MR and GMR Technology

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MR vs. GMR

The MR Effect was actually discovered way back in 1857 by British scientist Lord Kelvin. Magnetoresistive material is typically a nickel-iron alloy that shows higher electrical resistance when the current flow is parallel to the magnetic orientation. The resistance drops back to the initial value when the magnetic field is removed. Even the small magnetic domains on very dense disk drives will trigger the magnetoresitive effect sufficiently to permit the reading of stored bits. We can take advantage of the MR effect by making very thin sensor layers of MR film. The magnetic field orientation of the MR strip is parallel to the disk when no transverse magnetic field is applied and the electrical resistance is higher. A magnetic field rotates the sensor's magnetic orientation to reduce electrical resistance that can be detected.

The GMR effect, discovered by IBM in 1988 [2], is not just a scaled version of MR. Giant Magnetoresistive phenomenon is actually a quantum effect. The GMR sensors utilize the quantum nature of electrons that have two spin states, up and down. Conducting electrons with spin direction parallel to the sensor film's magnetic orientation move easily and thus produce low electrical resistance. But the movement of electrons of opposite spin direction is impeded by frequent collisions with atoms in the film thereby producing higher resistance. The socalled "spin valve" head structure incorporates a design where one magnetic film is pinned (magnetic orientation is fixed) and the second sensor film has a variable (free) orientation. These films are placed close together so that electrons of either spin direction can move back and forth.

Changes in the external magnetic field orientation provided by the rotating disk cause magnetic rotation of the sensor film's orientation. This changing magnetic orientation alters the electrical resistance of the sensor array. Low resistance occurs when the sensor and pinned films are magnetically orientated in the same direction because electrons with parallel spin direction move freely in both films. Higher resistance occurs when magnetic orientations of the pinned and sensor films are opposite because the electron movement of either spin direction is hampered by one or the other films.

GMR sensitivity is twice as high as MR and is now used for the highest performance disks. Magnetically-sensitive resistors, called spin valves, are built into very small read heads that must be in very close proximity to the rotating disk. Electrical current running through the GMR element fluctuates instantaneously with the polarity of the magnetic field. The resulting voltage changes become the signal that is first amplified and then decoded. The accompanying noise is digitally filtered out. Figure 1 shows the construction. The two shields help narrow the pulses allowing smaller bits to be read. The GMR element is extremely thin, now only 15 atom layers, and the dimensions will become even smaller in the future. Figure 1 also compares MR and GMR structures.

