Report on IPSW 4

Seungbum Hong and Yoon Chul Rhim

Probe-based data storage is a promising technology that is being examined within a number of companies and universities worldwide. While some research programs (such as IBM's Probe Storage Project) are nearing commercial development, the overall technology area is still relatively immature, and many research opportunities remain. It is the goal of the IPSW workshops to strengthen the community of industry and university researchers in probe storage through meetings in which we present visions of the technology, recent progress, and ongoing research challenges. In this workshop, we focused specifically on technology, with contributions from specialists in the areas of read/write principles, MEMS positioning and system architecture.

In overall statistics, over 50 researchers (including, specifically, PhD students) actually working in the field of probe recording components and devices attended the workshop and exchanged their ideas.

The workshop started with the welcome speech of Prof. Young-Pil Park, who is the chair of CISD (Center for Information Storage Devices) and SISS (The Society of Information Storage and Systems). The remaining parts comprised of 6 sessions with panel discussion included for envisioning the future direction of probe storage technology.

In Session I, we had invited speakers from IBM and Tohoku University. Dr. Michel Despont from IBM Zuerich presented the recent progress of IBM's probe storage device mainly addressing the interconnect technology. The array chip and microscanner were assembled together into a thin sandwich. The cantilevers were positioned directly below the polymer-covered scan table, with two sides of the array chip overlapping the edges of the scanner, giving access to the bonding pads. They mounted MEMS assembly on a printed circuit board, and used wire bonding technology to make electrical connections between the MEMS assembly and the circuit board. The minute signals from the individual cantilevers were read-back, filtered, and converted from analog to digital signals by the analog front-end (AFE) that includes 8 read-channels. They also developed a wafer-level interconnect technology that transfers the cantilever onto the AFE chip and uses the small feature size of the chip's last metallization layer to connect the cantilevers to the signal acquisition circuitry. Using a small-scale prototype, they have demonstrated the storage and retrieval of user data using 4,096 levers at densities up to 517 Gb/in^2 at few kbps.

Prof. Cho reported a data storage system based on scanning non-linear dielectric microscopy and a thin film of ferroelectric single-crystal lithium tantalite. His lab succeeded to form an smallest artificial nano-domain single dot of 5.1 nm in diameter and artificial nano-domain dot-array with a memory density of 10.1 Tbit/inch^2 and a bit spacing of 8.0 nm, representing the highest memory density for rewritable data storage reported to date. He also showed sub-nanosecond (500 psec) domain switching speed. Subsequently, he showed retention time of 16.9 years at 80℃ for 50 nm domains. Finally, he showed an elegant woman picture recording with bit error ratio of less than 1×10^{-4} at an areal density of 258 Gbit/inch^2.

In Session II, Dr. Armin Knoll at IBM and Prof. Leon Abelmann at University of Twente were invited and they presented talks on media design of probe storage device and magnetic probe storage concept. Dr. Knoll has extensively covered the effort to find the design window in terms of cross-linking density of the media to ensure wear-free condition. In addition, he has shown the role of pressure and temperature combination of writer on the wear character of the media for the same bit size. Prof. Abelmann has introduced a concept of using MFM tip as a writer and reader and magnetic dots as information bits. He showed the issue of coercive field distribution from bit to bit by applying macroscopic magnetic field to the patterned magnetic media.

In Session III, Prof. Heh-Nan Lin from National Tsing Hua University and Dr. Hyo-Jin Nam at LG Electronics Institute of Technology gave talks on AFM nanomachining and piezoelectric sensing based probe storage device. Prof. Lin introduced an innovative way of using AFM as a lithography tool to form gold nanodot array and nanowires with dimension below 70 nm. Dr. Hyo-Jin Nam presented a component level demonstration of multiprobe array attached to IC circuit that controls each cantilever. The mechanism shares the media and writing method with IBM, however, the reading mechanism differs and has advantage of no offset in read signal. Bits with diameter below 60 nm were feasible.

In Session IV, Dr. Haris Pozidis from IBM and Dr. Seungbum Hong from Samsung presented talks on control scheme of probe storage devices and resistive probe storage concept. Dr. Pozidis has introduced IBM's idea of macro-positioning using large power thermal sensors and servo/tracking concept of using ABCD burst technology. He showed an excellent servo/tracking performance with one sigma less than 2 nm. Dr. Seungbum Hong has introduced resistive probe storage concept that has a field effect transistor on top of the tip apex. Continued efforts on design optimization had led to resolution improvement down to 50 nm bit pitch, which corresponds to 250 Gb/in^2 potential density.

In Session V, Prof. Leon Abelmann from University of Twente and Prof. James Bain from Carnegie Mellon University gave talks on electrostatic positioning system and new application of probe storage technology into reconfigurable memory intensive logic device. Prof. Abelmann introduced a creative idea that uses electrostatic force to move the entity, which resembles the action of insects. Prof. Bain has raised the question whether probe storage technology will survive under the harsh competing circumstances with HDD, ODD and FLASH. He rather claimed that probe technology may find a blue ocean in the field of logic devices where routing itself makes a huge waste of space. His idea was to combine the thermal probe with phase change media for reconfigurable routing ability in small area.

In Session VI, Prof. Dae-Eun Kim has chaired the panel discussion with panelists representing the probe storage community. The issues of target market and market situation with FLASH technology, probe/media wear and shock related reliability design were addressed and discussed. In addition, there were consensus that probe storage technology might have wider application than expected and later it might be more appropriate to name the workshop as international probe technology workshop by replacing storage by technology.

In summary, we had participants over 50 researchers from academia to industry in the world. IBM has shown the leadership in terms of completeness and matureness. It was a big pleasure to see diverse ideas such as piezoelectric, magnetic, ferroelectric probe storage schemes that have cons and pros. Moreover, the

various trials to implement probe storage technology into other applications such as nanolithography or logic devices were impressive. We believe that the key technology of probe storage is design/fabrication/manipulation of nanoscale probe and it will create either a big business impact by realization of probe storage device or a step stone for other applications of nanotechnology.