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A study of giant magnetoresistance

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Abstract
In this Paper Giant magnetoresistance (GMR) is a quantum mechanical magnetoresistance impact saw in slight film structures made out of substituting ferromagnetic and nonmagnetic layers. The impact shows itself as a noteworthy reduction (normally 10–80%) in electrical obstruction within the sight of an attractive field. The impact is abused financially by makers of hard circle drives.

Keywords: Giant magnetoresistances

Introduction

Mainstream researchers off guard; didn't broadly accept that such an impact was truly conceivable. These trials were performed at low temperatures and within the sight of exceptionally high attractive fields and utilized difficultly developed materials that can't be mass-delivered, yet the extent of this disclosure sent researchers around the globe set for perceive how they may have the option to saddle the intensity of the Giant Magneto resistive impact [1-3].

Like other magnetoresistive impacts, GMR is the change in electrical obstruction in light of an applied attractive field. Progress metals are widely concentrates in numerous fields [4-10]. Their magnetoresistive impacts are likewise been given critical interests. It was found that the utilization of an attractive field to a Fe/Cr multilayer brought about a critical decrease of the electrical opposition of the multilayer. 1. This impact was discovered to be a lot bigger than either standard or anisotropic magnetoresistance and was, consequently, called "goliath magnetoresistance" or GMR. A comparative, however reduced impact was at the same time found in Fe/Cr/Fe trilayers.2. As was demonstrated later, high magnetoresistance esteems can likewise be gotten in other attractive multilayers, for example, Co/Cu. The adjustment in the opposition of the multilayer emerges when the applied field adjusts the attractive snapshots of the progressive ferromagnetic layers, as is shown schematically in Fig.1. Without the attractive field the polarizations of the ferromagnetic layers are antiparallel. Applying the attractive field, which adjusts the attractive minutes and soaks the polarization of the multilayer, prompts a drop in the electrical opposition of the multilayer.

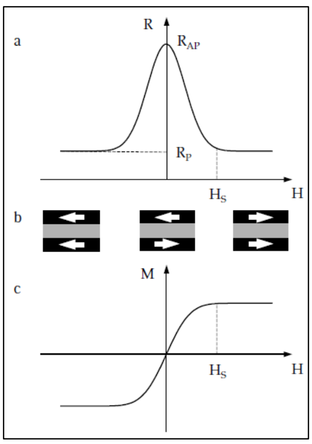

Fig 1: Schematic representation of the GMR effect

GMR can be subjectively perceived utilizing the Mott model, which was acquainted as ahead of schedule as 1936 with clarify the abrupt increment in resistivity of ferromagnetic metals as they are warmed over the Curie temperature. There are two central matters proposed by Mott:

To start with, the electrical conductivity in metals can be depicted regarding two to a great extent autonomous leading channels, comparing to the up-turn and down-turn electrons, which are recognized by the projection of their twists along the quantization hub. The likelihood of turn flip dispersing measures in metals is ordinarily little when contrasted with the likelihood of the dissipating measures in which the turn is moderated. This implies the up-turn and down-turn electrons don't blend over significant distances and, subsequently, the electrical conduction happens in equal for the two turn channels [1-3].

Second, in ferromagnetic metals the dispersing paces of the up-turn and down-turn electrons are very extraordinary, whatever the idea of the dissipating focuses is. The band structure in a ferromagnet is trade part, so the thickness of states isn't the equivalent for up-turn and down-turn electrons at the Fermi energy. Dissipating rates are relative to the thickness of states, so the dispersing rates and in this way resistivities are distinctive for electrons of various turn.

Utilizing Mott's contentions it is direct to clarify GMR. We expect that the dispersing is solid for electrons with turn antiparallel to the polarization heading, and is feeble for electrons with turn corresponding to the charge bearing. This should mirror the lopsidedness in the thickness of states at the Fermi level, as per Mott's subsequent contention. For the equal adjusted attractive layers, the up-turn electrons go through the structure nearly without dissipating, on the grounds that their turn is corresponding to the polarization of the layers. Unexpectedly, the down-turn electrons are dispersed unequivocally inside both ferromagnetic layers, in light of the fact that their turn is antiparallel to the charge of the layers. Since conduction happens in equal for the two turn channels, the complete resistivity of the multilayer is resolved for the most part by the profoundly conductive up-turn electrons and has all the earmarks of being low. For the antiparallel-adjusted multilayer, both the up-turn and down-turn electrons are dissipated firmly inside one of the ferromagnetic layers, in light of the fact that inside the one of the layers the turn is antiparallel to the charge course. Subsequently, for this situation the absolute resistivity of the multilayer is high.

