DOWNLOAD PDF DESIGN AND ANALYSIS OF MAGNETORESISTIVE RECORDING HEADS

Chapter 1 : Global Giant Magnetoresistive Heads Market Insights, Forecast to - RnR Market Research

*Design and Analysis of Magnetoresistive Recording Heads [Edgar M. Williams] on calendrierdelascience.com *FREE* shipping on qualifying offers. Magneto-resistive recording heads are sensors that exploit magneto resistance effects to read digital magnetically recorded data.*

This description is made for the purpose of illustrating the general principles of this invention and is not meant to limit the inventive concepts claimed herein. Referring now to , there is shown a disk drive embodying this invention. As shown in FIG. The magnetic recording on each disk is in the form of annular patterns of concentric data tracks not shown on the magnetic disk At least one slider is positioned near the magnetic disk , each slider supporting one or more magnetic head assemblies As the magnetic disk rotates, slider moves radially in and out over the disk surface so that the magnetic head assembly may access different tracks of the magnetic disk where desired data are written. Each slider is attached to an actuator arm by way of a suspension The suspension provides a slight spring force which biases slider against the disk surface Each actuator arm is attached to an actuator means The actuator means as shown in FIG. The VCM comprises a coil, movable within a fixed magnetic field, the direction and speed of the coil movements being controlled by the motor current signals supplied by controller During operation of the disk storage system, the rotation of the magnetic disk generates an air bearing between the slider and the disk surface which exerts an upward force or lift on the slider. The air bearing thus counter-balances the slight spring force of suspension and supports slider off and slightly above the disk surface by a small, substantially constant spacing during normal operation. The various components of the disk storage system are controlled in operation by control signals generated by control unit , such as access control signals and internal clock signals. Typically, the control unit comprises logic control circuits, storage means and a microprocessor. The control unit generates control signals to control various system operations such as drive motor control signals on line and head position and seek control signals on line The control signals on line provide the desired current profiles to optimally move and position slider to the desired data track on disk Write and read signals are communicated to and from write and read heads by way of recording channel With reference to FIG. The above description of a typical magnetic disk storage system, and the accompanying illustration of FIG. It should be apparent that disk storage systems may contain a large number of disks and actuators, and each actuator may support a number of sliders. In order to increase data density in magnetic recording systems, researchers have sought to develop magnetoresistive sensors capable of extending sensor performance beyond that available to GMR sensors. A capping layer can be provided above the second free layer to protect the layers , , during manufacture. The layers are sandwiched between first and second shield layers , , which can be constructed of an electrically conductive, magnetic material such as NiFe or CoFe so that they can function as electrically conductive leads as well as shields. Insulation layers , can be provided at either side of the sensor layers , , , as fill layers between the shields , The insulation layers , can be constructed of a material such as alumina. The first and second free layers , have magnetizations , that are biased to be oriented 90 degrees relative to one another in the absence of an external magnetic field. A hard magnetic bias layer , constructed of a magnetic material such as CoPtCr or some similar material is formed at the back of the sensor layers , , , opposite the ABS. The hard magnetic layer is separated from the sensor layers , and from the first shield by a thin insulation layer As can be seen with reference to FIGS. In the absence a magnetic biasing field, the magnetizations , would align in antiparallel directions oriented parallel with the ABS as a result of this antiparallel coupling and a shape enhanced magnetic anisotropy. However, as can be seen in FIG. This magnetic bias field pulls the orientation of the magnetizations , away from being perfectly parallel with the ABS. The amount of bias field is preferably fixed at such a strength that the magnetizations , will be oriented at 90 degrees with respect to one another, which can be seen more clearly in FIG. With the magnetizations , biased in 90 degrees with respect to one another, the magnetic response of the sensor is within a linear region of the transfer curve similar to the pinned and free layers of a standard GMR sensor. When in the presence of a magnetic field, oriented perpendicular to the plane of the ABS, the magnetizations , will move to be either more parallel to one another away from the ABS in FIG. As the magnetizations , become more parallel to one another the electrical resistance through the layers , , decreases. Conversely, as the magnetizations , become closer to antiparallel to one another the resistance across these layers , , increases. As can be imagined then, the motion of the magnetization , in response to a magnetic field, resembles the blades of a scissor. As can be seen then, structure described above does not require a magnetic pinned layer such as would be necessary in a standard GMR structure. Therefore, if a scissor structure such as the one described above could be constructed in a manner that would render a workable sensor, such a sensor would have, an advantageously small gap thickness G, which corresponds to a reduced magnetic hit length. Therefore such a structure has the potential to increase data density by decreasing bit length. Unfortunately, however, the structure described above suffers from excessive spin torque noise. Spin torque noise results when the spin polarization of electrons flowing through one layer affect the magnetization of a subsequent layer through which they flow. For example, as electrons flow from lead , to lead , they flow first through the free layer , then through the spacer and then through the second free layer As the electrons travel through the upper free layer the spin of the electrons tends to become polarized by with the magnetization As these electrons flow through the bottom free layer , this polarization of electrons tends affects the magnetization of the bottom free layer This affect on the magnetization is so great that the magnetization is completely destabilized. Sufficient signal noise is introduced that the sensor is not practical for use in a data recording system. Furthermore, this