



Effect of Magnetic Field and Electric Field Emission from Discharge Current in Gold Ball Bonding Process upon TMR Heads

*Sarunya Puapairoj, Sittisak Samornrit, Kanuengnit Marongmued, Sirinan Wonglam, Santipab Sainon and Chiranut Sa-ngiamsak**

Department of Electrical Engineering, Faculty of Engineering, Khon Kaen University, Khon Kaen 40002, Thailand

**Correspondent author: chiranut@kku.ac.th*

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Abstract

Tunnelling Magnetoresistive (TMR) heads in magnetic recording heads can be damaged by an electric field and degraded by an external magnetic field. This work presents the effects of electric-magnetic field emission caused by a discharge current on TMR head during making electrical connection in head gimbal assembly (HGA). A bonding current was acting as an Electromagnetic Radiation (EMR) source being captured by a current probe. The effects of electric and magnetic fields upon TMR heads were carried out by using a finite-integral-based simulator. The electric and magnetic field strength were monitored and compared with the threshold level of TMR head technology. The simulations show that the radiated magnetic field strength located at TMR heads is approximately 0.60 Oe while the radiated electric field strength caused by the discharge current is 0.14 GV/m. The dielectric strength of MgO is approximately 0.95 GV/m; therefore, the radiated electric field is 14.74% of the breakdown level while the radiated magnetic field is only 0.63% of threshold magnetic field (exchange bias field) of 100 Oe. In conclusion, during a gold ball bond process, the possibility of TMR heads being damaged by dielectric breakdown at MgO layer is 23.40% higher than the case of the magnetization reversal at AFM/FM interface.

Keywords: EMI, ESD, Dielectric Breakdown, Exchange Bias, TMR

1. Introduction

Currently, Thailand is the world's number one producer for hard disk drives (HDD); however, the central of advance technology of research and development is in the foreign countries. There are several concerning factors to maintain Thailand status as the world's number one HDD production base. Thailand should focus on R&D in advanced technologies in HDD production and should develop facilities for supporting the growth of HDD industry in the future (1, 2). Electromagnetic interference (EMI) has become an important issue in microelectronic manufacturing due to it can degrade the performance of devices or equipments (3). HDD production cannot avoid some processes which can expose the sensitive device such as the recording head to EMI such as EMI caused by spark gap during a head gimbal assembly level using a gold ball bonding machine (4).

A number of problems related to ESD and EMI phenomena in MR heads has been reported: including melting and diffusion caused by ESD current, dielectric breakdown failure resulting from induced voltages across any capacitive element caused by the electric field of the charge source called "field-induced breakdown" mechanism, and magnetization reversal owing to joule

heating and magnetic field from ESD current. On the other hand, an indirect damage is produced by the EMI. MR heads can magnetically and physical be damaged by EMI-induced current transient (5-14). EMI effect has been classified into three modes; a far field coupled mode, near field E-coupling, and near field H-coupling (3, 4). According to the actual process of ball bonding on TMR heads, this work focuses on near field coupling only.

The gold ball bonding (GBB) technology is an important electrical interconnection process owing to its precision and efficiency. Hard disk drive production employs this technology during a head gimbal assembly (HGA) process. As mentioned, MR heads can be degraded by EMI. This process is unavoidable metal-to-metal contact event and spark discharge phenomenon; hence, the ESD problem will occur (15). Consequently EMI has become an issue to investigate on this work.

The actual process of GBB is illustrated in Fig 1, a high voltage of 4 kV is periodically applied to a wand which then arcs to a tip of gold wire. The discharge generates enough heat to melt the tip of wire. Then wand moves away from a gold wire and ball bond is formed at the tip of gold wire. Finally ultrasonic power is given to the gold ball to make the permanent connection between two electrical leads (8).

