

TOSHIBA REVIEW

2011 VOL.66 NO.9

Special Reports

Semiconductor Nonvolatile Memories

Past, Present, and Future of Semiconductor Nonvolatile Memories

MOMODOMI Masaki

Trends in Semiconductor Nonvolatile Memories and Toshiba's Approach

OHSHIMA Shigeo

Large-capacity nonvolatile memories, as typified by NAND flash memories, have been expanding the market for external storage devices for mobile products, and are utilized in all areas of people's daily lives.

Toshiba's memory business has been achieving successful growth, and we have consistently realized innovations in various leading-edge technologies as the inventor of flash memory. Although the challenges over the physical scaling limit will become steep, we are aiming to overcome such issues by making use of our long-accumulated experience and record of innovations. We are also engaged in research and development for future technology breakthroughs, including innovative post-NAND nonvolatile memories, thereby maintaining our technical leadership in the world storage market.

Technologies Supporting Evolution of SSDs

TSUCHIYA Kenji

Notebook PCs equipped with solid-state drives (SSDs), featuring shock and vibration durability due to the lack of moving parts, appeared on the market around 2006. However, single-level-cell (SLC) NAND flash memories were used in SSDs at that time, and it was believed that multilevel-cell (MLC) flash memories, while they could double the storage capacity compared with SLCs, were not applicable because of a lack of reliability.

In 2008, Toshiba developed the world's first SSD equipped with MLC NAND flash memories and realizing a low write application factor (WAF), thereby increasing the reliability of MLC SSDs. This was achieved through the analysis of actual PC users' workload in detail, as well as the development of a new NAND cache system and an appropriate NAND management algorithm. MLC NAND flash memories have now become the mainstream for SSDs used in notebook PCs, and are contributing to new values such as a thin and small form factor (SFF), very low standby current, and instant-on capability.

Design Technology for 64 Gbit 2-Bit Multilevel-Cell NAND Flash Memory Using 24 nm Process

FUKUDA Koichi / SATO Junpei / EDAHIRO Toshiaki

The memory density (capacity per mm²) of NAND flash memories has been increasing by around 30% annually accompanying the scaling of memory cells. However, as the pace of scaling is showing a tendency to slow down because of the difficulties involved, there is a growing need for reduction of the peripheral area other than the memory cell array.

Toshiba has developed a 64 Gbit 2-bit multilevel-cell (MLC) NAND flash memory that achieves a memory density of 54

Mbytes/mm², together with both a high effective cell area of 79% and a small die size of 151 mm², using 24 nm complementary metal-oxide semiconductor (CMOS) technology.

BiCS Flash Memory for Realization of Ultrahigh-Density Nonvolatile Storage Devices

AOCHI Hideaki / KATSUMATA Ryota / FUKUZUMI Yoshiaki

Ultrahigh-density memory technologies to realize a three-dimensional (3D) memory cell array have been attracting considerable interest as a solution to deal with the continuous increase in bit density and reduction of bit cost expected in the future.

Applying its proprietary technologies, Toshiba has developed the world's first bit-cost scalable (BiCS) flash memory technology to achieve a 3D memory cell array with an extremely low fabrication cost. Using new array structures and technologies to improve the characteristics of the memory device, we fabricated a prototype 32 Gbit BiCS flash memory test array with a 16-layer memory cell using a 60 nm design rule, and verified its multilevel functionality.

Spin-Transfer Torque Writing MRAM with Perpendicular Magnetic Tunnel Junction Devices

YODA Hiroaki

Field writing magnetoresistive random access memories (MRAMs) have been actively developed as nonvolatile working memories because of their attributes including unlimited endurance and fast read/write speed, exceeding those of other nonvolatile memories. However, field writing MRAMs lack scalability due to their inefficient writing. In response to this situation, intensive efforts have been focused on spin-transfer torque writing MRAMs in recent years.

Toshiba has developed a magnetic tunnel junction device with perpendicular anisotropy (abbreviated as P-MTJ device) for storage devices to extend scalability. Since we demonstrated the world's first spin-transfer writing on P-MTJ devices in 2007, we have achieved small-current writing of several tens of microamperes and a large magnetoresistance (MR) of more than 200%. We are now engaged in research and development of practical applications for the realization of a large-capacity gigabit-class memory.

Erase and Program Conditions Affecting Retention Lifetime of NAND Flash Memories

MATSUKAWA Naohiro

The data retention lifetime of NAND flash memories is significantly affected by the erase and program cycling conditions including the interval and temperature, even when the number of times of cycling is the same. Therefore, data retention lifetimes corresponding to each application have to be estimated under various operating conditions. In order to estimate the data retention time more accurately, it is necessary to measure the decrease in the threshold voltage (*V_{th}*) of the memory cell responsible for data retention failure determined by two parameters; namely, the rate of change with time and time offset of *V_{th}*.

Toshiba has developed a model through experiments that explains the dependence of the erase and program cycling conditions on the two parameters for each generation of NAND flash memory, and provides our products with confirmed data retention lifetimes for each application.

Packaging Technologies Supporting High-Capacity Semiconductor Memories

OMORI Jun

The demand for high-density memories has been increasing as a result of the reduction in market prices of NAND flash memories and the shift from image data to moving-picture data in recent years. The emergence of mobile devices such as solid-state drives (SSDs), smartphones, and tablet PCs has also been a strong driver of this trend. In addition, high robustness against drop impact and temperature variation for packages offering high board-level reliability is required.

