ESD Testing of GMR Heads as a Function of Temperature

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Outline

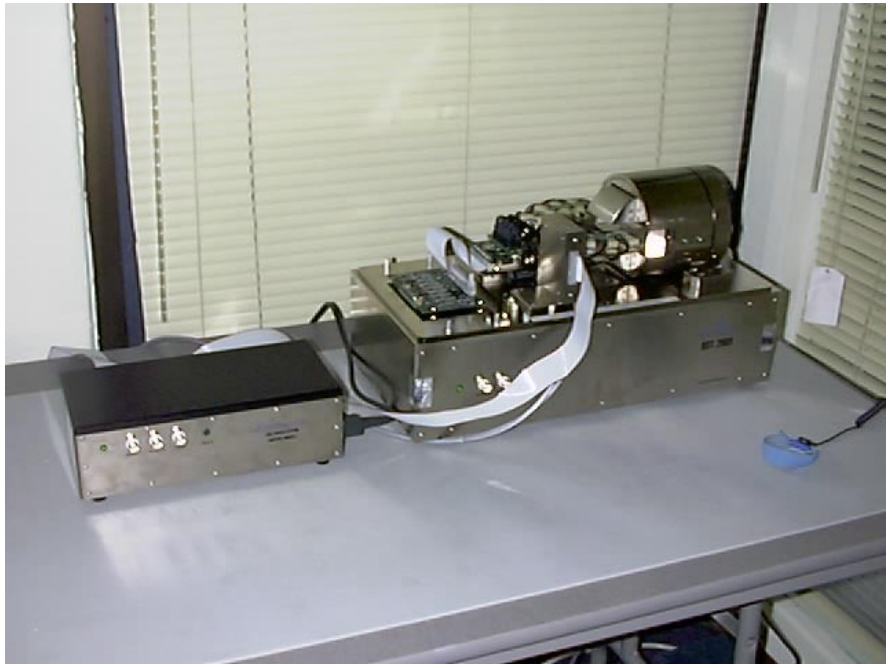
- **Motivation**
  - Why do ESD testing at higher temperatures?
- **Experimental Setup**
  - R(H) curve testing (QST)
  - HBM ESD Simulator
  - Temperature controlled substrate
- **Results**
  - IrMn spin valve design
  - PtMn spin valve design
- **Conclusions**

Motivation

- **Why do ESD testing of GMR heads vs. temperature?**
  - GMR sensor experiences higher temperatures at various steps in the process and in the drive
    - » deposition, annealing, curing, etc.
  - Could the ESD failure voltage or behavior be different at higher temperatures?
    - » Failure voltage expected to decrease
      - Higher resistance and closer to blocking temperature of exchange layer
  - Important to know the ESD failure voltage of GMR heads under every use condition
    - » Never been done before!