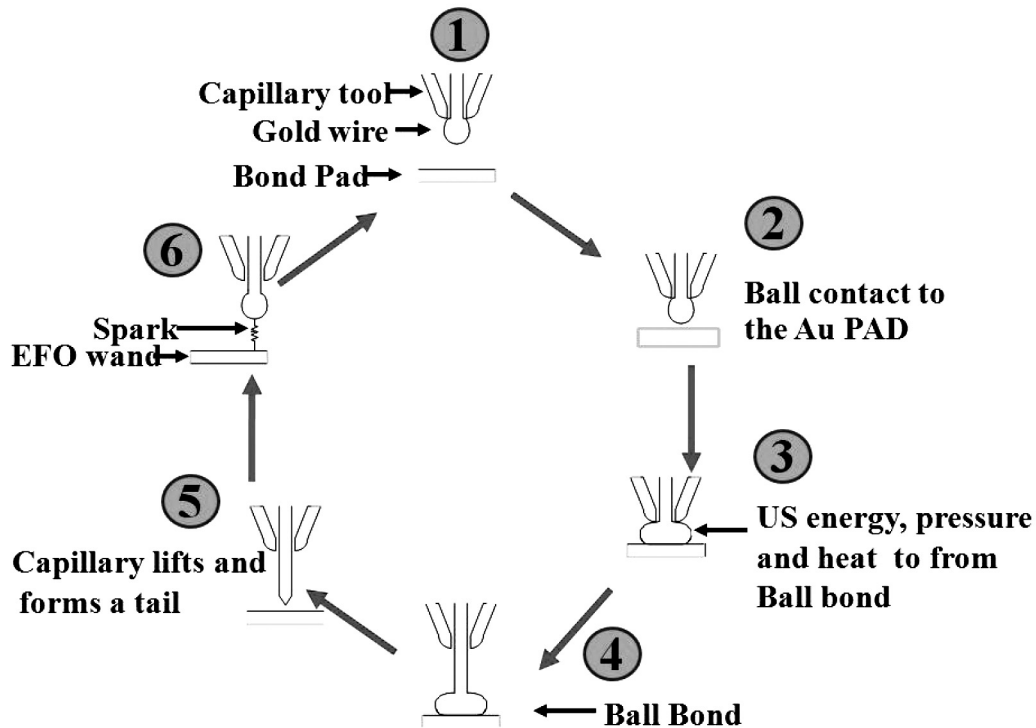


Figure 1. Ball bonding process

Most of the publications pay attention to the risk of EFO process (6th step in Fig. 1) due to it involves with high voltage and arc discharge phenomenon. Device can be damaged by directly arcing, EMI, and Charged Device Model (CDM) ESD (8, 15-17). Nevertheless, a bonding process (2nd step in Fig. 1) can be another threat to the reliability of MR heads apart from EFO process, because of ESD high frequency current induced EMI at this process. Some reports show that the EMI emission

during bonding process is even higher than EFO process (18).

This work for the first time investigated severity of EMI during bonding process on MR heads through an actual ESD phenomenon. The effects of electric field and magnetic field caused by a discharge current during bonding were investigated by finite integral technique (FIT) while an input to the simulator was captured from the live machine operation.

2. Methodology

Table 1. Methodology Research

OBJECTIVE	OUTPUT
1. Effects of Electric field on TMR head caused by discharge current during electrical connection	Dielectric breakdown (Threshold)
2. Effects of Magnetic field on MR head caused by discharge current during electrical connection	Exchange coupling field (Hex)

