DEVELOPMENT OF MAGNETIC SENSORS AS UNATTENDED GROUND SENSORS

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ABSTRACT

We will present data obtained from an array of seven commercially available anisotropic magnetoresistance (AMR) sensors. With the use of a new algorithm containing less than 100 lines of code that we developed, it will be shown that the straight-line path of a vehicle can be determined from this data with a high degree of accuracy. We also discuss our efforts at developing spin dependent tunneling sensors, including the development of a novel, insitu mask changing system that allows the deposition of sixteen magnetic tunnel junctions on a small piece of silicon wafer. We will then discuss the construction of our magnetic sensor test facility, which allows the evaluation of both commercially available sensor and the sensors we fabricate. Finally, our advances in the magnetic and mechanical modeling of a novel microelectromechanical (MEMS) flux concentrator will be covered. This flux concentrator has the potential to mitigate the *1/f* noise inherent in not only spin dependent tunneling sensors but also many other types of magnetic sensors.

1. INTRODUCTION

A network of unattended ground sensors (UGSs) can supply the soldier in the field with valuable information on enemy deployment. Such a network would incorporate various sensor types (acoustic, seismic, etc) so that the fusion of the data will increase the likelihood of locating and identifying a given enemy target.

Magnetic sensors have the advantage of being insensitive to weather conditions and having a small bandwidth output signal. As it is remarkably difficult to make vehicles and weapons that are entirely nonmagnetic, it is clear that magnetic sensors should be an integral part of the proposed sensor suite. When considering the criteria of cost, robustness, sensitivity and power consumption, one notes that the thin film "family" of magnetic sensors has the potential to meet all of the Army's requirements for low cost UGSs. This group of sensors includes anisotropic magnetoresistance (AMR) sensors, giant magnetoresistance (GMR) sensors, spin dependent tunneling (SDT) sensors and microelectromechanical systems (MEMS) magnetic sensors.

A discussion is presented of the various aspects of magnetic sensor research we are currently performing to develop a magnetic sensor that can be incorporated in a suite of various sensor types or be used in a tripwire system. First, we demonstrate the utility of magnetic sensors by presenting data obtained from a hexagonal array of seven AMR sensors and processed via the use of a new algorithm containing less than 100 lines of code that we developed. We then discuss the construction of our in-situ mask changing system for depositing spin dependent tunneling sensors, our new sensor test facility and our advances in the development of a novel MEMS flux concentrator.

2. AMR HEXAGONAL SENSOR ARRAY

We designed a hexagonal magnetic sensor array that consisted of seven Honeywell HMR 2300 AMR sensors, each with a sensitivity of 7 nT. The sensors were laid out at the vertices of a regular hexagonal array, with the seventh sensor at the center of the array. We performed experiments with two different distances between sensors: One with 10 feet between nearest neighbors and another with 20 feet between nearest neighbors. In both instances the x-axis of the sensors were aligned parallel to each other.

A LabView program is used to receive data from the sensor array, display the data in real time, and save the data to a file. Once executed, the program displays a representation of the array, allowing the user to visually track an object moving through or by the array. The maximum total field signal from each sensor is extracted from the data generated by the array. After subtracting the residual background at a given sensor from each maximum, the resulting signal and corresponding sensor number is entered into an algorithm developed by Dr. Edelstein. The algorithm determines the best straight line fit to the data. Figures 1 shows that for a vehicle following a straight path, the algorithm works quite well.

