Damage to Magnetic Recording Heads due to Electromagnetic Interference

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Abstract—The effect of electromagnetic interference (EMI) on giant magnetoresistive (GMR) recording heads is studied for the first time. It is shown that a GMR head connected to test equipment can be physically and/or magnetically damaged by a remote ESD event or other spark that causes radiated EMI. SEM failure analysis shows severe melting of the thin-film GMR sensor. It is concluded that it is important to understand, measure and prevent EMI damage to GMR recording heads, and that EMI testing has revealed a new and important failure mechanism for magnetic recording sensors.

INTRODUCTION

Magnetic recording hard disk drives use magnetoresistive (MR) sensors to read information stored on the spinning disk. The newest types of sensor utilizes the giant magnetoresistance (GMR) effect. [1] Although GMR heads are not yet widely used in disk drives, it is expected that they will replace existing MR heads in the near future.

The effects of a *direct* electrostatic discharge (ESD) to a GMR head has been studied, and it has been shown that an ESD event to one of the inputs of the GMR device can result in melting and/or magnetic damage. [2,3] Figure 1 shows the human body model (HBM) ESD failure current versus inverse head resistance for a GMR head design. Note that a GMR head with a resistance of 50 Ω is damaged magnetically by a peak current of only 18 mA. This corresponds to an HBM failure voltage of only 28 V.

While it is well known that a spark associated with an ESD event can induce electromagnetic interference (EMI) "noise" in the form of a current spike in nearby wires [4], ESD sensitive semiconductor IC devices are typically not damaged in any way by EMI. However, considering the very low current failure level for GMR heads, it seems possible that a remote ESD event could cause a GMR head to change magnetically or even melt.

One likely situation where EMI damage could occur is when the GMR head is connected to wires, e.g. during testing. In such cases, the wiring of the tester itself could act as an antenna. Figure 2 shows a lumped element equivalent circuit for a GMR head connected to a tester. One GMR input is shown connected to a wire (the antenna) and the other input is grounded. EMI from a nearby spark will induce a current pulse in the wire and result in current flow through the GMR sensor.

The goal of this work is to explore the effects of EMI on GMR heads and determine whether EMI from a remote ESD event can cause magnetic or physical damage to a GMR head.

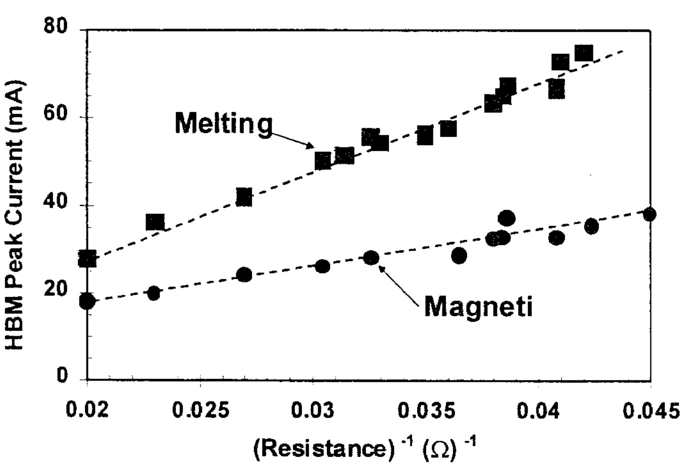

Figure 1. HBM peak current for melting and magnetic damage versus inverse head resistance for GMR heads.

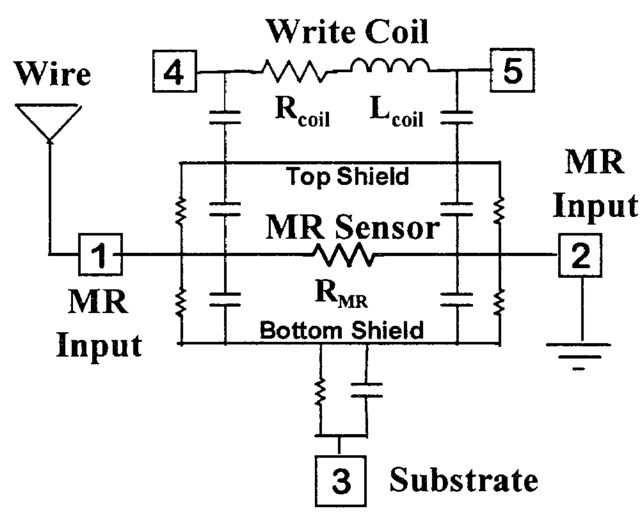

Figure 2. Lumped element equivalent circuit for a GMR head connected to a tester.

