Final Report

Study of Indirect Electromagnetic Interference (EMI) Effects to

Instability Test Parameters of Heat Assisted Magnetic Recording Heads

by

Assistant Professor Dr. Anan Kruesubthaworn

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Study of Indirect Electromagnetic Interference (EMI) Effects to Instability Test Parameters of Heat Assisted Magnetic Recording Heads

Assistant Professor Dr. Anan Kruesubthaworn, Khon Kaen University, Nong Khai Campus

Professor Dr. Apirat Siritaratiwat, Khon Kaen University (Mentor)

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Investigator: Assistant Professor Dr. Anan Kruesubthaworn

E-mail Address: anankr@kku.ac.th

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Abstract:

Electrostatic discharge (ESD) has been a significant problem in the manufacturing processes of the magnetic recording head technologies for many years. Besides direct discharge damage, ESD can also generate electromagnetic interference (EMI) which could possibly cause failure in magnetic read heads. The aims of this work are to measure the EMI from ESD simulator based on the standard IEC 61000-4-2 and to investigate the effects of EMI on tunneling magnetoresistive (TMR) read heads using the heat assisted magnetic recording. The discharge current and the EMI generated by ESD simulator are measured in the experiment. Also, the EMI is applied to the TMR read heads at various amplitudes and distances in order to evaluate the changes of read head parameters including the bit error rate, head resistance, read back signal amplitude, asymmetry, normalized noise, baseline noise, writer width, and overwrite of the head. The results show that the discharge current wave form is consistent with the IEC standard current waveform. In addition, it is found that the EMI is insufficient to cause a permanent change of the read head parameters at distances above 2 cm indicating the minimal impact on the head performance. Further experiments are proposed to carry out more detailed studies of the EMI effects on head parameters in order to improve the measurement methodologies to prevent the degradation of the heads performance which can be a latent failure in the magnetic read heads and to increase the robustness of the heads.

Keywords: Electrostatic Discharge (ESD), Electromagnetic Interference (EMI), tunneling magnetic recording head (TMR) and electrical test parameters of the head

Final report content:

1. Abstract

Electrostatic discharge (ESD) has been a significant problem in the manufacturing processes of the magnetic recording head technologies for many years. Besides direct discharge damage, ESD can also generate electromagnetic interference (EMI) which could possibly cause failure in magnetic read heads. The aims of this work are to measure the EMI from ESD simulator based on the standard IEC 61000-4-2 and to investigate the effects of EMI on tunneling magnetoresistive (TMR) read heads using the heat assisted magnetic recording. The discharge current and the EMI generated by ESD simulator are measured in the experiment. Also, the EMI is applied to the TMR read heads at various amplitudes and distances in order to evaluate the changes of read head parameters including the bit error rate, head resistance, read back signal amplitude, asymmetry, normalized noise, baseline noise, writer width, and overwrite of the head. The results show that the discharge current wave form is consistent with the IEC standard current waveform. In addition, it is found that the EMI is insufficient to cause a permanent change of the read head parameters at distances above 2 cm indicating the minimal impact on the head performance. Further experiments are proposed to carry out more detailed studies of the EMI effects on head parameters in order to improve the measurement methodologies to prevent the degradation of the heads performance which can be a latent failure in the magnetic read heads and to increase the robustness of the heads.

2. Executive summary

The EMI is generated by radiated field from ESD simulator using in the experiment based on the standard IEC 61000-4-2. The EMI is applied to the TMR read heads at various amplitudes and distances in order to evaluate the changes of reader and writer test parameters in the heads including the bit error rate, head resistance, read back signal amplitude, asymmetry, normalized noise, baseline noise, writer width, and overwrite of the head. The results show that the discharge current wave form is consistent with the IEC standard current waveform. Also, it is found that the EMI is insufficient to cause permanent changes of the reader and writer head parameters at

distances above 2 cm indicating the minimal impact on the head performance however, it maybe latent failures in the heads. Hence, further experiments are proposed to carry out more detailed studies of the EMI effects on head parameters in order to improve the measurement methodologies to prevent the degradation of the heads performance which can be a latent failure in the magnetic read heads and to increase the robustness of the heads.

3. Objective

3.1 To study indirect EMI from remote ESD events or spark associated with ESD events.

3.2 To study effect of indirect EMI events to test parameters of tunneling magnetic recording head (TMR).

3.3 To specific indirect EMI level induced by HBM, MM, and CDM ESD events that can damage TMR heads.

3.4 To gain a useful knowledge base for the hard-disk drive industry’s staffs to measure and characterize the indirect EMI damage in the HDD manufacturing processes.

3.5 To publish international journals in ISI/ SCOPUS data base with impact factor.

4. Research methodology

Electrostatic discharge (ESD) is an important issue in the manufacturing processes of data storage applications since it can cause the physical and magnetic failures in the magnetic recording heads especially, during the phase before inclusion in the hard disk drive (HDD) enclosure [1,2]. Also, ESD can generate electromagnetic interference (EMI) which is the term of describing a disturbance occurring in the electronic circuit as a result of electromagnetic field [3]. The EMI can be caused of the magnetic failures within the magnetic read heads, resulting in a decrease of the head reliabilities [4, 5]. The IEC 61000-4-2 standard specifies the test system for evaluating the immunity performance of electrical and electronic devices when subjected to ESD, which can occur as a contact discharge mode or an air discharge mode [6]. This test standard can produce a higher current than other ESD models at the same charging voltage, resulting in a higher radiated EMI. Nowadays, the tunneling magnetoresistive (TMR) sensor is extensively used as the magnetic read heads for HDD and has continuously received interest to improve the head performance due to its high magnetoresistance ratio, thin barrier, and low bias current [7, 8]. The performance of the magnetic read head can be exemplary evaluated using read head parameters such as the bit error rate (BER), read head resistance (RES), read back signal amplitude (AMP), asymmetry parameter (ASYM), the normalized noise (NORM_NSE) and baseline noise (BL_NSE) for the read head meanwhile the writer resistance (WR_RES), writer width (WR_WDT) and overwrite (OVW) for the write head performance [1, 9]. For the reader sensor parameters, the BER is a parameter used for investigating the probability of errors in data storage devices, which is proportional to a ratio between an amount of the bits causing an error and the total bits detected by the read head [10]. The RES is the resistance of the magnetic read head. The AMP shows strength of output signal from the read head while sensing the magnetic field from magnetic media whereas the ASYM is used for measuring the asymmetry between the positive and the negative signal from the head [9]. These parameters can be used to detect the magnetic degradation in the magnetoresistive read head, resulting from the ESD [1, 9, 11]. The NORM_NSE indicates the noise generated in the read head whereas the BL_NSE refers to the signal to noise ratio of the output signal scanned from the media track [12, 13]. For the parameters of writer head, the WR_RES is normally the resistance of the write head, the WR_WDT is the width of the write field generated by the writer and the OVW indicates the ability of a write head to write over the prior data bits [14-17].