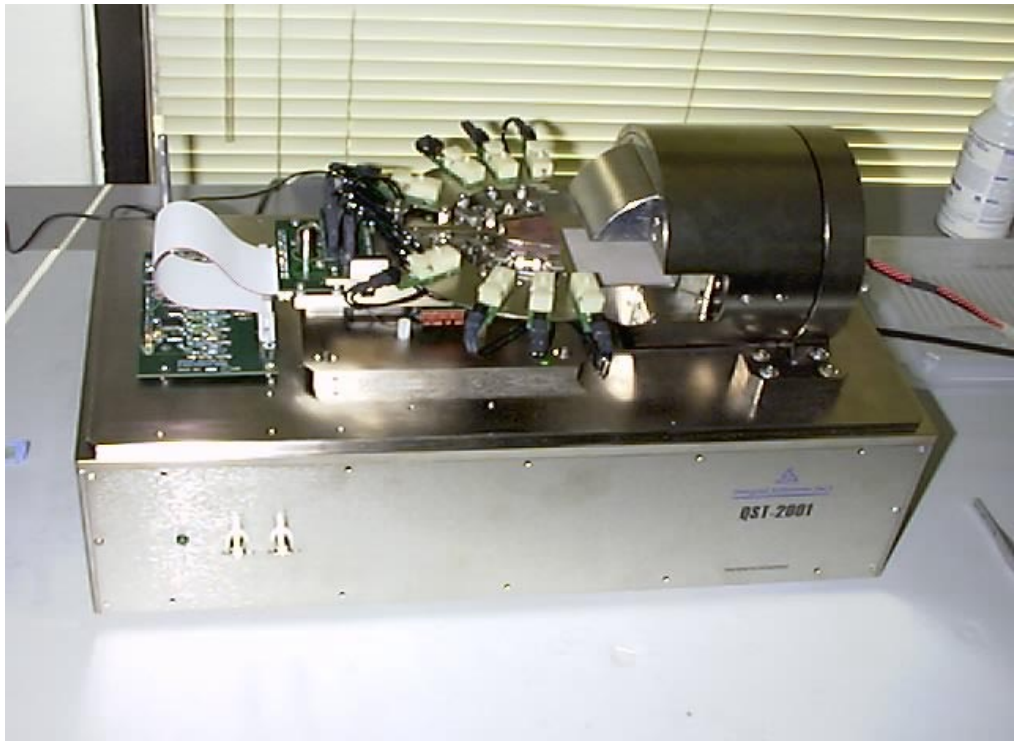
Overview of Experimental Setup

- Quasi-static (QST) tester
  - R(H) Tester
- HBM ESD simulator
  - Integrated programmable bipolar unit
- Temperature controlled substrate
  - Closed-loop temperature control system



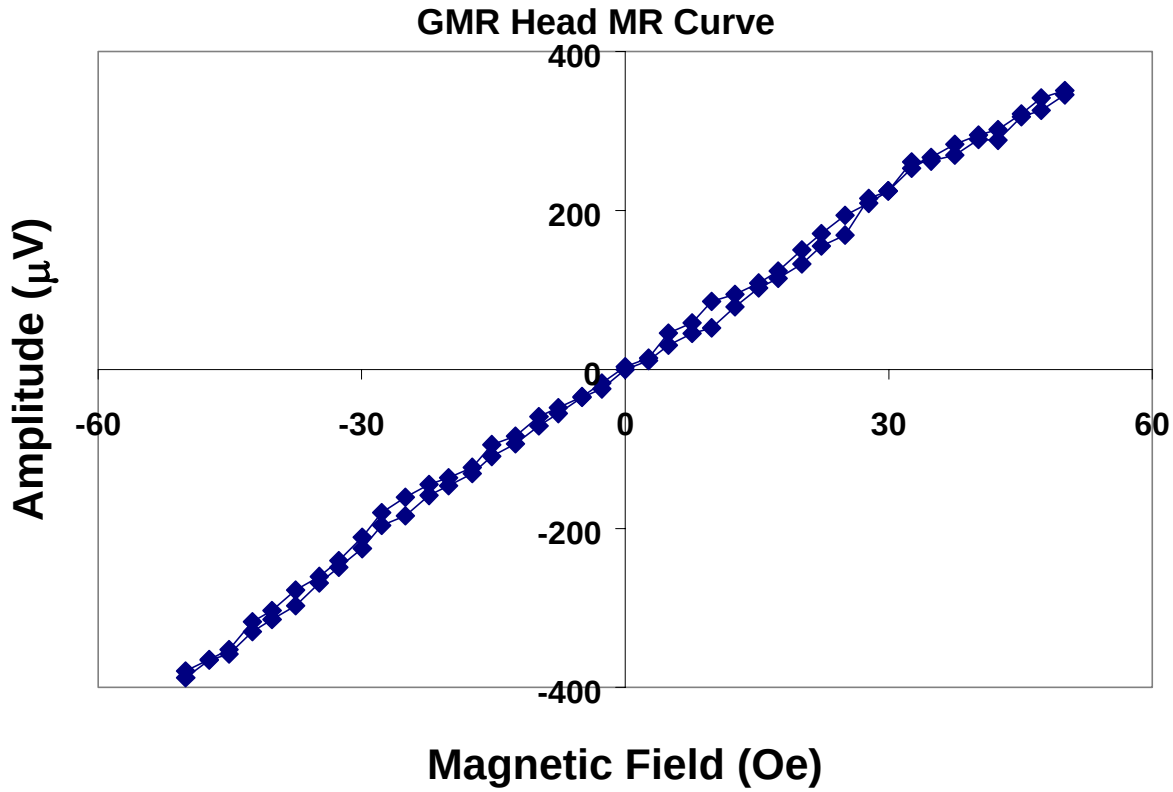
Quasi-Static Testing

- ISI QST-2001 MR Curve Tester
- +/- 750 Oe
- Testing of up to 8 heads at a time
- *In-situ* testing of heads up to 250 ^{o}C



