Electrostatic Discharge가 Magnetoresistive Head의 자기적 특성에 미치는 영향

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Acknowledgment

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Al Wallash, Quantum Corp., Milpitas, CA

- A. J. Wallash, and Y. K. Kim, 'Electrostatic Discharge Sensitivity of Giant Magnetoresistive Sensors', J. Appl. Phys. 81 (8), 4921 (1997).
- Y. K. Kim, and A. J. Wallash, 'Standardized ESD Testing of AMR and GMR Recording Heads', in Understanding ESD and EMI Issues in Magnetic Recording, International Disk Drive Equipment and Materials Association (IDEMA) Symposium, p. 51 (1997).
- A. Wallash and Y. K. Kim, 'Magnetic Changes in GMR Heads Caused by Electrostati Discharge', IEEE Trans. Magn., To be published (1998).

Outline

Introduction

Experimental
- MR curve tester + "Human Body" ESD simulator
- Sensor temperature during ESD transient

Results
- Resistance, amplitude and asymmetry versus ESD voltage, current and energy
- Transfer curve slope reversal
- Magnetic failure before melting

Conclusions

Introduction

- **GMR sensors are expected to replace AMR sensors**
- **Handling operations can result in current transients**
  - Electrostatic discharge (ESD)
- **What is the ESD sensitivity of GMR sensors?**
  - Physical melting damage has been studied [1]
  - Are there *magnetic* changes?

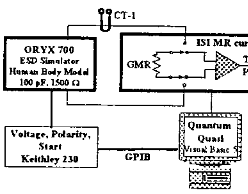
GOAL

Explore the effects of ESD current transients on the *magnetic* response of spin valve GMR sensors

1. A. Wallash and Y.K. Kim, J.Appl. Phys. 81 (8), 15 April 1997.

Experimental Setup

MR curve tester + ESD simulator
- measurement of the magnetic response of a GMR sensor before and after an ESD current transient

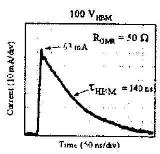


* Integral Solutions International Quasi 2000

ESD Simulator

"Human Body Model" (HBM) ESD transient
- used widely for ESD testing
- 100 pF, 1500Ω, L ~ 500 nH
- applied across two inputs of GMR read sensor

At each voltage level, two ESD transients were applied
- in the same direction as bias current (+ESD) and opposite (-ESD)

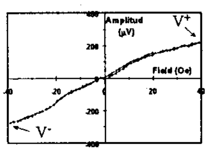


$$I_{peak} = \frac{V_{HBM}}{R_{GMR} + 1500}$$

$$Energy = \frac{I_{peak}^2 R_{GMR} \tau_{HBM}}{2}$$

MR Curve Testing

ISI MR curve tester
- flexible and easily integrated with other instruments

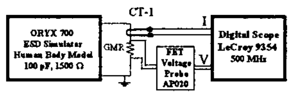


$$Amplitude = V^+ - V^-$$

$$Asymmetry = \left[\frac{V^+ - V^-}{|V^+| + |V^-|}\right] \times 100$$

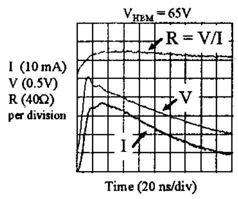
GMR heads used in this study
- Ta 5/NiFe 7.5/Co 2/Cu 3/Co 2/NiFe 7.5/**FeMn** 10/Ta 5 nm
- resistance = 30 Ω, stripe height = 1.3 μm, track width = 1.6 μm
- MR test conditions: 5 mA and +/- 40 Oe

Sensor Temperature during ESD



Measured voltage (V) and current (I) during transient
- R(t) = V(t)/I(t)

Use R_{peak} with TCR to calculate peak temperature



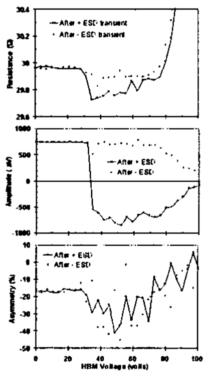
R(0.1 mA) = 33.6 Ω
TCR = 0.14%/°C
For V_{HBM} = 65V:
I_{peak} = 41 mA
V_{peak} = 1.8 V
R_{peak} = 52.7 Ω
T_{peak} = 425 °C

Results

First change at 35 V_{HBM}
- Small (1%) resistance change
  - nonpermanent and reversible
- Negative amplitude
  - slope reversal
- Asymmetry changes

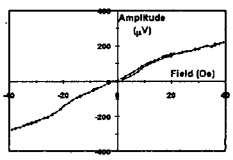
Permanent resistance change at 80 V_{HBM}
- melting or other physical damage

Magnetic failure threshold
- **35 V_{HBM}, 23 mA, 0.9 nJ**

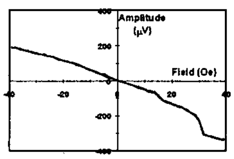


Slope Reversal of MR Curve

Transfer curve at start and up to 35 V_{HBM}

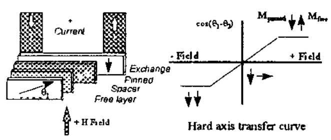


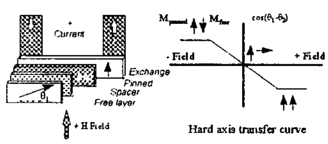
Transfer curve after +35 V_{HBM} ESD transient



- Slope reversal!
- Asymmetry shift
- Magnetic instability (kink)

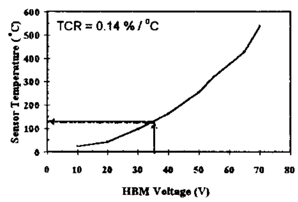
Slope Reversal of Transfer Curve





Slope reversal if pinned layer is *reversed.*

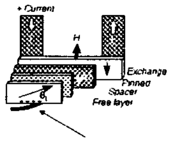
Temperature during ESD transient



- Slope reversal (magnetic failure) occurred at 35 VHBM
- Average calculated sensor temperature = 125 °C
- Consistent with blocking temperature (T_b) of FeMn exchange layer (~150 °C)

ESD ⟹ Temperature + Field

An current transient results in
- increased sensor temperature
- an internal magnetic field which can aid (- current) or *oppose* (+ current) the exchange direction



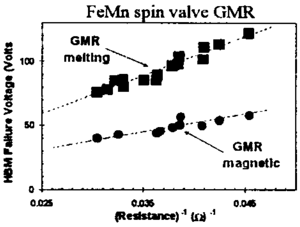
"Right hand rule"

I_{peak}	Temperature	Internal H-field	Result
> 23 mA	> T_b	opposite to original direction	Reversed exchange layer
> -23 mA	>T_b	in the original direction	Resets exchange layer back

Therefore the toggling back and forth of the slope

Melting and Magnetic Failure

FeMn spin valve GMR



Magnetic failure level ~ 40% of the melting failure level

Conclusions

ESD stress testing has revealed a new and important magnetic failure mechanism in spin valve GMR heads
- reversal of exchange layer
- magnetic failure levels much lower than melting failure
  - 35 V HBM (magnetic) vs. 80 V HBM (melting)
  - 0.9 nJ (magnetic) vs. 6 nJ (melting)

Test methodology can be used to compare magnetic failure levels for different spin valve designs
- different exchange materials with higher blocking temperatures