4.1 EXPERIMENT SETUP

4.1.1 Measurement methodology of discharge current and radiated EMI field from ESD event.

The experimental setup to measure the discharge current and the EMI amplitude is shown in Figure 1. In addition, the real test equipment and system in the shielded room is also shown in Figure 2. The ESD is generated by the Thermo Scientific MiniZap ESD simulator resulting in the discharge current flowing through the current target attached to a ground plane. A contact discharge mode is only considered in the measurement, because this mode can be linearly reproduced in the test system while testing the electronic devices. The radiated EMI from ESD is measured by the magnetic field (H-field) probe model HP 11940 A which has bandwidth of 30 MHz to 1 GHz, placed at distances, d, between 2 and 30 cm from the discharge point. An oscilloscope using Lecroy wavepro 7300A with 3 GHz bandwidth is used for measuring the signal from H-field probe and the discharge current is attenuated by the attenuator. The voltage of the magnetic field probe, V, is given by V = A x (dB/dt) where A is the loop area of the probe and dB/dt is the rate of change of the magnetic field, B. Thus, the magnetic field, $H = B/\mu_0$, can be obtained by an integration of voltage signal [12]. While measuring the H-field, the TMR read heads are placed at the same distance with the H-field probe in order to investigate the effects of EMI on the head, described in 4.1.2.

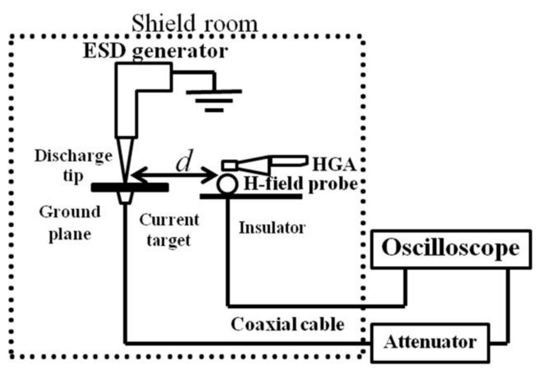

Figure 1. Experiment setup for measuring the discharge current and the radiated EMI field.

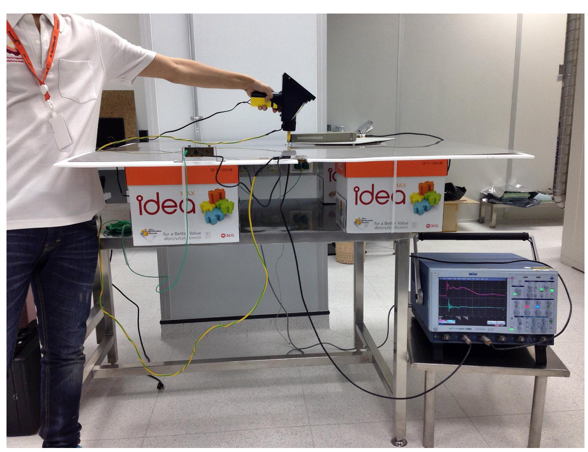

Figure 2. The real test equipment and system

4.1.2 Test parameter evaluation in TMR read head

To evaluate the effects of EMI on the TMR read heads, the EMI radiated from ESD with a charging voltage of 2, 6, and 8 kV are applied to TMR read heads placed at various distances with the air bearing surface (ABS) with facing the ESD. The EMI in terms of the H-field is mainly considered because H-field can affect the magnetization of magnetic layers inside the head. From Figure 1, the slider containing the TMR head is attached to head gimbal assembly (HGA) which is isolated from the ground plane by placing the HGA on an insulator. As can be seen in the magnified figure of a slider in Figure 1, the TMR read head comprises several magnetic layers which are a pinned ferromagnetic layer, a free ferromagnetic layer and the tunnel barrier layer. The sensing layers of the TMR read head used for detecting the data bits consist of the pinned and free layers, which are the ferromagnetic layers, separated by the spacer. The magnetization of the ferromagnetic layers is aligned in the in-plane direction. Also, the magnetization of the free layer is biased by the permanent magnet and can be tilted during the operation by the magnetic field from the media disk while the magnetization of the pinned layer is held by the exchange bias field from an anti-ferromagnetic layer. The magnetization of the pinned layer is perpendicular to the ABS whereas the magnetization of free layer is parallel to the ABS. The H-field is applied perpendicularly to the magnetization of the pinned layer inside the heads because this direction could permanently tilt the magnetization of pinned layer, which could affect the head parameters which are BER, RES, AMP, ASYM, NORM_NSE, BL_NSE, WR_RES, WR_WDT and OVW. After applying the EMI to the heads, these parameters are measured by the spin stand tester and are compared with the values before applying the EMI field. The parameters are considered in the measurement because it can be changed by tilting the magnetization alignment of the sensing layers which can be affected by the external magnetic field.

