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Design and Process Technology of Anisotropic Magneto Resistive Sensor Device on Silicon Substrate

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ABSTRACT

In this paper studied magneto resistive sensor technology using thin film technology. To grow a thin layer of material permalloy (Ni81Fe19) above the silicon (Si) substrate by way of evaporation or RF Sputtering. Using photolithography and etching process, permalloy layer and then patterned to form multiple interconnected microstructure into a bridge. By applying a magnetic field in the arms of the bridge structure facing each other, will create asymmetry in the bridge. In this way, it is expected microstructure formed can serve as a magneto resistive sensor that can detect the magnetic field of less than 5 mT, which are needed in the navigation system.

Key Word: Magneto resistive, Sensor, Thin Film, Permalloy, Navigation

INTRODUCTION

Sensors and transducers are subjected to an increasing interest because of their importance in many technological applications. Magneto resistance effect (MR) which arises in Permalloy based thin films is an attractive solution for the fabrication of magnetic sensors. [1-3].

Since the development of MicroTechnology of Integrated Circuit (MTIC) were researched and developed new magneto resistive microstructures, which are used as a magnetic field sensors in servomotors, rotative mechanisms and other automatic equipments. Solid state magnetic field sensors have an inherent advantage in size and power compared to search coil, flux gate and more complicated low-field sensing techniques such as Superconducting Quantum Interference Detectors (SQUID). As a physical phenomenon, this sensors are based on the anizotropic magneto resistive effect of thin ferromagnetic layers, deposit on the silicon mono crystalline substrate.

Anisotropic magneto resistance (AMR) occurs in ferrous materials. It is a change in resistance when a magnetic field is applied in a thin strip of ferrous material. The magneto resistance is a function of cos2 θ where θ is the angle between magnetization M and current flow in the thin strip. It has been observed that the resistivity strongly depends on ferromagnetic moments alignment of the adjacent layers, the surface roughness and the nature at atomic scale of the interfaces is considered very important for the magnetic behavior [4-7].

The aim of this work is the design and processing by micro technology of magneto resistive microsensor for the detection of small magnetic fields. The high values of resistance and the strong control of the flow current direction to the magnetic anisotropy axes were obtained by using conventional photoetching resulting a thin layer of a permalloy plane resistance [8].

Anisotropic magnetoresistance (AMR) occurs in iron materials, this is the change in resistance when a magnetic field is applied in strips (track) of thin iron materials. Magneto resistance is a function of cos2φ where φ is the angle between the magnetization M and current in a thin strip. It has been observed that the resistivity is very dependent on the moments of adjacent layers of ferromagnetic alignment, surface roughness and the atomic scale interface is very important for magnetic behavior. The purpose of this research is the design and processing by microtechnology of magnetoresistive microsensor to detect the small magnetic field. The high value of resistance and strong control the direction of current flow to the axis of the magnetic anisotropy is obtained by using a conventional photoetching to produce a thin layer of resistance lines permalloy. The basic configuration of the AMR sensor on a silicon substrate can be seen in the development of figure 1 below.

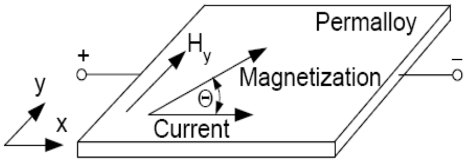

Figure 1. The basic configuration of the AMR sensor on a silicon (Si) substrate

METHODS

Using the anisotropic magneto resistive effect was designed a magneto resistive microsensor with thin layers of permalloy for detection of small magnetic fields: 0.1 - 5 mT. We have used deposition-induced uniaxial magneto cristaline anisotropy so as to obtain a zero sensing field a π/4 angle between the magnetization in the layer and current path. The conductor is wide enough to avoid the shape demagnetization of the element, which would counteract the canted induced anisotropy [2-4].

The magneto resistive response of the sensing layer is: $\Delta R/\Delta R\max=\sin\varphi\cos\varphi+1/2$,

where φ is the angle between magnetization and current in the sensing layer and $\sin \varphi=Hy/HK$.Here Hy stands for the sensing field, which has been vertically oriented and HK anisotropy field. The sensor performance is determined by the geometry of the strip, the anisotropy, resistivity and magneto resistance of the material, the exchange and demagnetizing energies.