R(H) Curve QST Testing

- Amplitude vs. magnetic field plot is known by many names
  - transfer curve
  - R(H) curve
  - MR curve
  - Quasistatic test (QST)

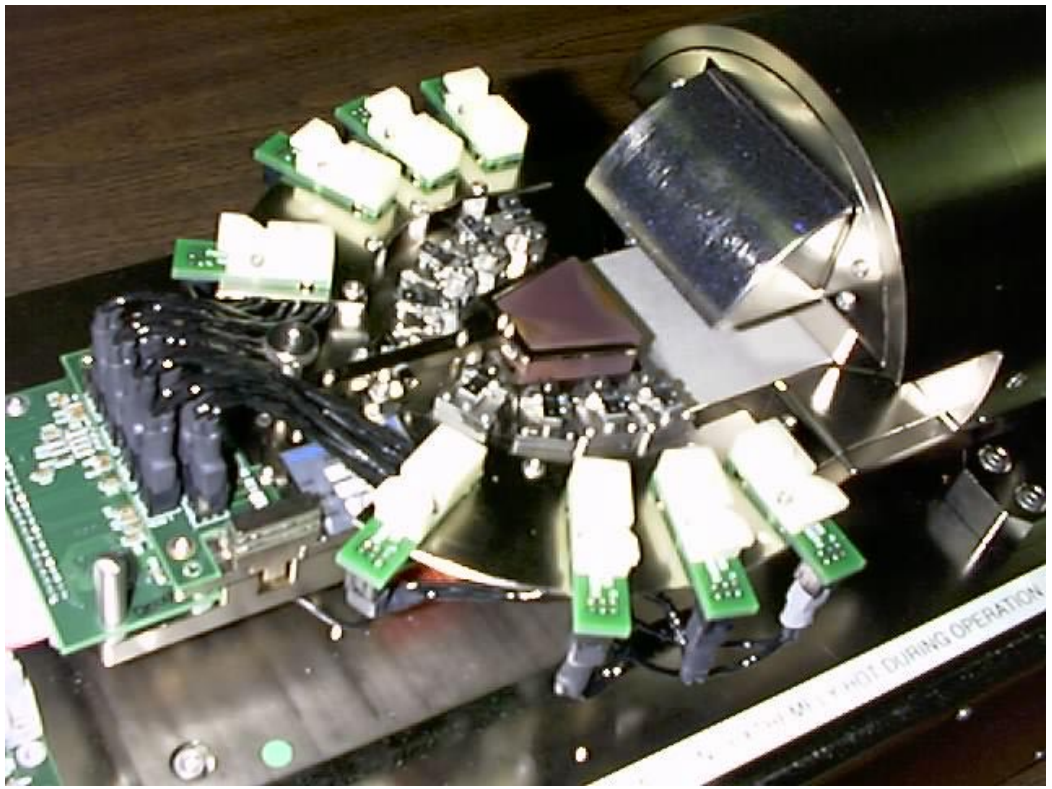


ESD Simulator

- Human Body Model (HBM) Module
- Jedec Standard HBM Waveform
  - 100 pF, 1500 Ω
- Range: +/- 500V
- Fully software controlled

Temperature Controlled Substrate

- **8x Hot Finger ***
  - Lake Shore Closed-Loop Temperature Controller LS340
  - 100 Watt Heater
  - Platinum Resistor Thermometer
  - 0.01C Stability



*See “Thermal Stability Testing of GMR Heads” by Al Wallash and Nelson Cheng. Paper DB-07 INTERMAG 99.