5. RESULTS AND DISCUSSIONS

The magnetic field was reconstructed according to the procedure explained in the experiment setup part A. Figure 3 shows an example of the signal measured by the H-field probe for 8 kV charging voltage at a distance of 2 cm. Then, the H-field is obtained by $H = B/\mu_0$, where the magnetic field, B, is calculated by integrating dB/dt, as shown in Figure 4. Also, Figure 4 illustrates a comparison of the waveform of the IEC standard current, the measured current, and the H-field generated by a 8 kV charging voltage at a distance of 2 cm from the discharge point. It is shown that the ESD current waveform measured in the experiment is consistent with the standard waveform. In addition, the H-field waveform is proportional to the discharge current as expected by Ampere's law. The peak magnitudes of H-field radiated from ESD with varying charging voltages at various distances are illustrated in Figure 5. This figure shows that the symmetry of H-field between the positive and negative charging voltage is found in the measurement. Also, the result shows an immediate decrease of H-field with increasing distance when the distance is approximately lower than 10 cm after that, the H field is slightly decreased with increasing distance. Normally, when the distance is varied, the magnitude of H-field is changed depending on the region where the H-field is measured. In the near-field region, the H-field is expected to be proportional to $1/d^2$ with increasing distance whereas in the far-field region, the H-field decreases by a factor of 1/d with increasing distance [13] Therefore, the change of H-field observed in the measurement is consistent with the model. For the investigation of EMI effects on the TMR read heads, the results of BER, RES, AMP, and ASYM were measured using a spin stand tester before and after the EMI with charging voltage of 2, 6, and 8 kV applied to the TMR read heads were presented in terms of the percent changes, shown in Figures 6-9, respectively. For each data point, the percent changes of test parameters of three heads are averaged. It is found that BER, RES, AMP, and ASYM show little change with respect to their initial values. However, the results indicate that there is no clear trend in the changes of test parameters neither by increasing distances above 2 cm nor increasing charging voltages up to 8 kV. In order to clarify the changes of head parameters in Figures 6-9, the head parameters are in addition measured twice without applying the EMI. It is found that the changes of the head parameters measured after applying EMI at various distances are within the variations found for the two tests of the same head without applying EMI. Therefore, the changes of test parameters in the experiment are within the tester variation. Then, it is concluded that there is no permanent effect on the BER, RES, AMP and ASYM by applying the EMI to the heads in the perpendicular direction to the magnetization of pinned layer. This is because the magnitude of EMI is much lower than the exchange bias field from anti-ferromagnetic layer which holds the magnetization of pinned layer and is insufficient to cause a permanent effect on the read head parameters by modification of the pinned layer. Additionally, the effects of EMI on the head parameters were investigated only after the EMI was applied to the heads in this experiment. Thu s, any temporary changes to the head that may affect the heads during the operation cannot be detected using this methodology. Hence, the investigation of the effects of EMI on the BER, RES, AMP, and ASYM in case the heads are placed closer than 2 cm from the EMI source and the parameters are measured under operating condition s is suggested as possible future work. By decreasing the distance between the EMI source and the heads, the magnitude of EMI can rapidly increase due to the $1/d^2$ dependence in the near-field region. This will increase the probability of EMI effects on test parameters of the head because the EMI magnitude could be large enough to permanently modify the pinned layer. Also, the possibility of a change in the parameters can be increased by measuring these parameters while the indirect EMI field is applied to the heads because this EMI is the transient source of the electromagnetic field. In addition, measuring the head parameters during the read operation is also suggested for further study. In this condition, the magnetization of free layer is tilted following the stray field from a magnetic disk. Since the EMI is applied perpendicularly to the initial magnetization of free layer, it can either oppose or support the magnetization of free layer tilted by the stray field during the read operation, which can be a cause of the temporary change in the head parameters. However, the present magnetic read heads are generally operated with several terabits on the magnetic media then, the changes of BER, RES, AMP, and ASYM could play a significant role during operation. Thus, the BER, RES, AMP, and ASYM are the important factors which can indicate the latent failure of the head and should be minimized in order to maintain the performance of magnetic read heads for higher areal density.

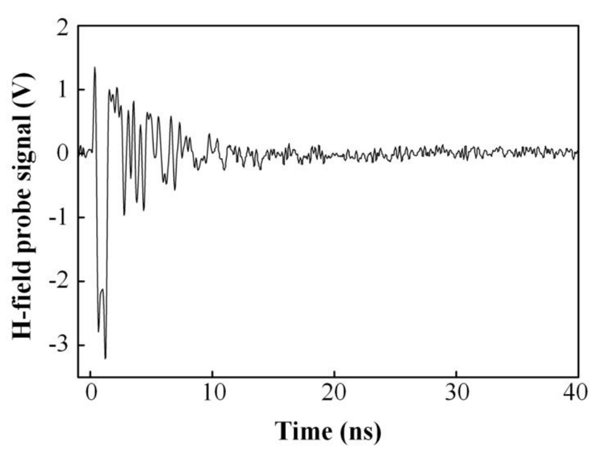

Figure 3. The output signal from H-field probe, *V*, resulting from ESD with 8 kV charging voltage at 2 cm distance.

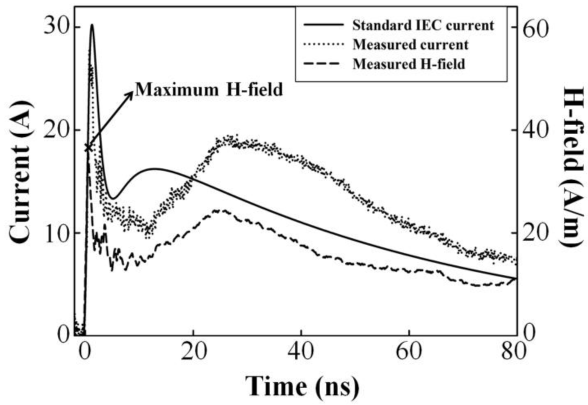

Figure 4. The comparison between the standard current, the measurement current and the measured H-field with ESD charging voltage of 8 kV at distance of 2 cm.

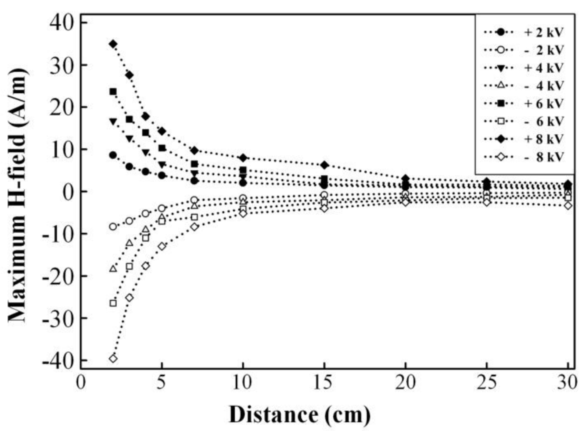

Figure 5. The maximum magnitude of H-field with varying ESD charging voltages at various distances.