stabilization affect goes both ways. As described above, the upper free layer destabilizes the bottom free layer However, the bottom free layer has a similar affect, destabilizing the upper free layer One way to reduce this spin torque noise is to construct the sensor as a tunnel valve having an electrically resistive barrier layer rather than an electrically conductive spacer layer. A tunnel valve operates based on the spin dependent tunneling of electrons through a thin, electrically resistive barrier layer. As such a tunnel valve has a higher resistance than a GMR sensor and, therefore, has reduced current flow through the sensor. This results in reduced spin torque noise. However, interfacial coupling between through the very thin barrier layer causes the magnetizations of the free layers to be oriented, parallel to one another, making it virtually impossible to maintain the 90 orientation of the scissor structure described above. With reference to FIGS. For purposes of illustration, FIG. The sensor includes first and second magnetic free layers , , with a thin, non-magnetic barrier layer sandwiched between the free layers , It should be pointed out that, while the present invention, is being described as a tunnel valve structure, it could also be embodied in a GMR structure in which case the layer could be an electrically conductive layer such as Cu. With continued reference to FIGS. The third magnetic layer can be constructed of the same material as the first and second free layers , , or could be constructed of another magnetic material. The antiparallel coupling layer can be constructed of a material such as Ru, and is constructed to such a thickness as to antiparallel couple the third magnetic layer and the second free layer A capping layer can be provided above the layers to protect the layer during manufacture. In addition, a seed layer such as Ta, Ru, Cu, NiFeCr or a combination of these materials may be provided beneath the first free layer to promote a desired crystalline grain growth in the above layers The layers are sandwiched between first and second magnetic shields , A hard magnetic bias layer is provided at the back of the sensor layers opposite the air bearing surface ABS. The hard magnetic bias layer is separated from the sensor layers and from the shield by a thin insulation layer to prevent sense current from being shunted through the hard bias layer In other words, simply for purposes of illustration, the layer is not magnetized and provides no magnetic field. In the absence of a magnetic field, the first and second magnetic free layers , are coupled by interfacial coupling through the very thin barrier layer This interfacial coupling, along with shape induced magnetic anisotropy causes the first and second free layers , to have magnetizations , that are aligned in the same direction parallel with one another in a direction parallel with the ABS in the absence of a magnetic field either external or from the bias layer The third magnetic layer has a magnetization that is oriented in a direction opposite anti-parallel to the magnetizations , of the first and second free layers , This is due to the antiparallel coupling of the layer with the second magnetic layer across the antiparallel coupling layer The magnetization of the third magnetic layer is not pinned, but is free to move in response to a magnetic field. Therefore, the third magnetic layer could be considered to be a third free layer. However, the third magnetic layer does not contribute to the magnetoresistive effect, because it is not separated from the adjacent free layer by a barrier layer such as the barrier layer or as spacer in the case of a GMR sensor. The third magnetic layer is actually part of an AP coupled synthetic second free layer structure The third magnetic layer has a thickness that is greater than that of each of the first and second magnetic free layers , In fact the layer preferably has a thickness that is about equal to the combined thicknesses of the first and second free layers. More accurately, the layer has a magnetic thickness that is about equal to sum of the magnetic thicknesses of the first and second magnetic layers. The magnetic thickness can be defined as the physical thickness of a layer multiplied by the magnetic moment of the layer. Therefore, if the layers , , are constructed of the same material, then the physical thickness of the layer would be about equal to the sum of the physical thicknesses of the layers , If the layer is constructed of as different material than the layers , , then the layer will have a physical thickness such that the magnetic thickness of the layer is about equal to the sum of the magnetic thicknesses of the layers , With reference now to FIG. This bias field pulls the magnetization of the third magnetic layer away from being parallel with the ABS. Because the layer is antiparallel coupled with the layer , the magnetization of the second free layer moves in an opposite direction as indicated by the arrow in FIG. Because the layer is magnetically thicker than layer , there is a net magnetic difference between the two layers. This allows the magnetization of the thicker layer to follow the bias field while the magnetization of the second magnetic layer moves in an antiparallel fashion relative to the magnetization The resulting orientation of the magnetizations , , can be seen more clearly with reference to FIG. As can be seen, the magnetizations , of the first and second free layers , are oriented at 90 degrees relative to one another and also are oriented at 45 degrees relative to the air bearing surface ABS. Also, the magnetization of the third magnetic layer is oriented at degrees relative to the magnetization of the second magnetic layer In other words, the magnetizations and are antiparallel with one another, even after being biased by the bias field The magnetization of the third magnetic layer is also oriented at 90 degrees relative to the magnetization of the first magnetic layer As mentioned above, the first and second free layers , are exchange coupled, such that interfacial coupling between the layers , causes the magnetizations , to tend to align in the same direction. On the other hand, the layers and are antiparallel coupled, and layer is significantly thicker than layer Therefore, between layers and , there is a net magnetic moment that allows the magnetization to follow the bias field The antiparallel coupling between the layers and causes the magnetization to remain antiparallel with the magnetization even in the presence of the magnetic bias field However the magnetization of the first magnetic layer is not antiparallel coupled with the third magnetic layer , and therefore, the magnetization is free to follow the bias field, allowing, the layers and to be oriented at 90 degrees relative to one another in the absence of a magnetic field.