We have obtained the high values of resistance and the strong control of the flow current direction to the magnetic anisotropy axes by using conventional photo etching, resulting a thin layer of a permalloy resistance. Four of these microstructures are interconnected to form a bridge. We apply bias magnetic fields with opposed bias directions to adjacent arms of the bridge, in order to create the necessary asymmetry resulting the unbalance of the bridge, when an external magnetic field is applied.

These MR sensors are made by etching a permalloy layer in which an easy axis was induced during deposition.

In order to minimize the demagnetizing field of these miniature sensors we have used the canting of current path with respect to the easy axis.

AMR sensor design type Even type sensors. This type of design in the form of a bridge which consists of 4 parts AMR as shown in Figure 2.

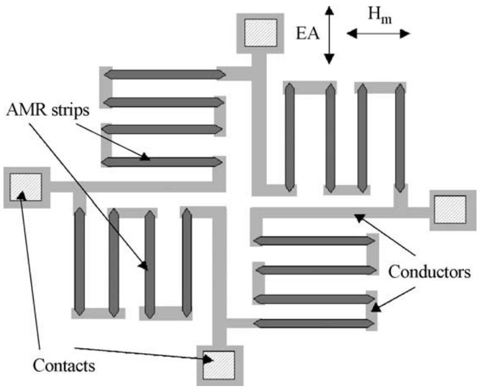

Figure 2. Design of sensor even types (Source: ref 9,10)

Each element consists of a strip AMR whose position is aligned and connected in series. One pair that intersect (diagonally) direction of the easy axis (Easy Axis / EA) and another one pair perpendicular to the easy axis. Given the measured magnetic field perpendicular EA (9). So that each pair of strip have values different angles. One pair of strip has the greater angle, while the other pairs have smaller angle to the easy axis. As a result, the resistance value of the pairs of diagonally will be even greater, whereas the other pair will be smaller resistance value that indicates the output signal level.(10)

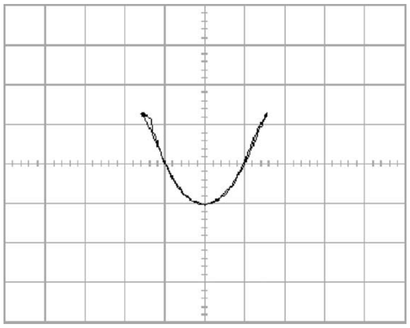

Figure 3. Even type of sensor response to the alternating magnetic field with amplitude 5 Oe (9)

Results of measurements of this type shows that when calibrated magnetic field up to 4 Oe no hysteresis that appears. The new hysteresis appears when given a higher magnetic field, but does not provide residual magnetization effect (memory effect) which means (9).

Odd type sensors Image sensor design for odd types can be seen in Figure 4.

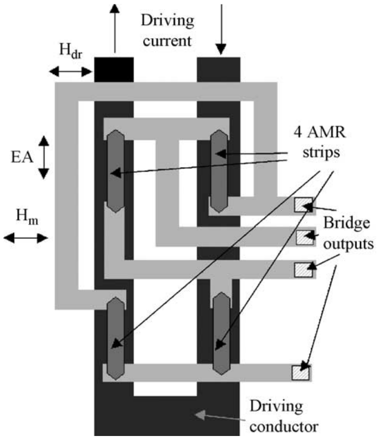

Figure 4. Design of odd-type sensor (9)

Sensor is designed in the form of a bridge with a four-part AMR strip. Each section consists of a strip of AMR. Each AMR is the direction of the easy axis. AMR strip mounted above the conductor to produce a magnetic field perpendicular to the strip AMR (9,10). Calibration results show that these designs produce a linear response to a magnetic field up to 25 Oe. This sensor has a low intrinsic noise, high-frequency spectrum, and field hysteresis occurs in the value of the field is much higher than on the type of event (9).

This design allows it to be made single layer or multi-layer or multi-layer. Advantages of single layer is able to reduce the flow of control and more sensitive, but the drawback is the appearance of hysteresis and requires additional features se / reset. For multi layer has a small hysteresis.

When there is no external magnetic field that works, and when the current is given, then all the magnetization vector of all the strip direction of the easy axis but each pair of strips cancel each other because they are in opposite directions. When the external field is given, then a pair of strips will deviate as far as + φ, while the other pair would stray so far – φ.