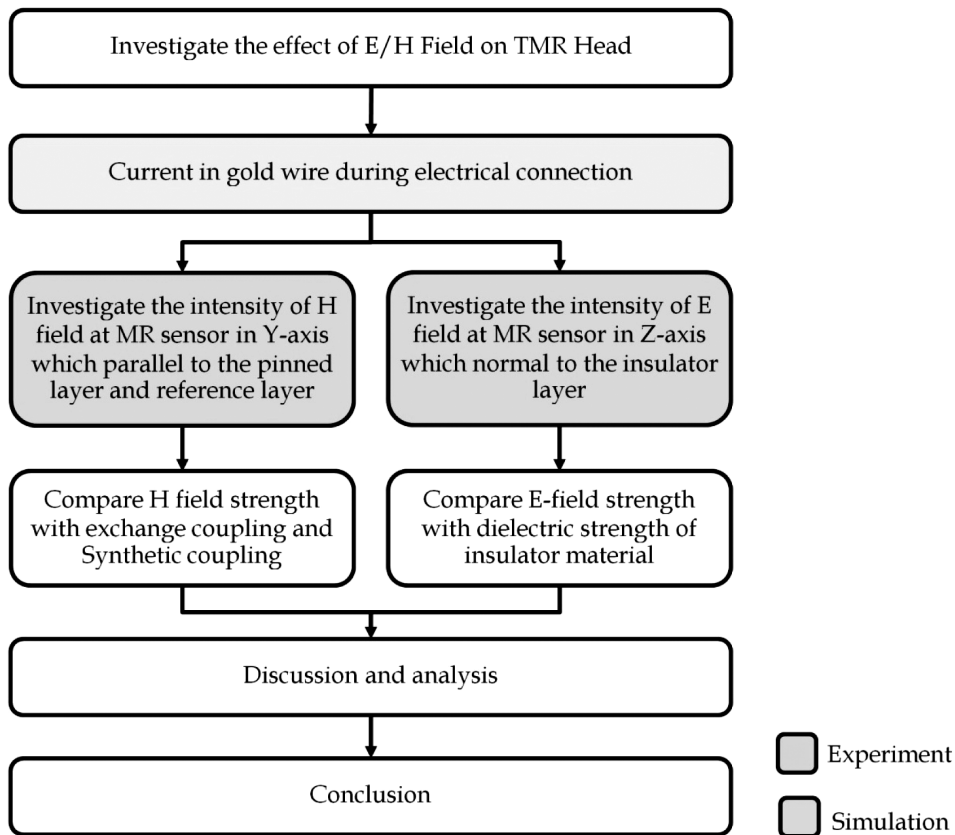


Figure 2. Diagram of research methodology

The investigation on the effects of electric field and magnetic field emission during electrical connection from GBB process was carried out by measuring the current in gold wire; and the captured live current was fed as an input current source to the simulator based on FIT. After that, the electric field and magnetic field emission were monitored.

3. Experiments

3.1 Experimental Setup

EMR source during electrical connection in GBB process was monitored. The experiment setup is shown in Fig.4; and it consists of the following components:

- 1) Tektronix CT-6 current probe
- 2) LeCroy DDA-125, 1.5 GHz bandwidth, 8 GS/s

- Single – Shot mode
- 5 V per division
- 50 ns per division

The discharge current was detected with CT-6 current probe. The waveforms were captured using Lecroy DDA– 125 oscilloscope.

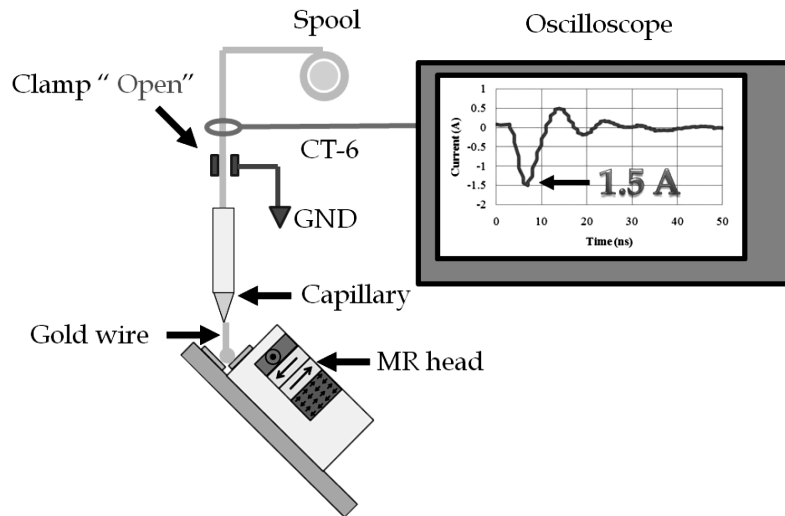


Figure 3. Position of measurement and captured discharge current

3.2 Experimental Result

During a free air ball being formed, the clamp was closed and the current flow from the EFO wand to the wire and then passed through the ground (GND) because of its low resistance comparing with the unground floated wire. The discharge current is produced by accumulated charge in gold wire or capillary or device was expected and captured at the location above the clamp (15, 16, 18). This accumulated charge result from plasma during EFO process and/or the closed time of clamp may not long enough to dissipate the current which used to form the free air ball. The accumulated charge causes a discharge current in two ways.

First is spark discharge. It occurred when the free air ball move toward to the electrical pad. The electric field was generated by accumulated charge and increased due to gap between the free air ball and electrical pad decreased. If the electric field exceeded the dielectric strength of air, the discharge current occurred (19).

Second is metal-to-metal contact. The electrostatic discharge occurs during the free air ball making contacts to the electrical pads.

Based on the experimental results, the high frequency discharge current during bonding process being captured by CT-6 is illustrated in Fig.3.

4. Effects of EMR on TMR head

The effects of EMR upon the MR heads directly because the degradation of the head stability is caused by both electric field (E) and magnetic field (H) (20, 21) were investigated in this session. The simulation was carried out by investigating the radiated E and H separated using finite integral simulator.