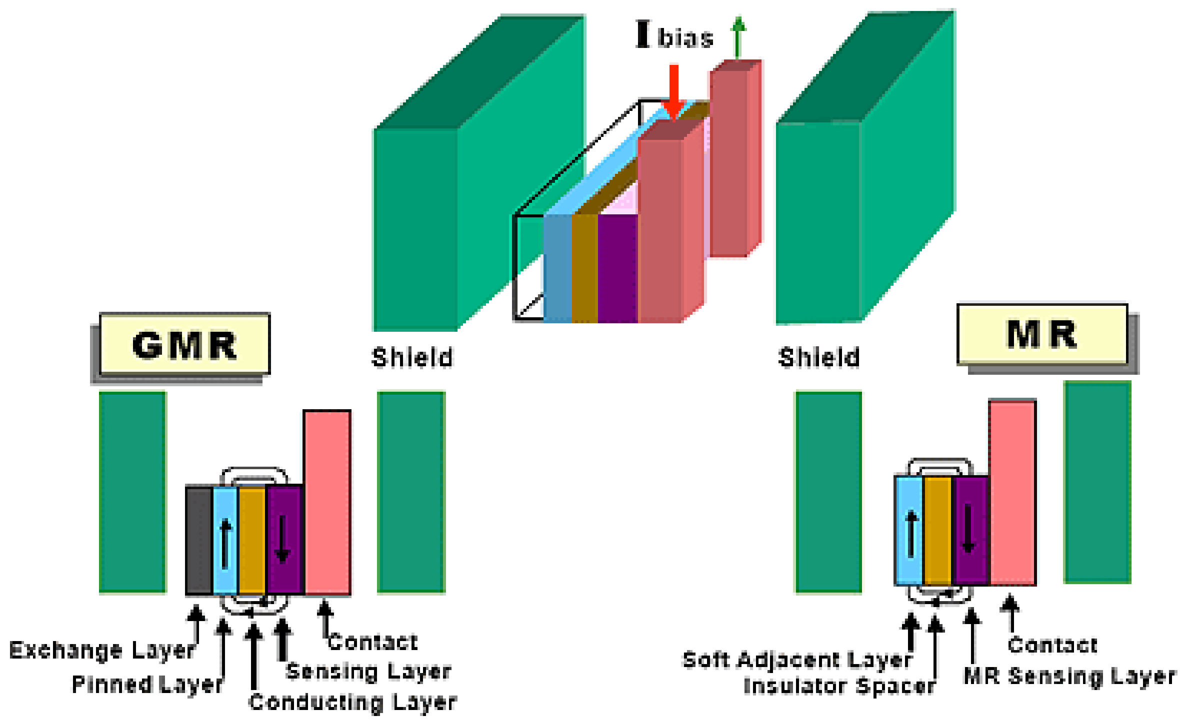

FIGURE 1

Writing

Modern magnetic heads combine elements of the read and write functions into a single, or a "merged head" using the IBM terminology. This offers better manufacturing economics and also greater density. Writing employs a magnetic coil that is activated each time a bit is written, or magnetized on the spinning disk. A simplified writing head is shown in Figure 2. The small, concentrated magnetic field magnetizes, or "turns on", a region on the disk by induction. The gap at the bottom concentrates the field over the disk. When current is applied to generate the magnetic field, the "hard" disk medium is permanently magnetized with a polarity that matches the writing field. Reversing the current reverses the polarity on the disk bit to rewrite or erase the information stored in digital format.

The write head may be less than 30 microns above the rapidly spinning disk and the transaction is virtually instantaneous. In the future, higher density may require a near-zero gap. Figure 3 shows the process of writing on magnetic disk medium.

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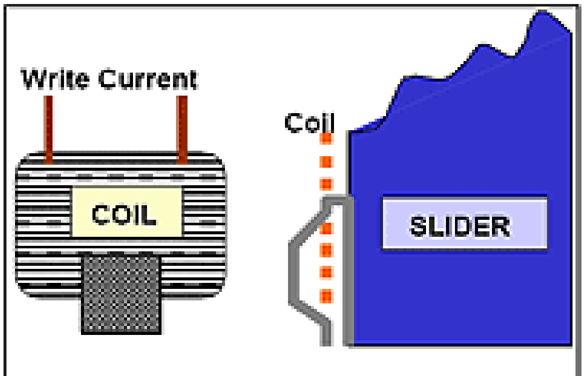