Chapter 2 : Design and analysis of magnetoresistive recording heads - CORE

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The magnetoresistive element includes an antiferromagnetic layer a pinned layer in exchange coupling with the antiferromagnetic layer, a free layer whose magnetization rotates or switches according to a media magnetic field, and an intermediate layer between the free layer and the pinned layer. The intermediate layer includes magnetic grains surrounded by an insulator. The magnetic grains connect the free layer and the pinned layer by means of a nano contact. The free layer is oversized with respect to the pinned layer and the intermediate layer which are distanced from a media side end of the shield layers. Field of the Invention The present invention relates to a magnetoresistive head with an oversized free layer for thermal and magnetic stability. Description of the Related Art In a conventional head, a spacer between a free layer and a pinned layer is non-magnetic comprising either a conductive layer in the case of GMR, or an insulator in the case of tunneling TMR. Therefore the magnetic flux of the media media flux will change the magnetization direction of the free layer only. The magnetization of the pinned layer is fixed and not being affected by the media flux. As disclosed in G. The magnetic domain wall is created when the magnetization in these two ferromagnetic layers are anti-parallel. The size of the magnetic domain wall is in the nanometer scale, the scattering of electron is strong. The BMR value depends on the magnetic domain wall configuration and the scattering of electron when the electron passes through the magnetic domain wall in the nano-contact region. For the application of BMR to a read head it is important to guarantee the stability of the nano-contact against an external field. Its magnetic configuration should be determined only by the change in the free layer magnetization direction. Furthermore, this design will also solve thermal stability issues in both free and pinned layers. The magnetoresistive element 12 comprises a pinned layer 18 in exchange coupling with an antiferromagnetic layer 20, a free layer 22 whose magnetization rotates or switches according to a media magnetic field, and an intermediate layer 24 between the free layer 22 and the pinned layer The intermediate layer 24 includes magnetic grains 24A surrounded by an insulator 24B. The magnetic grains 24A connect the free layer 22 and the pinned layer 18 by means of a nano contact. The free layer 22 is oversized with respect to both the pinned layer 18 and the intermediate layer 24 which are distanced from a media side ends 14A, 16A of the shield layers 14, As the nano-contact part is distanced from a floating surface media side and surface of the magnetoresistive head, that is hard to be affected by media flux, then, a stability of the magnetic domain within the nano-contact area will be improved. It can be either up or down direction. The height h of the pinned layer 18 and the intermediate layer 22 from the media side ends 14A, 16A of the shield layers 14, 16 is between 10 nm and 40 nm or preferably 20 nm and 40 nm. The pinned layer is single, or formed from two antiferromagnetically coupled layers separated by a spacer made from Ru, Rh, Ir or their combinations. The height h shown in FIG. The reproductive sensitivity tends to decrease as the free layer 22 is far from the media magnetic field, i. On the other hand, when the height h is decreasing the nano-contact area will be more sensitive to the media field leading to an instability of the domain wall. The magnetoresistive element 12 is more specifically described referring to FIG. In the magnetoresistive element 12, the magnetic grains 24A and the insulator 24B constitute the intermediate layer The magnetic grains 24A are decoupled from each other by increasing the grain boundary region formed by the insulator 24B, which is formed from an oxide or a nitride preferably. The pinned layer 18 and the free layer 22 are made from a magnetic single layer, a synthetic structure composed from two antiferromagnetically coupled layers separated by a non magnetic spacer like Ru, Rh, Cu etc. The material of the magnetic grains 24A composing the nano-contact is made from the same or a different material than the pinned and free layers 18, The thickness of the intermediate layer 24, between the pinned layer 18 and the free layer 22, is below 10 nm. It is preferably around 1 nm. The MR ratio in BMR is much higher as the size of nano-contact both in terms of the height and width decreases. For BMR, if many nano-dots or grains are formed between the free and pinned layers 22, 18, there should be no interaction. This is because the magnetic domain wall created in the nano-contact within grains is responsible for a high BMR. If there is an interaction between grains this might affect the magnetic