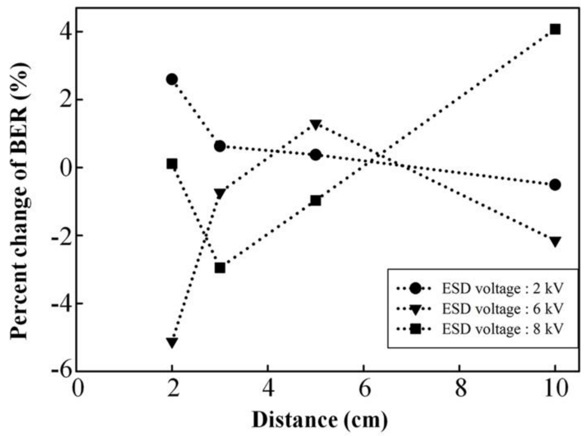

Figure 6. The percent changes of the BER of TMR read heads

at various distances for 2, 6, and 8 kV charging voltage.

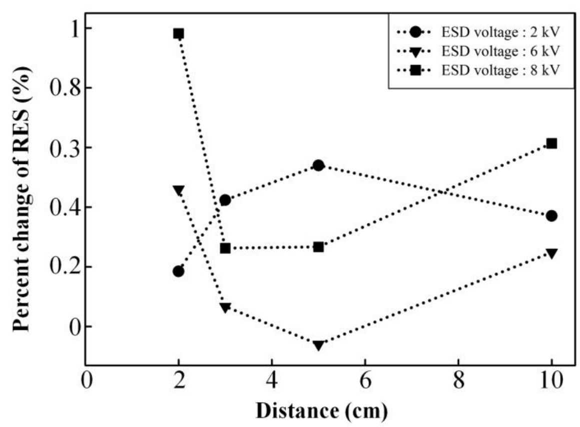

Figure 7. The percent changes of the RES of TMR read heads

at various distances for 2, 6, and 8 kV charging voltage

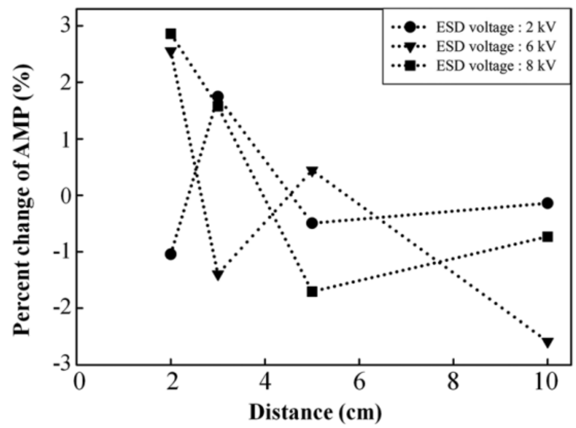

Figure 8. The percent changes of the AMP of TMR read heads

at various distances for 2, 6, and 8 kV charging voltage.

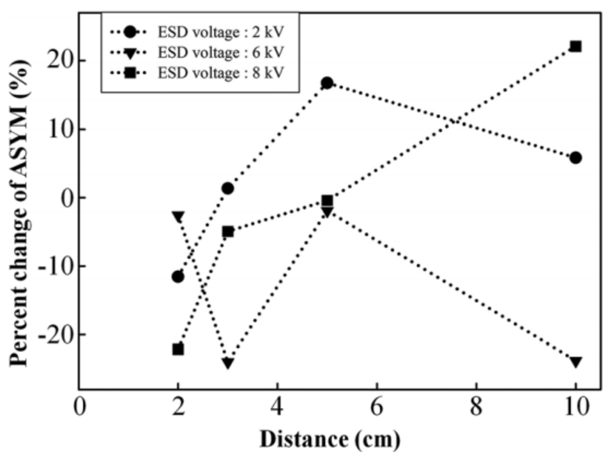

Figure 9. The percent changes of the ASYM of TMR read heads

at various distances for 2, 6, and 8 kV charging voltage.

To evaluate the EMI effects on the heads, the percent changes of WR_RES, WR_WDT, OVW, NORM_NSE and BL_NSE measured pre- and post- the applied EMI are shown in Figure 10-14, respectively. The percent changes of the test parameters measured from three heads were averaged at each data point. It was found that the test parameters were changed randomly either by rising charging voltages up to 8 kV or increasing the distance above 2 cm. Then, the random changes of head parameters need to be clarified. Hence, the test parameters were additionally measured twice without applying the EMI. The results indicate that the test parameters can be changed although there is no EMI applied to the magnetic recording head. Also, the percent changes of the parameters without applying the EMI can be varied within the same variations as the heads with EMI. Therefore, the variances of test parameters measured in this work are the results of a tester variation. Then, there are no permanent effects from the EMI applied to the magnetic heads in the perpendicular direction to the pinned layer magnetization. The reason is that the magnitude of the EMI is very small to cause any permanent cause on the magnetization of the pinned layer held by the exchange bias field from anti-ferromagnetic layer. Another reason why the changes of the test parameters were not detected is that the test parameters were measured only after the heads are completely received the effects from the EMI. Thus, this experimental procedure cannot be used to detect the temporary effects during applying the EMI to the head.

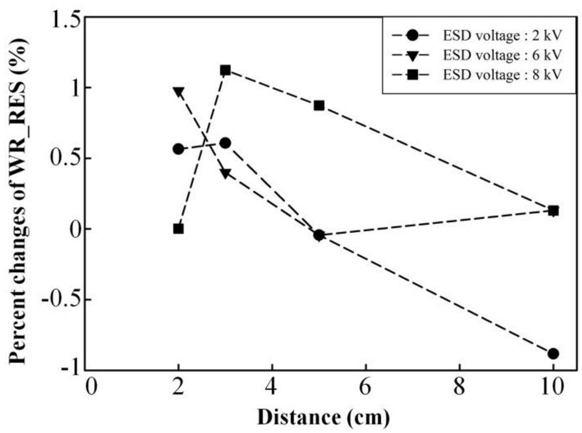

Figure 10. The percent changes of the WR_RES of write heads

at various distances for 2, 6 and 8 kV charging voltage.

