Magnetic nanowire memory for realizing ultra-fast data transfer rate: Magnetic and magneto-optical detection of current-driven domain motion

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To record the video data of 8K ultra-high definition TV, future storage devices require not only a large capacity but an ultra-high data transfer rate. In fact, an enormous transfer rate of more than 144 Gbps is required for recording the uncompressed full-featured 8K video, and of course, an extremely high data transfer rate over 1 Tbps may be required for the future 3D video recording. However, there is no way to treat such terrible “data flood” using conventional memories. For example, even solid-state drives (SSDs), which use semiconductor memory and are currently the fastest commercially available storage devices, have a fundamental data transfer rate of only several Gbps. As a result, SSDs are incapable of recording the uncompressed full-featured 8K video unless multiple devices are used simultaneously.

The racetrack memory[1)] that utilizes the high-speed current-driven domain walls motion[2)] in the magnetic nanowire (NW) has been proposed as a non-volatile random access memory with large capacity. Here, by limiting the direction of current-driven domain motion in one way for the racetrack memory, sequential memory architecture suitable for video recording can be constructed. We have proposed this new sequential “magnetic nanowire memory” consisting of parallel aligned magnetic NWs, as shown in Fig. 1. Each magnetic NW acts as a recording medium, and a pair of write and read head (writer and reader) is attached on. The data are stored along the magnetic NWs direction as the magnetic domains with upward or downward magnetization directions. These troops of domains are shifted quite fast by applying optimum current pulses along the NW direction for data writing and reading purposes. The ultra-high speed storage device will be achieved if the domains in thousands of parallel aligned NWs can be controlled synchronously by applied current pulses.

To demonstrate the operational principle of this NW memory, we adopted a magnetic recording head, in which a pair of write head and read head is equipped, as the writer and the reader in NW memory element. We have succeeded in recording, shifting and detecting the domain motion along the fabricated NW with perpendicular magnetic anisotropy by a magnetic head with current pulses application in our previous work[3)].

In this study, in order to search the artificial lattice NW materials with high domain wall velocity, the multiple magnetic domains motion along an entire NW area was observed by magneto-optical Kerr effect microscopy (MOKE), since a magnetic head can detect only the change in magnetization beneath the reader. As shown in Fig. 2, we could observe the current-driven magnetic domains toward the electron flow along a NW with 1.5 μm-width in real-time. Since an MOKE can detect the multiple domains motion in the entire NW area, it is suitable for investigating the control of synchronous current driven magnetic domains. For realizing parallel aligned magnetic nanowire memory, both magnetic and magneto-optical detection methods are essential to study micron to sub-micron behavior of current driven domain motion.

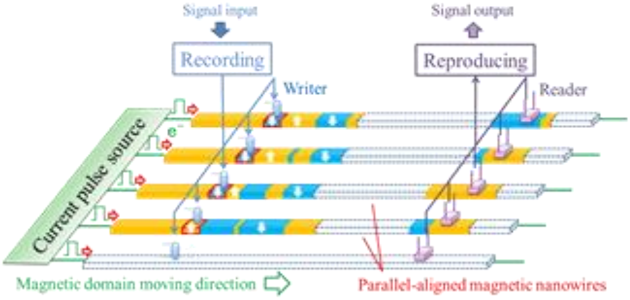

Fig. 1 Schematic illustration of magnetic NW memory consisting of parallel aligned NWs.

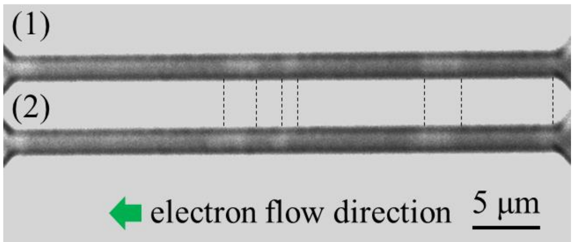

Fig. 2 (1) Initial MOKE image and (2) MOKE image after injection of current pulse. The width of NW is 1.5 μm. Queue of written domains moves along the electron flow direction.

References
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3) M. Okuda *et al.*: IEEE Trans. Magn., 52, 7, 3401204 (2016)