FIGURE 2 WRITE HEAD

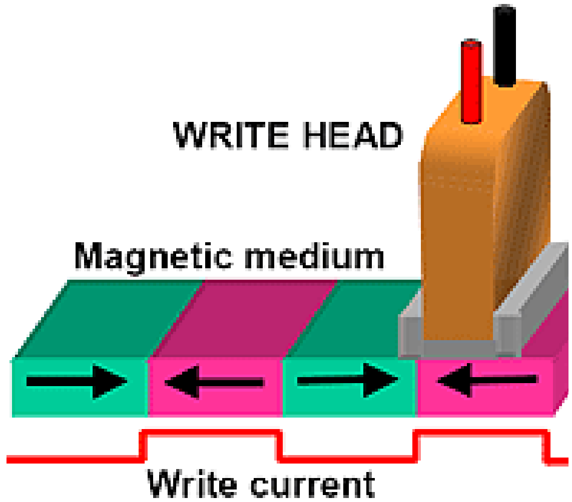


FIGURE 3

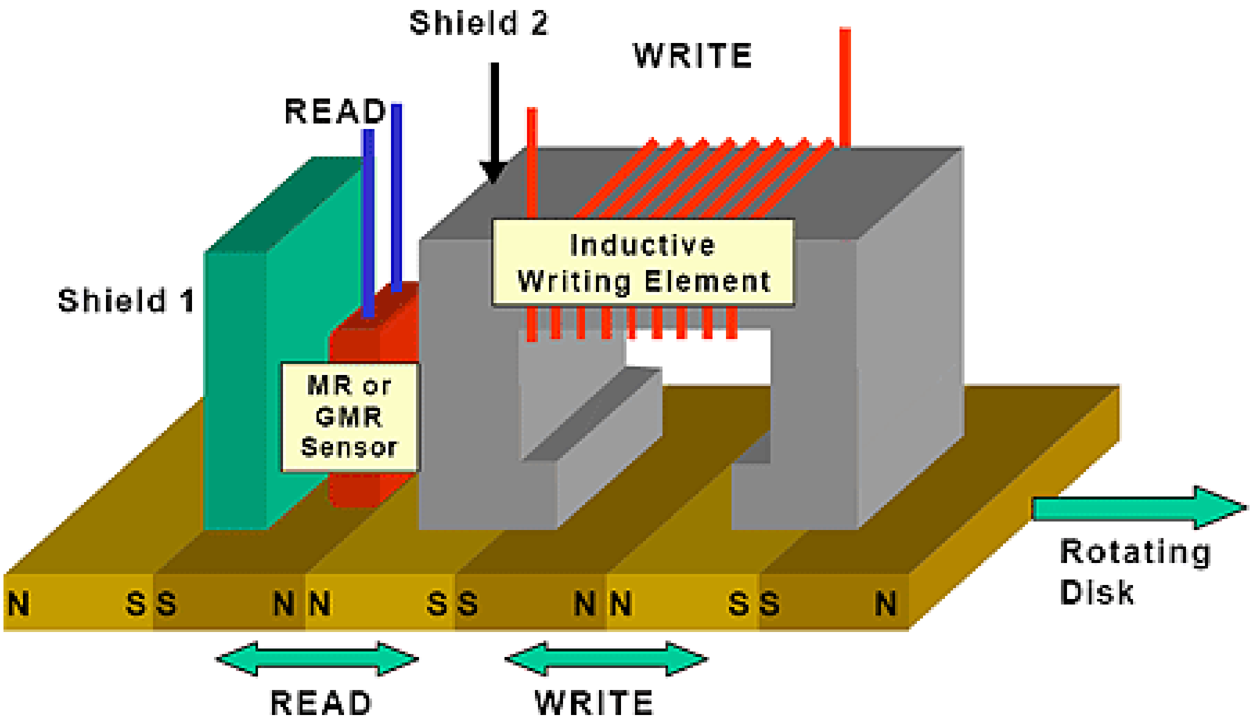
A timing clock is synchronized with disk rotation so that the location of the head with the magnetic "bit cells" is precisely known and controlled. Bits represent ones and zeros (reversed magnetic polarity). Although the disk is permanently magnetized, bits are easily reversed, or rewritten, as the head applies an opposite magnetic field produced by simply reversing the coil current. MR and GMR require more precise synchronization since the domains are smaller.

Reading

The task of the READ portion of the head is to read the disk data bits. Reading is where the state-of-the-art technology is being applied and where MR and the newest GMR principles are being applied. Both MR and GMR use a somewhat similar head structure. The very thin MR or GMR sensor strips are sandwiched between oppositely biased contact elements and this component is placed between two magnetic shields to reduce stray magnetic fields. MR and GMR head structures are shown in Figures 3 and 4. The Soft Adjacent Layer (SAL) is magnetized by the nearby field. The SAL produces a magnetic field that biases the magnetization in the MR element so that its magnetic field angle is shifted to 45o, the optimum angle for this type of sensor.

Merged Heads

Although reading and writing are independent functions, it is critical to place the write and read heads close together and near the recording medium. Writing heads are therefore fabricated directly onto the spin valve GMR reading heads. The top shield of the GMR sensor becomes the bottom magnetic pole of the writing head as shown in Figure 4 to form an integrated or merged head design. The GMR head and writing head share one magnetic layer. The efficient integrated READ-WRITE assembly is referred to as a merged head.



MERGED READ-WRITE HEAD
Figure 4

Manufacturing MR and GMR Head Elements

Head elements are produced using several semiconductor processes that include photolithography, vacuum deposition and ion beam etching. Multiple layers of metals and alloys are vacuum-deposited to achieve high sensitivity to magnetic perturbations. Once the complex wafer structure has been crafted, it must be carefully sawn with a dicing blade. Multi-blade saws are now being used for higher productivity where five or more cuts can be made concurrently. The first step is to thin and polish the wafer by lapping. The lapped wafer is next sliced into rows that are further processed. The very first step, however, is to bond entire wafer to a base platform material like lava stone or graphite. Graphite is becoming popular because it helps with ESD (electrostatic discharge) when the grounded blade comes in contact with this partially conductive material.