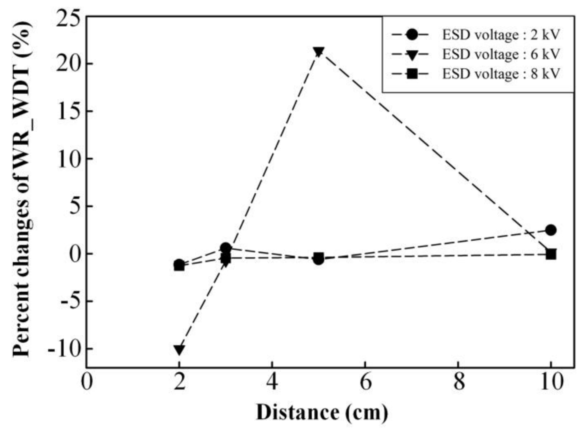

Figure 11. The percent changes of the WR_WDT of write heads

at various distances for 2, 6 and 8 kV charging voltage.

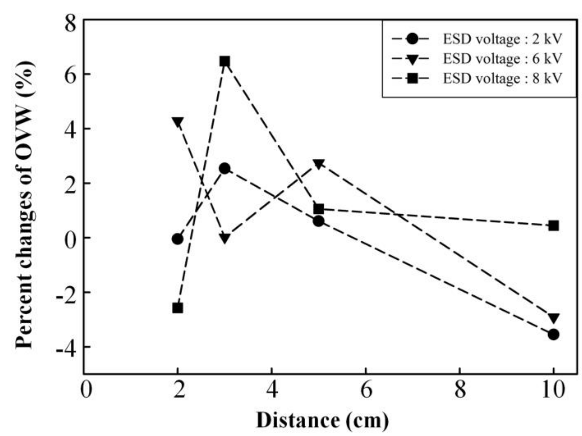

Figure 12. The percent changes of the OVW of write heads

at various distances for 2, 6 and 8 kV charging voltage.

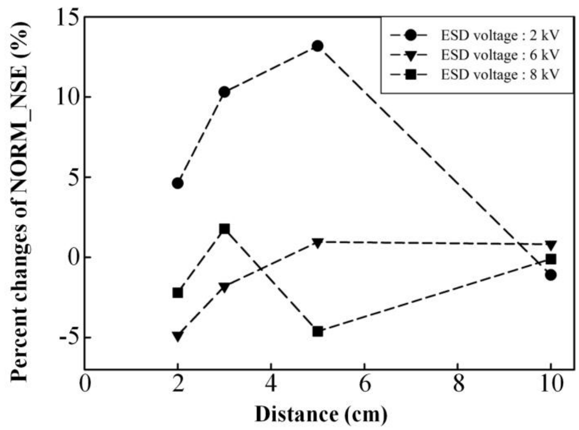

Figure 13. The percent changes of the NORM_NSE of read heads

at various distances for 2, 6 and 8 kV charging voltage.

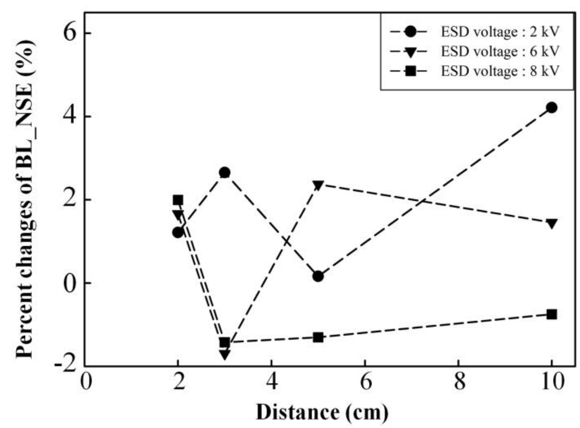

Figure 14. The percent changes of the BL_NSE of read heads

at various distances for 2, 6 and 8 kV charging voltage.

6. CONCLUSIONS

The EMI radiated by ESD standard IEC 61000-4-2 is experimentally evaluated. The discharge current waveform measured in the experiment verifies that the test system is in good agreement with the standard test procedure. Proportionality between the discharge current and the H-field waveform, as expected by the Ampere's law, is also shown in the measurement. In addition, the H-field radiated by ESD is measured by the H-field probe at various distances. The results indicate that the H-field is essentially inverse proportional to the distance squared in the near-field region whereas it is slightly decreased by increasing distance at the far-field length. Furthermore, the effects of EMI on the heads are investigated by an evaluation of the changes of read head parameters including the bit error rate, head resistance, read back signal amplitude, asymmetry, normalized noise, baseline noise, writer width, and overwrite after applying the EMI to the TMR read heads in the perpendicular direction to the magnetization of pinned layer. It was found that there is no obvious tendency on the changes of test parameters by applying the EMI to the heads neither with charged voltage between 2 to 8 kV nor at length over 2 cm. This is because the amplitude of radiated EMI is very tiny to cause the permanent effects on the magnetic recording head by modifying the pinned layer. Then, an investigation of the EMI effects on the test parameters of the heads when the EMI are applied to the heads at distances closer than 2 cm is suggested as the future work. Also, the EMI effects on read head parameters should be detected under the operating condition of the read processes. Hence, the magnitude of EMI is insufficient to play a permanent role on the head parameters which can imply the latent failure of the head before the magnetic failure occurs.

7. Appendix

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International Journal Publication

Anan kruesubthaworn*, Pirat Khunkitti, Apirat Siritaratiwat, Arkom Kaewrawang, Tim Mewes, Claudia K. A. Mewes, “Investigation of Electromagnetic Interference Effects by ESD Simulator on Test Parameters of Tunneling Magnetic Recording Heads”, submitted to Journal of Magnetism and Magnetic Materials on April 24, 2015.

Submissions Being Processed for Author anan kruesubthaworn, Ph.D.

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Action	Manuscript Number	Title	Initial Date Submitted	Status Date
Action Links	MAGMA-D-15-00761	Investigation of Electromagnetic Interference Effects by ESD Simulator on Test Parameters of Tunneling Magnetic Recording Heads	Apr 24, 2015	May 07, 2015

Page: 1 of 1 (1 total submissions) Display 10 results per page.

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Manuscript Draft

Manuscript Number: MAGMA-D-15-00761

Title: Investigation of Electromagnetic Interference Effects by ESD Simulator on Test Parameters of Tunneling Magnetic Recording Heads

Article Type: Regular Submission

Keywords: Electrostatic discharge (ESD), Electromagnetic interference (EMI), Magnetic recording head, Tunneling magnetoresistive (TMR)

Corresponding Author: Dr. anan kruesubthaworn, Ph.D.

Corresponding Author's Institution: Khon Kaen University

First Author: anan kruesubthaworn, Ph.D.

