We have achieved success in our research into the perpendicular magnetic recording heads and recording media in order to realize a compact and large capacity storage system for use in portable devices such as PDAs and mobile phones.

In our research into the perpendicular magnetic disk, we have focused on an amorphous medium with a superior thermal decay characteristic. Using computer simulations, the amorphous medium was shown to be capable of ultra-high recording density of approximately 400 Gbit/inch² (Figure 1). We fabricated an experimental amorphous medium and analyzed the recording magnetization patterns using magnetic force microscopy (MFM). The spike noise generated at the soft magnetic layer was reduced by adding to the exchange coupling between the soft magnetic layer and the antiferromagnetic underlayer.

In addition, we have investigated the recording mechanisms employing a ring head both by theoretical analysis and by recording pattern observation using MFM. It was found that a double-layered medium is recorded not by the head gap field, but by the field from a head pole surface. From this finding it is possible to determine the effective magnetic field distribution for application to ultra-high recording density.

With regard to the high density perpendicular magnetic read-out head, we have focused on a new configuration of the front-yoke stacked type of TMR (tunneling magnetoresistive) head, as shown in Figure 2. Computer simulations confirmed that this type of head is adaptable for achieving a recording density close to 400 Gbit/inch², and that the optimization of the yoke shape caused less waveform distortion in reproduced signals. This will eliminate the need for the conventional waveform equalization differential circuit.

We have also improved the crystal structure of the Al₂O₃ insulation films used in the TMR heads. Stoichiometric Al₂O₃ films with the desirable characteristics of a low junction resistance and few pinholes structure can be deposited using a reactive ion beam sputtering method. A high TMR characteristic can be attained by using an antiferromagnetic material consisting of platinum manganese thin film deposited on a copper underlayer by hetero-epitaxy.

Figure 1: Recorded magnetization pattern at a recording density of 400 Gbit/inch²

Figure 2: Structure of the front-yoke stacked type of the TMR head
To achieve high-capacity and high-data-transfer-rate tape storage unit with the ability to store digital content compactly for the efficient use of such material, research proceeded on a MR (Magnetoresistive) head for rotary drum and on an ultra-thin magnetic layer MP (Metal Particulate) tape.

We improved the abrasion resistance of an MR head using ferrite for the head foundation, in addition to enhancing its sensitivity and narrowing the track width to 2.5\(\mu\)m. The thickness of the magnetic layer used on MP tape was reduced to 35 nm, or one-eighth the thickness of a conventional layer, corresponding to reproduction characteristics with the high-sensitivity MR head.

Advancements were also made on forming smaller magnetic particles in an attempt to attain low noise and broadband characteristics.

We combined the test manufactured high-sensitivity MR head with the ultra-thin magnetic layer MP tape, and evaluated its reproduction characteristics using a head tester. The experiment clarified that an areal recording density of 1Gbit/inch\(^2\) and a volume recording density 40 times higher than that of a D-3VTR at 100Mbps/ch are achievable. This is equivalent to a 2.5-hour high picture quality HDTV video recording on a small cassette with 6mm wide tape.

Video reproduction experiments were conducted on a system that combines a helical scan VCR system incorporating the prototype high-sensitivity MR head, and the newly developed ultra-thin magnetic layer MP tape (inserted figure). We transmitted the sensing current for the MR head operation via a rotary transformer with no physical contact parts. This realized stable video reproduction with a byte error rate of 10\(^{-5}\).

\section{Tape Storage}

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