Measurable magnetic field works perpendicular to the axis of the terrain is easy and caused by currents in conductors. Under the influence of a magnetic field measured, the direction of the magnetization vector will move towards certain. Relying on the direction of the field measured on the arm bridge AMR strip, φ absolute price will be reduced and the two other arms will grow. As a result, the resistance value pair strip diagonally will increase, while the other pair is reduced which shows the output signal level.

Optimal thickness for this sensor is 24 nm for single layer and 12 nm for multi layer. This is because the layer is thicker, the sensitivity is reduced and vice versa with a thinner thickness caused the fall of the value of magneto resistance (10).

AMR sensor design can be seen in Figure 5 below.

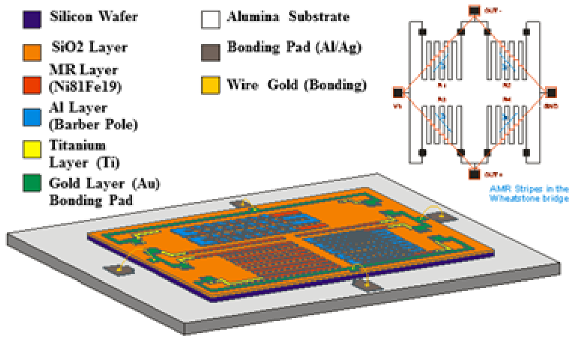

Figure 5. Design of AMR Sensor Device.

RESULT AND EXPLANATION

Our experimental results have lead to the manufacturing process of these magneto resistive microsensors, which have several processed steps can be seen in figure 6.

1. Material: silicon single wafer polishing, Type: P or N, Orientation: 111 or 100, Resistivity: 1-10 Ohm-cm, Diameter: 3 inches.
2. Oxidation Process: Q: 1100 0C, Flow O2: 2 liters / min (Dry / Wet / Dry), Time: minutes, Thickness: 5 micron (SiO2)
3. Photolithography process: Coating Resist Positive (AZ), Spinner with rotation: 3000 RPM, time: 30 seconds, prebake: 85 0C for 15 minutes and post bake: 120 0C for 30 minutes.
4. The process of irradiation (Exposure): UV, time: 2 minutes, negative mask (Process Lift Off), Developer: TMAH
5. Process Coating Materials Magnets: Process Technology: RF-Sputtering, Materials (Target): Ni81Fe19, thickness: 20 nm or 200 Angstorm or 0.02 microns.
6. Resist Stripping Process: dissolve in Aceton.
7. The process of photolithography: Coating Resist Positive (AZ), Spinner RPM: 4000, t: 30 seconds, Prebake: 85 0C for 15 minutes.
8. The process of irradiation (Expose): UV rays, for: 2 minutes, negative mask (Process Lift Off), Developer: TMAH.
9. The process of Coating Materials barberpole: Process Technology: DC-Sputtering with Materials (Target): Aluminum or Gold (Al or Au).