Order of Authors: anan kruesubthaworn, Ph.D.; Pirat Khunkitti; Apirat Siritaratiwat, Prof. Dr.; Arkom Kaewrawang, Assist. Prof. Dr.; Tim Mewes, Assoc. Prof.; Claudia K. A. Mewes, Assist. Prof. Dr.

Abstract: Electrostatic discharge (ESD) has been an important issue in the manufacturing processes of hard disk drive. It can also generate electromagnetic interference (EMI) which could possibly damage to the magnetic recording heads. The aims of this work are to measure the EMI from ESD events and to examine the effects of EMI on the heads. The discharge current and the EMI generated by ESD simulator were experimentally measured. Also, the EMI was applied to the heads to evaluate the changes of head parameters to measure the stabilities of the writer and reader sensor in the heads. The results verify that the discharge current waveform is consistent with a theoretical waveform. Additionally, it is found that the EMI applied at distances above 2 cm could not play any significant effects on the changes of head parameters. Hence, further detailed experiments are proposed to evaluate the EMI effects on recording head parameters in order to improve the measurement methodologies to prevent the degradation of the heads performance and to increase the robustness of the heads

To editors of the Journal of Applied Physics

Authors would like to submit the manuscript to the Journal of Magnetism and Magnetic Materials (JMMM). The title of this work is “Investigation of Electromagnetic Interference Effects by ESD Simulator on Test Parameters of Tunneling Magnetic Recording Heads”. Authors include Assist. Prof. Dr. Anan Kruesubthaworn, Mr. Pirat Khunkitti, Prof. Dr. Apirat Siritaratiwat, Assist. Prof. Dr. Arkom Kaewrawang, Assoc. Prof. Tim Mewes and Assist. Prof. Dr. Claudia K. A. Mewes. Corresponding author should be addressed to Assist. Prof. Dr. Anan Kruesubthaworn. The electronic mail and the telephone number of the corresponding author are anankr@kku.ac.th. and +66 (8) 1391-7474, respectively.

The objectives of this work are to experimentally investigate the effects of the electromagnetic interference (EMI) on tunneling magnetoresistive (TMR) read heads. The EMI was applied to the TMR read heads in order to evaluate the changes of the normalized noise (NORM_NSE), baseline noise (BL_NSE), writer resistance (WR_RES), writer width (WR_WDT) and overwrite (OVW) after being affected by EMI. It is found that the EMI is insufficient to cause a permanent change of the head parameters under the conditions proposed in this work. In addition, further experiments are suggested to investigate the EMI effect on head parameters under the operating condition.

Best Regards,

Authors

Investigation of Electromagnetic Interference Effects by ESD Simulator on Test Parameters of Tunneling Magnetic Recording Heads

A. Kruesubthaworn[b], P. Khunkitti[a], A. Siritaratiwat[a], A. Kaewrawang[a], T. Mewes[c], and C.K.A. Mewes[c]

[a]KKU-Seagate Cooperation Research Laboratory, Department of Electrical Engineering, Khon Kaen University, Khon Kaen 40002, Thailand
[b]Faculty of Applied Science and Engineering, Khon Kaen University, Nong Khai Campus 43000, Thailand
[c]Department of Physics and Astronomy, MINT Center, University of Alabama, Tuscaloosa, Alabama 35487, USA
*corresponding author email : anankr@kku.ac.th

Electrostatic discharge (ESD) has been an important issue in the manufacturing processes of hard disk drive. It can also generate electromagnetic interference (EMI) which could possibly damage to the magnetic recording heads. The aims of this work are to measure the EMI from ESD events and to examine the effects of EMI on the heads. The discharge current and the EMI generated by ESD simulator were experimentally measured. Also, the EMI was applied to the heads to evaluate the changes of head parameters to measure the stabilities of the writer and reader sensor in the heads. The results verify that the discharge current waveform is consistent with a theoretical waveform. Additionally, it is found that the EMI applied at distances above 2 cm could not play any significant effects on the changes of head parameters. Hence, further detailed experiments are proposed to evaluate the EMI effects on recording head parameters in order to improve the measurement methodologies to prevent the degradation of the heads performance and to increase the robustness of the heads.

***Index Terms*— Electrostatic discharge (ESD), Electromagnetic interference (EMI), Magnetic recording head**

1. Introduction

Electrostatic discharge (ESD) is a main issue in the hard disk drive (HDD) manufacturing processes. It can cause soft, hard and latent failures in the HDD components during the assembly processes [1, 2]. The soft and hard failures can be detected by commercial equipment however, the latent failure is very hard to detect by commercial tool and methodology. It must be detected by complex methodology [3, 4]. Generally, an ESD event can generate and radiate electromagnetic field that disturbs an electronic circuit called electromagnetic interference (EMI) [5]. Many studies found that the magnetic recording heads, especially read sensor can be damaged by applying the EMI to the heads which can reduce the read performance and stabilities [6, 7] nevertheless, the effects of EMI on the writer of the head have not been studied yet. The performance of the magnetic recording head can be examined by monitoring the test parameters of the read/write head such as, the normalized noise (NORM_NSE) and baseline noise (BL_NSE) for the read head meanwhile the writer resistance (WR_RES), writer width (WR_WDT) and overwrite (OVW) for the write head performance [8-11]. For the reader sensor parameters, the NORM_NSE indicates the noise generated in the read head whereas the BL_NSE refers to the signal to noise ratio of the output signal scanned from the media track [8, 9]. For the parameters of writer head, the WR_RES is normally the resistance of the write head, the WR_WDT is the width of the write field generated by the writer and the OVW indicates the ability of a write head to write over the prior data bits [10, 11].

Several researches interested in improving the performances of the read heads by focusing on the developments of the reader heads which are tunneling magnetoresistive (TMR) sensor since it has many outstanding advantages such as, high magnetoresistance ratio, thin insulator, and small sense current [12, 13], however it is very sensitive to ESD and EMI events as well [1]. Some of the TMR read head parameters affected by the EMI were experimentally investigated by P. Khunkitti *et al* [14].

The IEC 61000-4-2 ESD standard is a standard for testing the performance of the electronics systems when dominated by ESD including a contact or an air discharge mode [15]. This standard can provide a higher current than other models of ESD at the same charged voltage which also generate a higher radiated EMI.

