit reduced instruction set computers (RISC) as a host processor as well as peripheral modules. This LSI lowers the system cost by utilizing unified memory architecture (UMA) with a 64-bit double data rate (DDR) synchronous DRAM (SDRAM) system. It integrates a configurable media processor as a controller for the dedicated hardware modules. A section filtering accelerator is implemented in the controller by means of the functional extension mechanism of the media processor.

*System LSI Technology for MPEG-4 Audiovisual LSI

TAKAHASHI Masafumi NISHIKAWA Tsuyoshi

Toshiba has developed an MPEG-4 audiovisual coding/decoding LSI for mobile applications such as PDAs and IMT2000 cellular phone terminals. Various audiovisual and multiplexing standards can be handled by the MPEG-4 LSI with its 16-bit reduced instruction set computer (RISC) processors and dedicated hardware accelerators. Embedded DRAM technology and other low-power techniques are employed in order to reduce power consumption.

This latest MPEG-4 audiovisual LSI is fabricated with 0.18- μm CMOS technology and consumes only 75 mW when operating for video telephony processing.

*SD Card and SD Host Controller LSIs

TAKADA Tomoji UETA Seiji OKAMOTO Hiroshi KII Masayuki

The secure digital (SD) card is a small-size, lightweight, high-speed, and low-power-consumption media card. It has a copy protection scheme for contents protection. The secure digital input/output (SDIO) card, providing more function modules, has recently been defined.

To realize these cards, Toshiba has developed SD memory and SDIO card controllers. Furthermore, Toshiba has also developed SD host controllers and an SD microprocessor to facilitate the use of SD cards in application systems. This paper describes these SD card controllers, host controllers, and the SD microprocessor.

*Application of IC Cards and System LSI Technology

ODA Hiroshi

Visa International proposed a design for making credit cards into integrated circuit (IC) cards about 20 years ago. The purpose of such a change is to minimize damage due to forgery and unauthorized use accompanying the wide dissemination of credit cards. Increasing attention is now being paid to security in Japan, although companies in other countries already began to enter the business of security authentication and evaluation about 10 years ago with a focus on the secure characteristics of IC cards. The arrival of the network business era has further accelerated this trend. As a result, IC card technology is being applied in a variety of fields and has evolved accordingly.

Feature Articles

*"DAISEIKAI" Series Room Air Conditioners Featuring High Energy Efficiency and Reduced Maintenance

KOMAZAKI Megumi YAMANASHI Yasushi TAKEYA TAKEYA Nobuyuki

We launched the "DAISEIKAI" series of room air conditioners, featuring high energy efficiency and reduced maintenance, on the market in 2001. As the quality of indoor air is currently attracting attention, air conditioners equipped with air purifiers and negative ion generators have become strongly selling products.

This paper introduces new technologies used in the "DAISEIKAI" series. These include a sensorless vector control inverter unit that achieves high efficiency and reduces noise, and a self-cleaning control system that lengthens the maintenance-free period and provides long-term energy conservation.

*Ph-8 Personal Digital Cellular Phone

YAHAGI Mitsuru IZUKA Kazuhiro SAKAI Masaki

The year 2001 was indeed the era of the cellular phone in Japan, as the number of cellular phone subscribers overtook that of fixed-line subscribers at the beginning of the year. In 1991, the personal digital cellular (PDC) phone radio specification was set by RCR (now the Association of Radio Industries and Businesses: ARIB). Since 1994, Toshiba has been working on the development of the PDC phone. In the summer of 2001, Toshiba released the Ph-8 (Phase 8) model PDC phone on the market equipped with a 120 x 160-dot, 65,536-color LCD, a mobile camera with a flash unit, and Java functions. The Ph-8 model thus has a rich array of features to satisfy user needs.

*High-Precision Flip Chip Bonder

KUBO Tetsuya HASHIMOTO Masanori MIYAMOTO Yuusuke

With the increasing miniaturization and higher functionality of cellular phones and other mobile devices in recent years, LCD driver ICs are required to accommodate high pin counts, fine pitch, and film of a thickness that enables folding. The use of the chip on film (COF) method, which involves flip chip bonding of an IC on film, is expanding rapidly as a result.

To meet these requirements, based on the development technology for a high-speed flip chip bonder (precision $\pm 5 \mu\text{m}$), Toshiba has developed a flip chip bonder that has an alignment accuracy of $\pm 5 \mu\text{m}$, in collaboration with Shibaura Mechatronics Co.

Techno Notes

*Machine Translation Technology Supporting Global Communication

Toshiba Technologies for the New Century

*10. Prospects for High-Temperature Superconductivity Technology