Types of GMR

Multilayer GMR: In multilayer GMR two or more ferromagnetic layers are separated by a very thin (about 1 nm) non-ferromagnetic spacer (e.g. Fe/Cr/Fe). At certain thicknesses the RKKY coupling between adjacent ferromagnetic layers becomes antiferromagnetic, making it energetically preferable for the magnetizations of adjacent layers to align in anti-parallel. The electrical resistance of the device is normally higher in the anti-parallel case and the difference can reach more than 10% at room temperature. The interlayer spacing in these devices typically corresponds to the second antiferromagnetic peak in the AFM-FM oscillation in the RKKY coupling.

The GMR effect was first observed in the multilayer configuration, with much early research into GMR focusing on multilayer stacks of 10 or more layers.

Spin valve GMR: In spin valve GMR two ferromagnetic layers are separated by a thin non-ferromagnetic spacer (~3 nm), but without RKKY coupling. If the coercive fields of the two ferromagnetic electrodes are different it is possible to switch them independently. Therefore, parallel and anti-parallel alignment can be achieved, and normally the resistance is again higher in the anti-parallel case. This device is sometimes also called a spin valve.

Research to improve spin valves is intensely focused on increasing the MR ratio by practical methods such as increasing the resistance between individual layers interfacial resistance, or by inserting half metallic layers into the spin valve stack. These work by increasing the distances over which an electron will retain its spin and by enhancing the polarization effect on electrons by the ferromagnetic layers and the interface. The magnetic properties of nanostructures are dominated by surface and interface effects due to the high local ratio of atoms as compared to the bulk.

Pseudo-spin GMR: Pseudo-spin valve devices are very similar to the spin valve structures. The significant difference is the coercivities of the ferromagnetic layers. In a pseudo-spin valve structure a soft magnet will be used for one layer; where as a hard ferromagnet will be used for the other. This allows the applied field to flip the magnetization of one layers before the other, thus providing the same anti-ferromagnetic affect that is required for GMR devices. For pseudo-spin valve devices to work they generally require the thickness of the non-magnetic layer to be thick enough so that exchange coupling is kept to a minimum. It is imperative to prevent the interaction between the two ferromagnetic layers in order to exercise complete control over the device.

Granular GMR: Granular GMR is an effect that occurs in solid precipitates of a magnetic material in a non-magnetic matrix. To date, granular GMR has only been observed in matrices of copper containing cobalt granules. The reason for this is that copper and cobalt are immiscible, and so it is possible to create the solid precipitate by rapidly cooling a molten mixture of copper and cobalt. Granule sizes vary depending on the cooling rate and amount of subsequent annealing. Granular GMR materials have not been able to produce the high GMR ratios found in the multilayer counterparts.

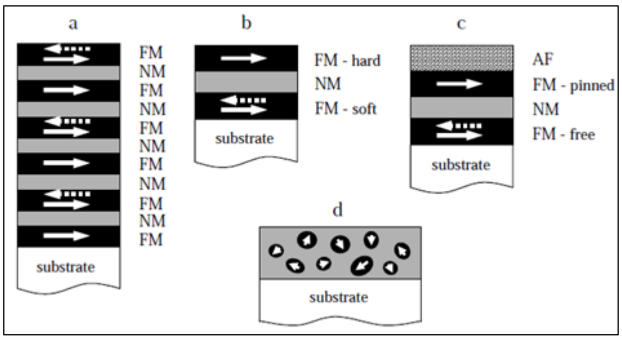

Fig 2: Various structures in which GMR can be observed: magnetic multilayer

Comparison of four different types of GMR: Various structures in which GMR can be observed: magnetic multilayer (a), pseudo spin valve (b), spin valve (c) and granular thin film (d). Note that the layer thickness is of the order of a few nanometers, whereas the lateral dimensions can vary from micrometers to centimetres. In the magnetic multilayer (a) the ferromagnetic layers (FM) are separated by nonmagnetic (NM) spacer layers. Due to antiferromagnetic interlayer exchange coupling they are aligned antiparallel at zero magnetic field as is indicated by the dashed and solid arrows. At the saturation field the magnetic moments are aligned parallel (the solid arrows). In the pseudo spin valve (b) the GMR structure combines hard and soft magnetic layers. Due to different coercivities, the switching of the ferromagnetic layers occurs at different magnetic fields providing a change in the relative orientation of the magnetizations. In the spin valve (c) the top ferromagnetic layer is pinned by the attached antiferromagnetic (AF) layer. The bottom ferromagnetic layer is free to rotate by the applied magnetic field. In the granular material (d) magnetic precipitates are embedded in the non-magnetic metallic material. In the absence of the field the magnetic moments of the granules are randomly oriented. The magnetic field aligns the moments in a certain direction.

Application of GMR

The largest technological application of GMR is in the data storage industry. IBM was first to put on the market hard disks based on GMR technology, and nowadays all disk drives make use of this technology.