domain wall and consequently the BMR. Assisted oxidation can be performed in a vacuum chamber using a low oxygen pressure and an ion beam, which acts on the surface of the film to accelerate the oxidation of the metallic non-magnetic film. As shown in FIG. The second embodiment has two advantages compared to the first embodiment. In the magnetoresistive head 10 shown in FIG. The free layer 22 cannot be completely aligned in the same direction as the pinned layer magnetization. In the magnetoresistive head 30 shown in FIG. However, in this second case, it is preferable to use in-stack bias or others schemes for stability magnetization. The second advantage for the magnetoresistive head 30 in FIG. Then, as the size of the free layer in its magnetization direction become smaller, high demagnetization field in the opposite direction to the magnetization direction is generated. The thermal stability will be decreased by the demagnetization field. A perpendicular magnetoresistive head 40 according to a third embodiment is described referring to FIG. In the magnetoresistive head 40, the pinned layer is replaced by a hard layer hard magnet layer 42 having perpendicular magnetic anisotropy. In this case, as the hard layer is a ferromagnetic layer having high coercive force Hc, the magnetization direction of the pinned layer hard magnet layer 42 is not affected by other magnetic flux and changed. Then, no antiferromagnetic layer is needed. In this scheme, the demagnetizing field of the pinned layer can be small and thermal stability can be obtained. The magnetization directions of the free layer 32 are denoted by arrows 33A, 33B like as in the second embodiment and the magnetization direction of the pinned layer 42 is denoted by an arrow 43, which is perpendicular to arrows 33A, 33B. A magnetoresistive head 50 according to a fourth embodiment is described referring to FIG. In the magnetoresistive head 50, the media side part of the insulator 26 is replaced by an enlarged portion 17 of the shield layer 16 for narrowing the shield-to-shield spacing. By adjusting the shield-to-shield spacing, a narrow bit can be sensed, and the two shields layers 14, 16 can avoid the media flux coming from adjacent bits. This would be a big advantage for narrow bit sizes. The total thickness of the BMR multilayer can be larger than the shield-to-shield spacing. This spacing can be achieved by adjusting the deposing conditions of the insulator Further, the magnetization direction may be substantially fixed in the pinned layer Therefore, the antiferromagnetic layer may be replaced by a hard magnet layer having high coercive force Hc see the third embodiment or the pinned layer may be replaced by a hard magnet layer without the antiferromagnetic layer. A magnetoresistive head comprising a magnetoresistive element, and two shield layers sandwiching the magnetoresistive element, the magnetoresistive element comprising a pinned layer whose magnetization direction is substantially fixed , a free layer whose magnetization direction rotates or switches according to a media magnetic field, and an intermediate layer between the free layer and the pinned layer, the intermediate layer including magnetic grains surrounded by an insulator, the magnetic grains connecting the free layer and the pinned layer by means of a nano contact, and the free layer being oversized with respect to the pinned layer and the intermediate layer which are distanced from a media side end of the shield layers. The magnetoresistive head according to claim 1 , wherein the height of the pinned layer and the intermediate layer from the media side end of the shield layers is between 10 nm and 40 nm. The magnetoresistive head according to claim 1 , wherein the height of the pinned layer and the intermediate layer from the media side end of the shield layers is between 20 nm and 40 nm. The magnetoresistive head according to claim 1 , wherein at least one of the pinned layer and the free layer is a single ferromagnetic layer, and the single ferromagnetic layer includes at least one of Fe, Co, and Ni. The magnetoresistive head according to claim 1 , wherein at least one of the pinned layer and the free layer is formed from two ferromagnetic layers separated and coupled by a spacer made from one selected from the group consisting of Ru, Rh, Ir and a combination thereof, and the ferromagnetic layers include at least one of Fe, Co, and Ni. The magnetoresistive head according to claim 1 , wherein the pinned layer is made from a hard magnet layer. The magnetoresistive head according to claim 1 , wherein an insulator fills a space between an oversized part of the free layer and one of the shield layers when there is no external field. The magnetoresistive head according to claim 9 , wherein the media side part of the insulator is replaced by an enlarged portion of the shield layer.

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