EXPERIMENTAL

Spin-valve GMR sensors made of Ta 5/NiFe 7.5/Co 2/Cu 3/Co 2/NiFe 7.5/FeMn 10/Ta 5 nm were used in this study. The nominal stripe height and track width were 1.3 μm and 1.6 μm, and the resistance ranged from 20 Ω to 50 Ω.

The experimental setup consisted of a quasi-static MR transfer curve tester and a hand-held KeyTek MiniZap ESD gun. An MR curve tester measures the amplitude from a GMR sensor vs. magnetic field, and the plot of amplitude vs. magnetic field is called an MR curve. The combination of an MR curve tester and an ESD simulator permitted measurement of a GMR sensor's resistance and output signal before and after the occurrence of a remote ESD event.

A 30 cm long dipole antenna connected to an HP54542C digital oscilloscope was placed near the GMR head. The dipole length is half-wave at 500 MHz, which is the bandwidth of the scope. Since the antenna impedance was 50 Ω, it provides an estimate of the current induced in a nearby 50 Ω GMR head.

Figure 3 shows a typical waveform from the dipole antenna for a 4kV contact discharge of the MiniZap to its own ground wire. The ESD gun was held 4 feet from the antenna. The peak voltage is 2V, which translates into a peak current of 40 mA into the 50 Ω load. Note that 40 mA is more than twice the current that would result in magnetic failure of a 50 Ω GMR head (18 mA). The peak current of 40 mA is even in the range of currents (25 mA to 80 mA from Fig. 1) which would result in melting damage and resistance increases in the GMR sensor. Based upon the data from the dipole antenna, it seems likely that EMI could result in a current transient that would cause magnetic and even physical damage to GMR heads.

RESULTS

Figure 4 shows two MR curves for the same GMR head before and after a remote ESD event. The curve labeled "Initial" shows the typically behavior of a good GMR head. The peak to peak amplitude was 1300 μV. The MR curve in fig. 4 labeled "After EMI" was measured immediately after a 4kV contact discharge of the MiniZap to its own ground wire 4 feet from the MR curve tester. After the EMI event, the peak-to-peak amplitude changed to only 300 μV. There was no significant change in resistance of the GMR sensor. The amplitude decrease signifies that a serious and undesirable magnetic change has occurred in the GMR sensor without physical or melting damage.

However, when the MiniZap ESD gun was moved to within 1 foot of the GMR head, a 4kV contact discharge resulted in a resistance increase and an amplitude decrease. This resistance increase is consistent with melting of the GMR sensor due to Joule heating by the induced current transient.

Melting damage of the GMR sensor can be detected using a scanning electron microscope (SEM). Figure 5 shows SEM photos of three different GMR sensors after a 4kV contact discharge 12 inches from the MR curve tester. The resistance increases of the heads shown in Figs 5 were 50% (top), 100% (middle) and 150% (bottom). The physical damage to the sensor involved a combination of thinning, melting and/or protrusion of the sensor. The type of damage seen in these EMI damaged heads is similar to that seen after direct contact charged device model (CDM) testing. [5] Therefore, it is not possible to tell from an SEM alone whether a GMR head was damaged indirectly by a remote EMI event, or by a direct ESD event to one of the GMR head inputs.

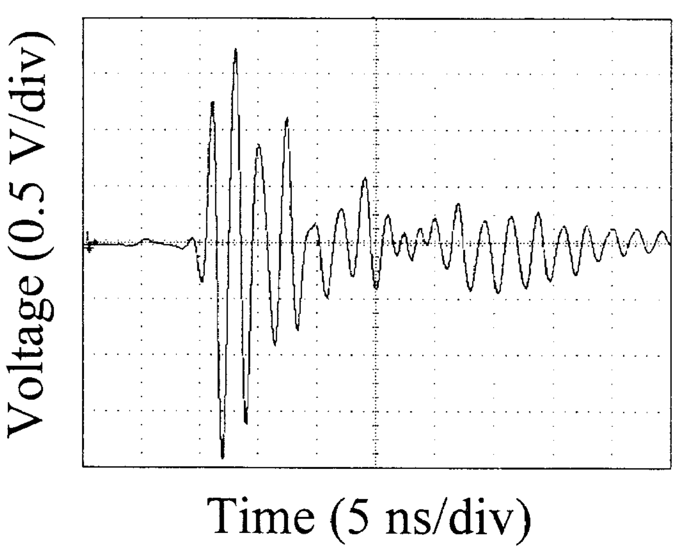

Figure 3. Voltage waveform measured by the dipole antenna.