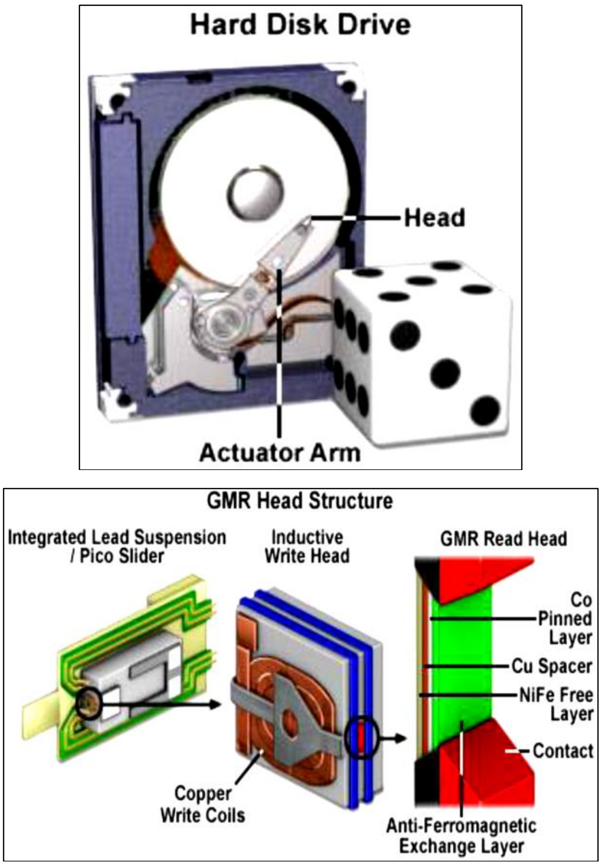

Fig 3: Structure of hard disk and GMR head

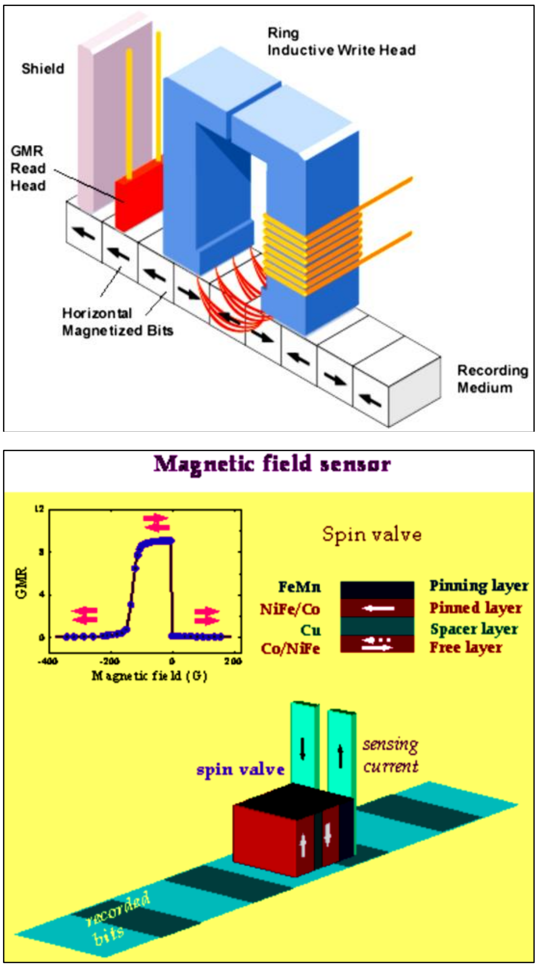

Fig 4: Illustration of reading and writing

The GMR read head sensor in a hard plate is assembled utilizing a turn valve. Turn valve obstruction exhibits a lofty change in the little field range near H=0. As the attractive pieces on the hard drive pass under the read head, the attractive arrangement of the detecting layer in the turn valve changes bringing about the opposition change.

As the read head disregards the circle, the free layer moves its attractive direction to coordinate that of the spot. So in some cases the bearing of the free layer's attractive field is lined up with the field of the stuck layer (which never shows signs of change), and now and then it is inverse. At the point when they are adjusted, a large portion of their electrons will have the equivalent up or down turn. As a portion of these electrons go through the layers as current, there will be insignificant dissipating. The low obstruction implies a current will be distinguished, and the PC registers a 1 cycle.

At the point when the free layer's attractive direction changes to inverse that of the stuck layer, there's a vastly different outcome. The electrons in the two layers have restricting twists. So as the current goes through the polarized layers, those electrons will disperse in either of them, bringing about an a lot more fragile current and a 0 bit.

Conclusion

This reorientation of the attractive minutes modifies both the electronic structure and the dispersing of the conduction electrons in these frameworks, which causes the adjustment in the obstruction. Different sorts of attractive layered structures have been discovered which show sizable estimations of GMR. Most elevated qualities are acquired in attractive multilayer structures, for example, Fe/Cr and Co/Cu, which stay alluring from the perspective of contemplating the central material science included. The trade one-sided turn valves show a blend of properties that make these frameworks more valuable for applications in low-field sensors, for example, perused sets out toward attractive chronicle.

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