Then, this work is the further part to measure the effects of EMI on the magnetic recording head by evaluating the changes of the other test parameters including WR_RES, WR_WDT, OVW, NORM_NSE and BL_NSE after the EMI was applied to the head by using the IEC 61000-4-2 ESD test standard. The areal density of the magnetic recording head used in this evaluation is 150 GB/in^2.

2. Experiment setup

A. Measurement of the discharge current and radiated EMI field from ESD events

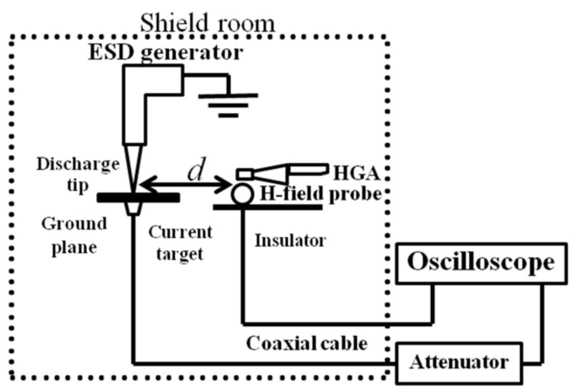

FIG. 1. Experiment setup [15].

In order to measure the discharge current and the EMI amplitude generated by the ESD, the experiment setup in Fig. 1 based on the IEC 61000-4-2 standard was described in Ref. [15]. The EMI was measured at the distances, *d*, between 2 to 30 cm from the discharge point. The H-field was reconstructed following the methodology explained by G.P. Fotis *et al* [16]. Also, the magnetic recording heads were placed at the same length with the H-field probe while measuring the H-field in order to evaluate the EMI effects on the head, described in B.

B. The evaluations of magnetic recording head by using test parameters of the head

To investigate the EMI effects on the recording heads, the EMI radiated from remoted ESD with a charging voltage of 2, 6 and 8 kV were applied to the recording heads placed at various distances. The direction of the applied EMI is similar to the experiment shown in Ref. [15]. The head gimbal assembly (HGA) attached with the slider at the tip is placed on an insulator in order to isolate the slider from the ground. The slider comprises the writer and reader of magnetic heads and the heater which is used to protrude the head to reduce the head/media spacing. The read head which is the TMR sensor consists of various magnetic and non magnetic layers. The sensing layers used to detect the data bits have been focus in this work. This is because it can be affected by the external H-field. Normally, the sensing layers of the TMR read head consist of two ferromagnetic layers separated by an insulator which are the pinned/spacer/free layers. In this experiment, both of pinned and free layers of the head have the magnetization in the in-plane direction. The magnetization of the free layer is forced by a pair of permanent magnet and will be tilted following the magnetic stray field from the media meanwhile, the magnetization of the pinned layer is biased by the an anti-ferromagnetic layer. The magnetization of the pinned layer and free layer are aligned in the perpendicular and parallel direction to the ABS. Also, the H-field was applied to air bearing surface of the slider in the direction perpendicular to the magnetization of the pinned layer because it was expected to affect the read head by interrupting the magnetization orientation of the pinned layer, which could be a cause of the noise generated in the recording head. The spin stand tester is used to measure the heads parameters which are WR_RES, WR_WDT, OVW, NORM_NSE and BL_NSE to compare the parameters during pre- and post-EMI exposure.

3. Results and Discussions

It was confirmed that the discharge current of the test system based on the IEC 61000-4-2 standard was verified by a consistency between the standard and the measured waveform, as shown in Ref. [15]. In addition, the amplitudes of H-field at various distances with different charged voltages were obtained. It was shown that the magnitude of H-field is slightly decreased with increasing the distances at approximately above 10 cm whereas a rapid increase of H-field is found when decreasing distances lower than 10 cm [15]. In principle, the magnitude of H-field depends on the length between the source and the measured point. In the near-field length, the H-field is decreased by a factor of $1/d^2$ with increasing distance whereas it is proportionally decreased by $1/d$ factor with increasing distance in the far-field length [17].

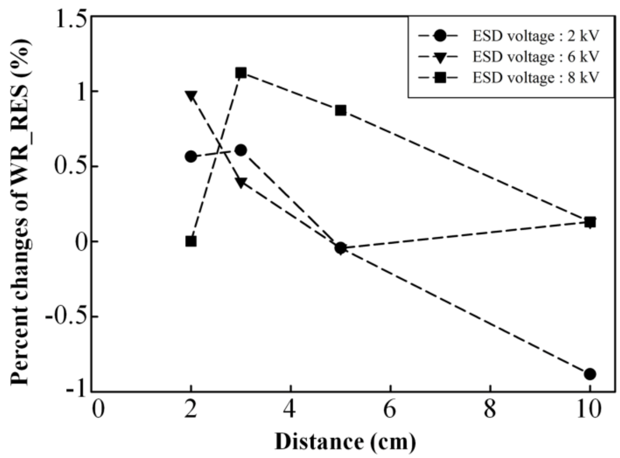

FIG. 2. The percent changes of the WR_RES of write heads at various distances for 2, 6 and 8 kV charging voltage.

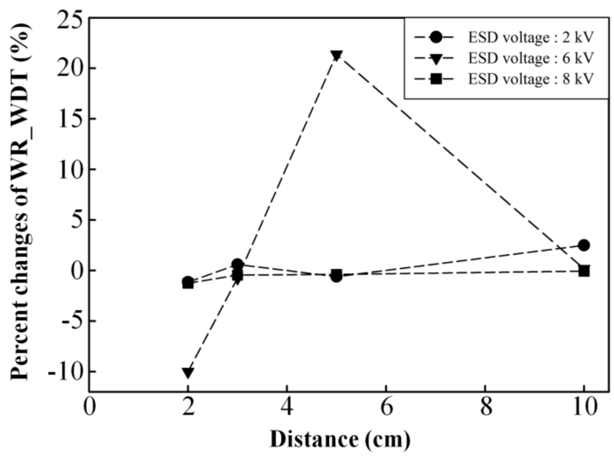

FIG. 3. The percent changes of the WR_WDT of write heads at various distances for 2, 6 and 8 kV charging voltage.