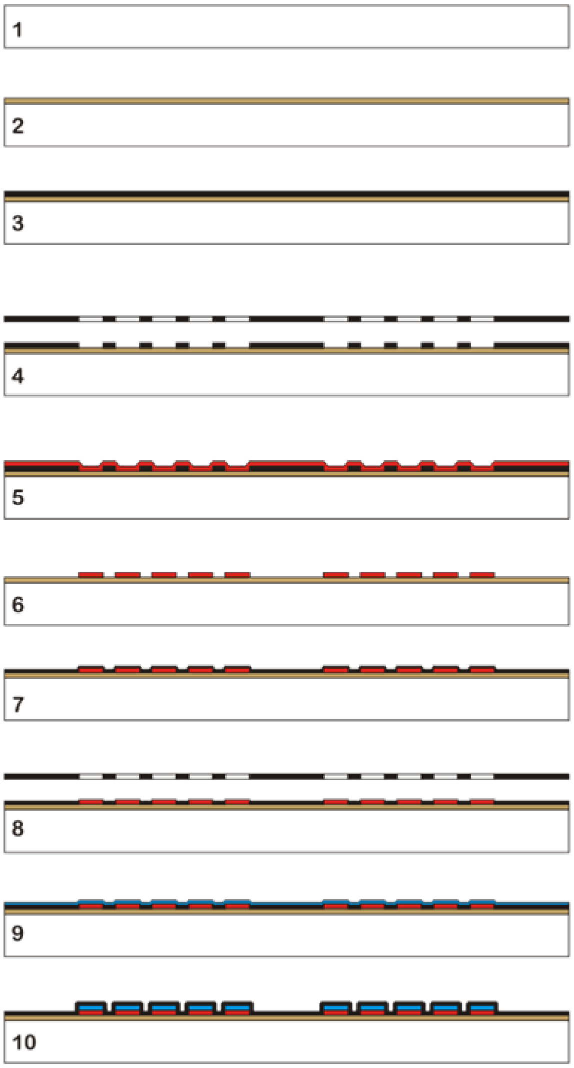

Figure 6a. Fabrication sequence of an AMR sensor on silicon substrate

10. The process of stripping Resist: dissolve in Aceton.
11. The process of photolithography: Positive Resist Coating (AZ), Spinner with Rotation: 3000 RPM, time: 30 seconds, Prebake: 85 0C for 15 min, irradiation (Expose): UV, Mask Negative, Developer: TMAH.
12. Titanium Coating Process (subcontact), Process Technology: DC-Sputtering Target: Ti and Thickness: 200 microns.
13. Resist Stripping Process: dissolve in Aceton.
14. The process of photolithography: Positive Resist Coating (AZ), Spinner with Rotation: 3000 RPM, Time: 30 seconds, Prebake: 85 0C for 15 minutes.
15. The process of irradiation (Expose): UV, Time: 2 minutes, Mask Negative (Process Lift Off), Developer: TMAH.
16. The process of coating Contact Bonding: Process Technology: DC-Sputtering, Materials (Target): Gold (Au) with thickness: 2000 micron.
17. Resist Stripping Process: dissolve in Aceton
18. Bonding Process: Material Gold Wire, Substrate Material: Alumina (Al2O3), Technology: Bold Bonder, Number Bonding: 4 points of the Wheatstone Bridge.

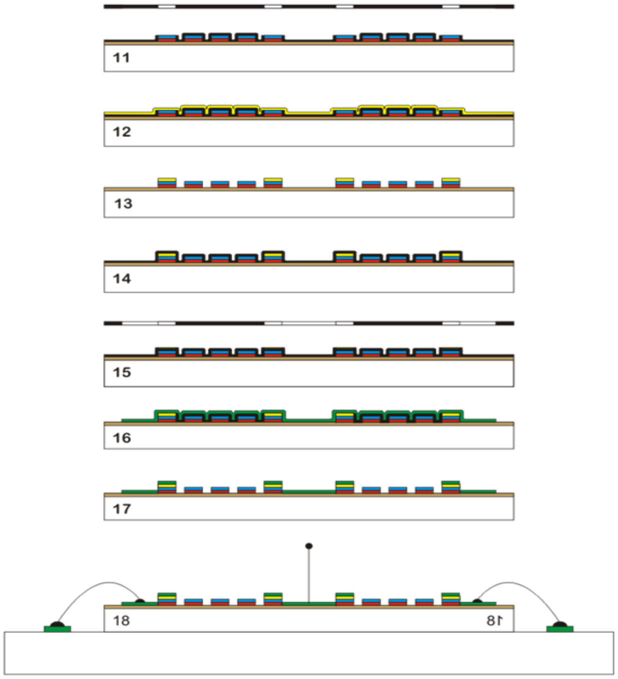

Figure 6b. Fabrication sequence of an AMR sensor on silicon substrate

CONCLUSION

We have designed an anisotropic magneto resistive micro sensor for the detection of small magnetic fields, by using the anizotropic magneto resistive effect. To design this AMR sensor with 18 stages of the process with Thin Film and Microengineering technology.

In the design and fabrication of this AMR sensor, there are several steps processes including thermal oxidation of the silicon substrate (Si) to form a SiO2 layer followed Photolithography and Lift-off processes. The process of coating or deposition of Ni81Fe19 by RF-Sputtering method and deposition Barber pole by DC-Sputtering with a target of aluminum (Al) or gold (Au). Also a layer of titanium (Ti) as subcontact deposited by DC-Sputtering and also Contact bonding as a layer of gold (Au) deposited by DC-Sputtering. Finally with Gold Wire bonding process on alumina (Al2O3) substrate processed by Bold Bonder bonding technology with number 4 points of the Wheatstone Bridge

The anisotropic magneto resistance of permalloy thin films strongly depends on the conditions of high vacuum deposition, roughness and composition. We have studied thin layer permalloy bridge with four active arms for magnetometer application..

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