To meet these requirements, Toshiba has been developing memory packaging and assembly technologies including high-capacity packaging technologies and multi-die stacking technologies for thin packages. We are also promoting quality improvement activities to design robust packages that are guaranteed in accordance with board-level reliability using simulation technologies.

Feature Articles

Document Structure Analysis for Expressive e-Book Reading

FUME Kosei / SUZUKI Masaru / MORITA Masahiro

To provide new and enjoyable experiences for e-book readers, Toshiba has been developing expressive technologies related to e-book reading. In addition to our current high-quality text-to-speech (TTS) systems, we have focused on the realization of more natural talking e-books by developing new functions such as auto-pause insertion utilizing document logical structures, auto-talker selection, and talking style selection, according to each sentence type in the input document. As one of these functions, we have developed a technology for document structuring that makes it possible to generate TTS control metadata from the input document features.

This technology is implemented as prefilter for TTS systems, and the resultant data can be obtained in extensible markup language (XML) format as well as in speech synthesis markup language (SSML), which is a standard format used in the TTS domain. By incorporating this function into TTS systems as needed, we can provide an expressive as well as impressive e-book reading experience to readers.

Rotation Balancing Technology for CT Scanners

YAMANAKA Takeshi / TOYOSHIMA Takeshi / SHINDO Yasutaka

Recent computed tomography (CT) scanners have become more advanced in terms of increases in the number of rows of detectors and faster rotation speeds, in order to rapidly gather a wide range of high-definition data. However, as multiple rows of detectors and high-speed rotation are a factor in increased gantry vibration, the introduction of countermeasures against vibration such as rotation balancing has become necessary to secure the stability of CT scanners.

Toshiba has developed a rotation balancing algorithm that can reduce gantry vibration in consideration of not only rotation imbalance but also all of the vibration generated by vibration, using an influence wave method. We have also developed a rotation balancing system incorporating this algorithm, which allows highly precise rotation balancing of CT scanners to be easily performed.

Optimization Technologies Supporting Expansion of Notebook PC Lineup for Enterprise Use

MURAYAMA Tomomi / SUZUKI Yoshiaki / FUJIWARA Nobuto

Toshiba has been developing notebook PCs for enterprise use based on the concepts of high performance, thin profile, and light weight. We have developed the dynabook_{TM} R series as a new addition to our notebook PC lineup for enterprise use, incorporating the following optimization technologies: chassis technologies for high stiffness using magnesium alloy and high-stiffness resin, high-density mounting technologies for printed circuit boards (PCBs), and a cooling technology for improvement of the radiation structure.

High-Quality Audio and Visual Technologies of REGZA Tablet_{TM} AT300

IMAMURA Akira / OSADA Masataka / MORI Hirofumi

Toshiba has developed the REGZA Tablet AT300, a hardware keyboard-free slate tablet powered by AndroidTM that allows users to enjoy e-books, movies, and other contents in both indoor and outdoor settings. To fulfill various users' requirements, we have developed the following audio and visual enhancement technologies: "Resolution+" video enhancement technology and an adaptive display technology to deliver a clearer and sharper viewing experience, and an audio enhancer technology as well as a noise equalizer technology to improve the clarity and quality of voices and music and maximize the capabilities of compact stereo speakers.

Transport Planning and Management System for West Japan Railway Company

KANEFUJI Minoru / IKEDA Katsumi / SHINMYO Seiji

A new transport planning and management system commenced operation for all conventional railway lines of West Japan Railway Company in April 2010. This system has realized a series of functions including not only the planning of timetables, rolling stock operations, and crew schedules, but also the distribution of information and preparation of documents used in each field.

Toshiba developed a part of this transport planning and management system, called the transit field management system, for branch offices, district offices for crews, and stations. This system is equipped with two functions: a document preparation function that automatically prepares a wide variety of specific forms for each field and allows comments by staff to be manually entered, and a crew management system that prepares timetables for rolling stock and crews and manages the working time of crews based on actual working records.

Image Processing Equipment for Advanced Cruise-Assist Highway System

KURATA Ryoichi / UEDA Hirofumi

Intelligent transport system (ITS) spot services have been introduced in Japan to realize the next-generation ITS service, the so-called Smartway. ITS spot services provide advanced highway traffic services including wide-area road traffic and safe cruise-assist information by performing high-speed and large-capacity communication between roadside units called ITS spots and onboard units for ITS spots in vehicles.

Toshiba has developed image processing equipment for the Advanced Cruise-Assist Highway System (AHS) applying a vector image processing technology, which detects hazardous events such as traffic congestion and stationary vehicles and provides running vehicles with safe cruise-assist information. We have delivered this equipment to Metropolitan Expressway Co., Ltd. and confirmed its effectiveness in practical use.

Representative Sentence Generation Technology and Application to Highly Efficient FAQ Generation

KURATA Saori / OGAWA Akio / KANO Toshiyuki

Document classification and analysis technologies are required in order to extract useful knowledge from large amounts of information inside and outside an enterprise, and to utilize it. However, these processes involve the expenditure of considerable time and effort.

Toshiba Solutions Corporation has developed a representative sentence generation technology for call tracking analysis, which makes it possible to automatically and efficiently create representative sentences from a group of documents. We have confirmed the effectiveness of this technology by applying it to the generation of frequently asked questions (FAQs) in a contact center.

Frontiers of Research & Development

Multiframe Super-Resolution Technology to Restore High-Resolution Moving Images

Tacit Knowledge Sharing Method for Defining High-Quality Requirements in System Development