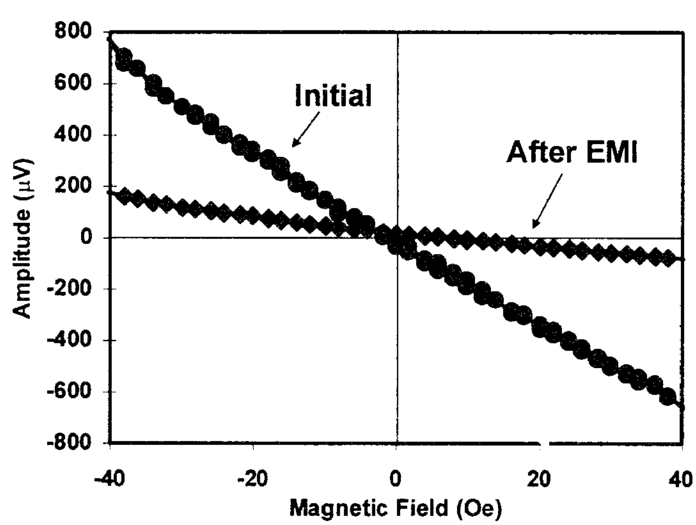

Figure 4. Two MR curves for the same GMR head: before (initial) and after the influence of EMI (after EMI).

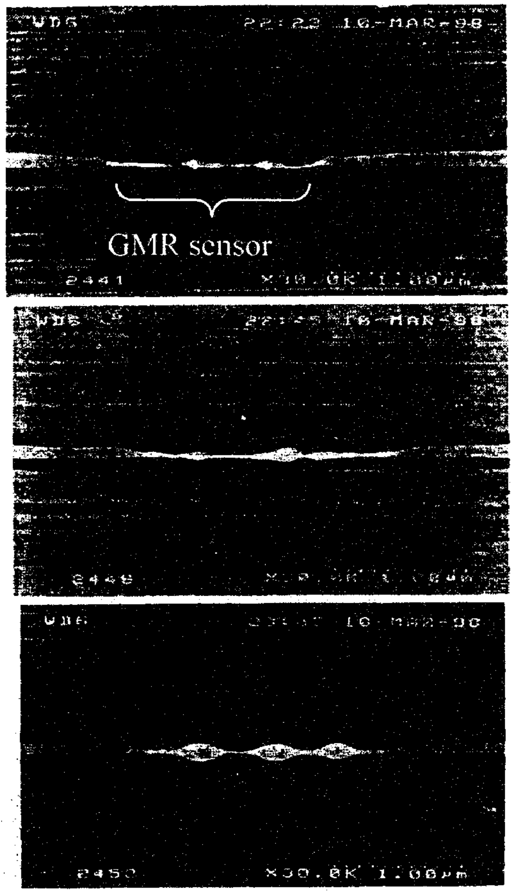

Figure 5. SEM photos of three different GMR heads which showed resistance increases after EMI testing. The sensor width is ~ 1.2 µm. Magnification is 30,000X. EMI damage causes the sensor region, which should be smooth and uniform, to melt and become thinner and/or protrude.

DISCUSSION

It is important to understand that in all of this testing, there was no direct charge transfer between the ESD gun and the GMR head. The current transients in the tester wires and GMR head itself were due to EMI "noise" currents. The reason GMR heads can be damaged by EMI is that they are ultra-ESD sensitive devices that are magnetically (physically) damaged by a current transient with a peak current of only 18 mA (25 mA).

The explanation for the magnetic changes in GMR heads is as follows. The Joule heating during the current transient briefly raises the temperature of the GMR sensor. For example, it has been shown that a 20 mA current transient can increase the temperature of the GMR sensor to about 150 °C. At this temperature, a critical magnetic temperature, called the "blocking temperature" of the exchange film, is exceeded and its magnetic properties are altered. These current induced changes in the exchange film result in severe amplitude loss of the GMR head. [3]

CONCLUSIONS

It is shown for the first time that GMR sensors connected to an MR curve tester can be damaged magnetically and/or physically by the indirect EMI from a 4 kV spark within 4 feet of the head. The serious and undesirable magnetic changes are due to the elevated sensor temperature caused by the EMI induced current transient. The melting damage appears similar to the damage from a direct contact CDM ESD event. It is concluded that EMI testing of GMR sensors has revealed a new and important failure mechanism when handling and testing of GMR heads. The implication of this work is that a process involving GMR heads should be free from EMI caused by a remote ESD event, or other spark that causes radiated EMI.

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