4.1 Structure and Model

The simplified structure was used to investigate the effect of EMR during bonding process and position of TMR head at the observing point is illustrated in Fig. 4(a), including the electromagnetic radiation source (captured discharge current) while the Fig. 4(b) shows the structure and direction of magnetization of TMR head

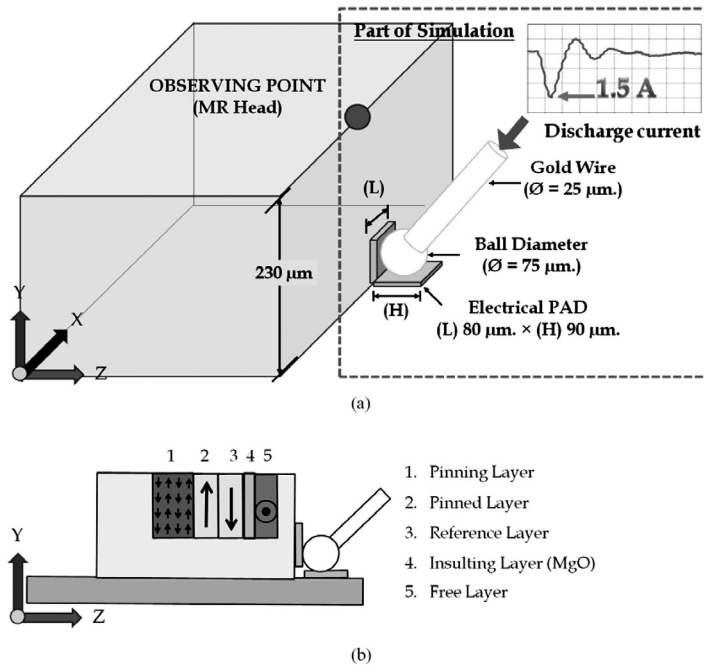


Figure 4. (a) Structure of gold wire, gold ball, and electrical PAD
(b) Structure and direction of magnetization of TMR head

4.2 Simulation Results and Discussion

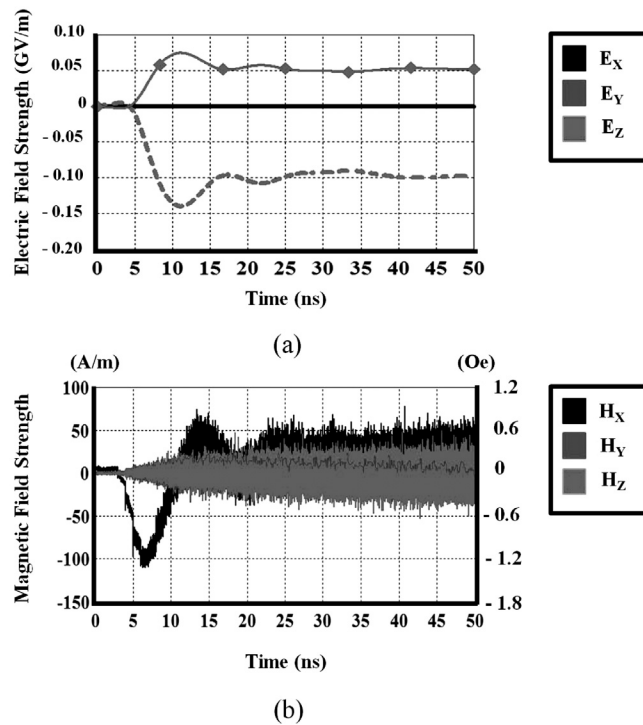


Figure 5. (a) Electric field strength at TMR head and (b) magnetic field strength at TMR head

Fig. 5(a) shows the electric field strength in three-dimensional. Considering the magnetic field in Z-axis that due to this direction is normal to direction of insulating layer. The maximum electric field strength is approximately 0.14 GV/m that it is lower than dielectric breakdown (Dielectric strength is about 0.95 GV/m); hence, barrier layer has defect like pinhole or the thickness of barrier is decreased, the electric field from discharge current during electrical connection can possibly threat the TMR head which consists of insulating layer.

Fig. 5(b) shows the magnetic field strength in three-dimensional. Considering the magnetic field in Y-axis due to this axis is parallel to direction of magnetization of pinned layer and pinning layer. The maximum magnetic field strength is 50 A/m (0.625 Oe); that it not high enough to degrade the magnetic performance of MR heads due to the exchange bias field is more than hundreds oersted.

5. Conclusion

The conclusion of this work is listed as following:

a) The radiated electric field is 14.74% of the breakdown of the oxide level while the radiated magnetic field is only 0.63% of the threshold level of MR heads at the ball bonding process; hence this process the electric field plays a stronger role to MR heads than the radiated magnetic field. This can be an issue particularly with Tunneling Magnetoresistance (TMR) heads.

b) The possibility of TMR heads being damaged by dielectric breakdown at MgO layer is 23.40% higher than the case of the magnetization reversal at AFM/FM interface during a gold ball bond process.

c) Direction of TMR heads during bonding process play a role in the magnetic fields alignment of

TMR heads which result in the magnetic instability of TMR heads.

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