3. IN-SITU MASK CHANGING SYSTEM

In order to develop SDT sensors, we needed to be able to deposit magnetic tunnel junctions (MTJs) in our

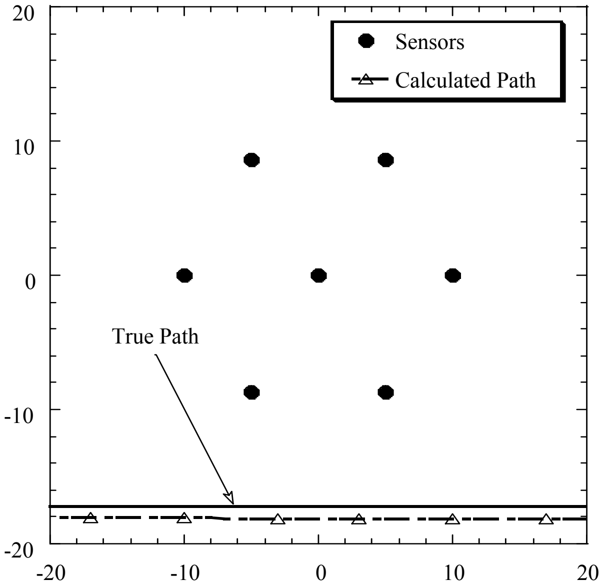

Figure 1. Results for vehicle passing array.

ion beam sputtering unit without breaking vacuum. As the MTJ structure consists of multiple layers of materials, each layer consisting of a “pattern”, an in-situ mask changing system was designed. Masks are initially stacked in a box, pushed one by on along tracks until positioned over a substrate, and then pushed further into a drop box. This design allows for the deposition of up to 16 MTJs on a single piece of substrate, each MTJ measuring 1mm on a side. The unit is shown in Figure 2.

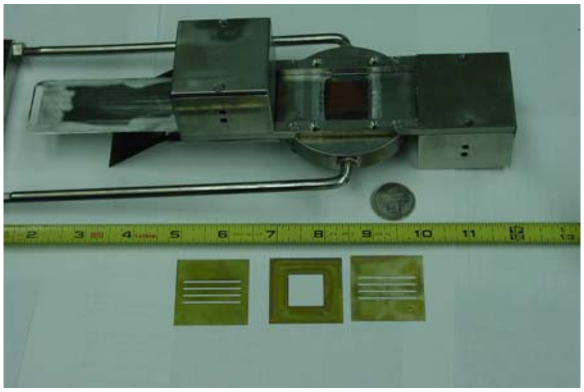

Figure 2. In-situ mask changing unit, shown with masks.

4. MAGNETIC SENSOR TEST FACILITY

We constructed a magnetic sensor test facility to (1) allow magneto-resistance (MR) measurements of MTJs fabricated at ARL to be performed and (2) allow us to test the noise characteristics and sensitivity of sensors produced for ARL via SBIRs and collaborations. The facility has 3-axis Helmholtz coils that allow us to null out the Earth’s magnetic field, a single axis coil system that is used to apply a field to the sample and an all wood construction table possessing a non-magnetic sample mount system. The entire system is LabView driven, allowing for control of coils and data acquisition.

The mount system consists of a brass and aluminum structure that allows samples to roll smoothly into position inside the coils, a boom microscope stand, and micropositioners to position four electrical contacts with 1 mm accuracy, and a brass, vacuum sealed sample mounting block.

5. MEMS FLUX CONCENTRATOR

Dr. Edelstein has developed a MEMS flux concentrator to be incorporated into the design of a SDT sensor. This particular design not only concentrates flux lines but also modulates the magnetic field because the flux concentrator flaps are driven electrostatically. This effectively shifts the operating frequency for detecting military targets from less than one Hz to kHz, thus mitigating the problem of *1/f* noise. Magnetic and mechanical modeling indicate that we can increase the sensitivity of a sensor by two orders of magnitude by incorporating this device.

6. CONCLUSIONS

We are investigating many promising technologies in order to produce cheap, robust, sensitive low power consumption magnetic sensors. Modifications to our sputtering unit allow us to make 16 MTJs in one run without breaking vacuum. A flux concentrator has been designed which should nearly eliminate *1/f* noise in SDT sensors, prototypes of which are currently being produced. The utility of magnetic sensors as tripwires and for tracking has been demonstrated with a network of AMR sensors and a new algorithm containing less than 100 lines of code. Our newly designed and equipped magnetic sensor test facility allows us to evaluate devices made at ARL as well as those produced for us, so as to determine which sensor technologies are best suited for the U.S. Army’s needs.

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