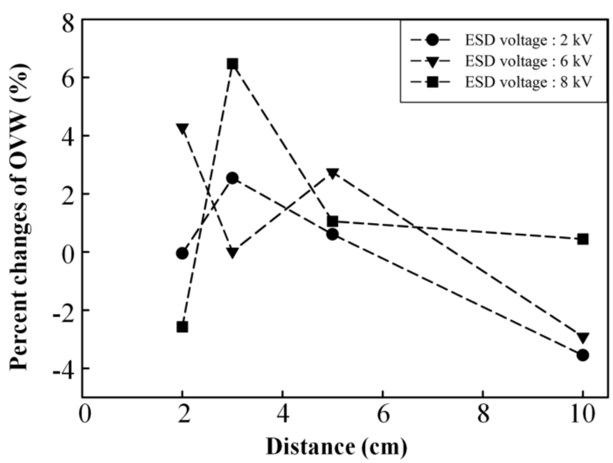

FIG. 4. The percent changes of the OVW of write heads at various distances for 2, 6 and 8 kV charging voltage.

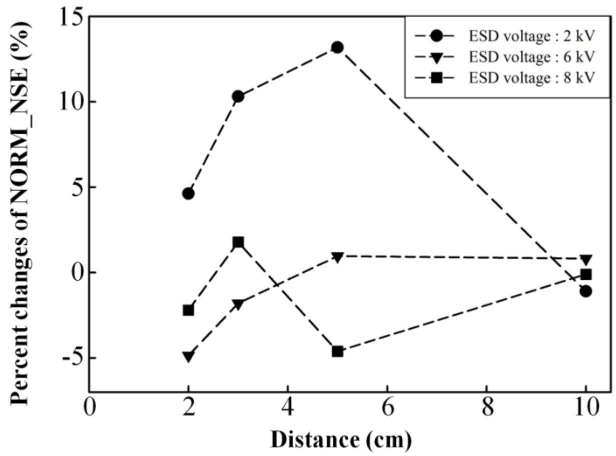

FIG. 5. The percent changes of the NORM_NSE of read heads at various distances for 2, 6 and 8 kV charging voltage.

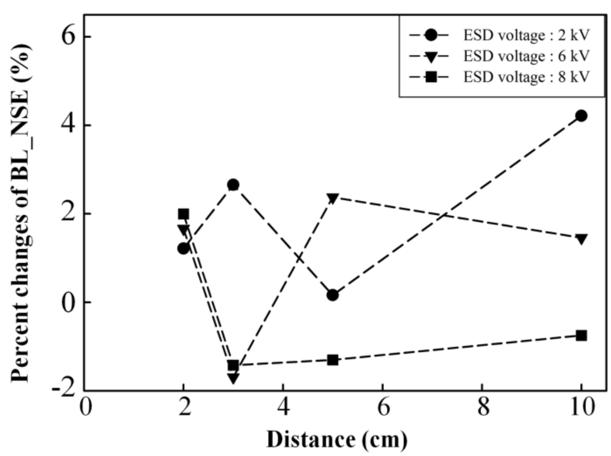

FIG. 6. The percent changes of the BL_NSE of read heads at various distances for 2, 6 and 8 kV charging voltage.

To evaluate the EMI effects on the heads, the percent changes of WR_RES, WR_WDT, OVW, NORM_NSE and BL_NSE measured pre- and post- the applied EMI are shown in Fig. 2-6, respectively. The percent changes of the test parameters measured from three heads were averaged at each data point. It was found that the test parameters were changed randomly either by rising charging voltages up to 8 kV or increasing the distance above 2 cm. Then, the random changes of head parameters need to be clarified. Hence, the test parameters were additionally measured twice without applying the EMI. The results indicate that the test parameters can be changed although there is no EMI applied to the magnetic recording head. Also, the percent changes of the parameters without applying the EMI can be varied within the same variations as the heads with EMI. Therefore, the variances of test parameters measured in this work are the results of a tester variation. Then, there are no permanent effects from the EMI applied to the magnetic heads in the perpendicular direction to the pinned layer magnetization. The reason is that the magnitude of the EMI is very small to cause any permanent cause on the magnetization of the pinned layer held by the exchange bias field from anti-ferromagnetic layer. Another reason why the changes of the test parameters were not detected is that the test parameters were measured only after the heads are completely received the effects from the EMI. Thus, this experimental procedure cannot be used to detect the temporary effects during applying the EMI to the head.

The future work is suggested to measure the changes of test parameters while the EMI is applied to the recording head and/or the head is placed at distances closer than 2 cm. This is because the magnitude of EMI will be suddenly increased by a factor of $1/d^2$ with decreasing distance in the near field length. Accordingly, the probability that the EMI could affect to the test parameters will be increased by this condition because of the very large magnitude of EMI which could modify the magnetization of the head. In addition, the dimension of the magnetic recording head needs to be shrunk for the future technology. Also, another suggested work is measuring the changes of test parameters while the EMI is applied to the magnetic recording heads, which could represent the operating condition of the heads. Then, the temporary changes of the test parameters can be detected by the tester in this condition. Nevertheless, the little changes in WR_RES, WR_WDT, OVW, NORM_NSE and BL_NSE could still be an important factor for a development of the magnetic recording head because the dimension of the heads, the heads output signal and the bit size will be reduced due to a continual increase of areal density. Thus, the test parameters of the magnetic recording heads including the WR_RES, WR_WDT, OVW, NORM_NSE and BL_NSE which indicates the performance of magnetic recording heads should be optimized in order to sustain the stability and robustness of the heads.

4. Conclusion

The EMI radiated by ESD was measured following the IEC 61000-4-2 standard. The H-field at various distances and charging voltage are in addition measured. The results also show the rapid change of H-field by changing distances within the near field region whereas the changes of H-field become slightly in the far-field length. Furthermore, in order to evaluate the effects of EMI on the magnetic read/write heads, the changes of the test parameters including the WR_RES, WR_WDT, OVW, NORM_NSE and BL_NSE were measured after the heads received the effects of EMI. It was found that there is no obvious tendency on the changes of test parameters by applying the EMI to the heads neither with charged voltage between 2 to 8 kV nor at length over 2 cm. This is because the amplitude of radiated EMI is very tiny to cause the permanent effects on the magnetic recording head by modifying the pinned layer. Then, an investigation of the EMI effects on the test parameters of the heads when the EMI are applied to the heads at distances closer than 2 cm is suggested as the future work. In addition, the changes of the test parameters should be measured during the operating processes. Thus, the EMI radiated from ESD in this work is inadequate to cause any permanent changes on the test parameters which could be an important factor to indicate the latent failure of the magnetic recording head.

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