Experimental: Design 1

- Design 1: Spin valve GMR design with IrMn exchange layer
- R(H) curve test conditions
  - +/-5 mA
  - +/- 50 Oe
- Test Temperatures:
  - 26 ^{o}C, 100 ^{o}C, 125 ^{o}C, 150 ^{o}C, 200 ^{o}C

Experimental: Design 2

- Design 2: Spin valve GMR design with PtMn exchange layer
- R(H) curve test conditions
  - +5 mA
  - +/- 150 Oe
- Test Temperatures:
  - 26 ^{o}C, 100 ^{o}C, 150 ^{o}C, 200 ^{o}C

Test Methodology

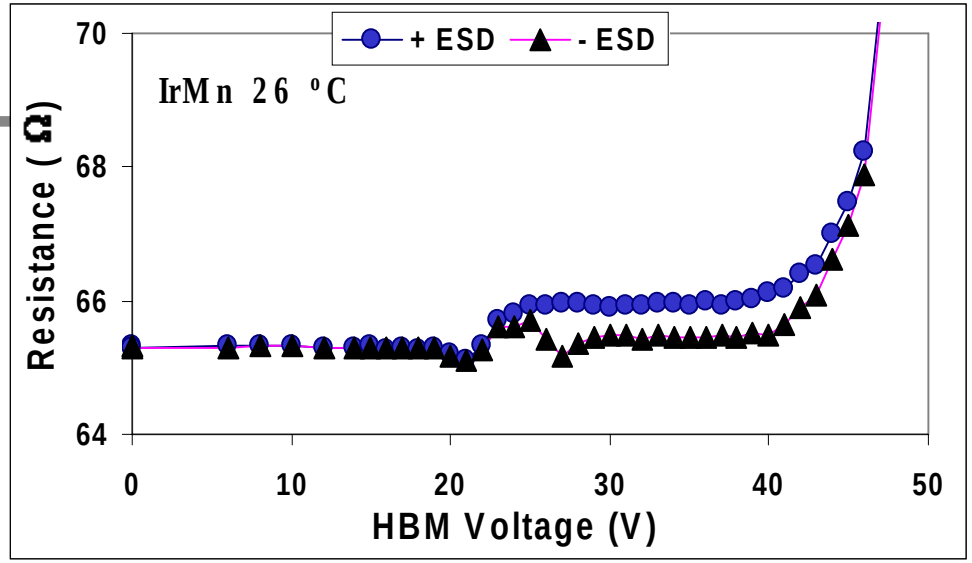
- Ambient temperature transfer curve was measured as a benchmark
- Head brought to target temperature and checked for stability
- Head subjected to ESD step stress testing

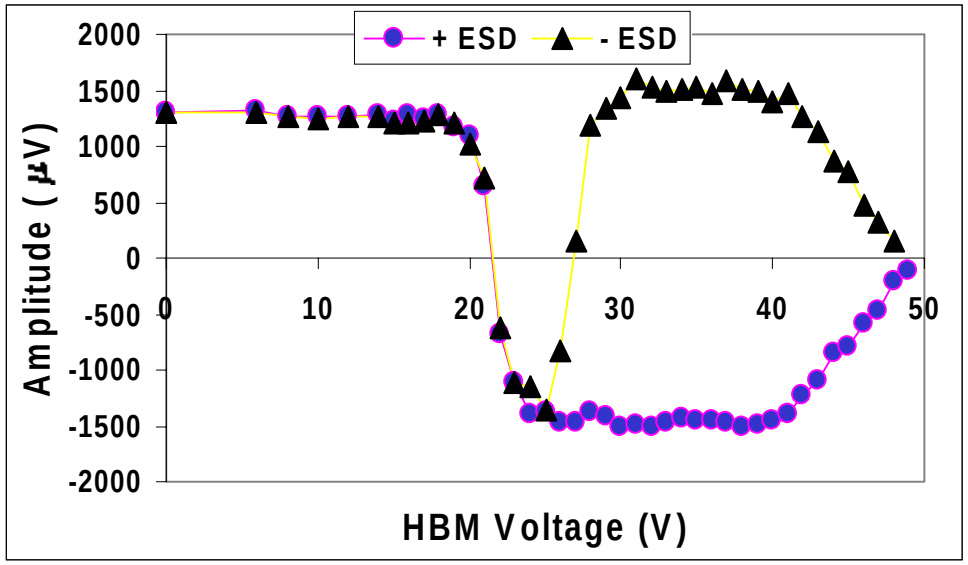
ESD Testing Configuration

- Bias current remained on during testing except during injection of ESD pulse
- Bipolar ESD pulse at each voltage
  - positive first
- Testing of heads at both positive and negative bias currents for IrMn

IrMn:
+ 5 mA: 26 ºC

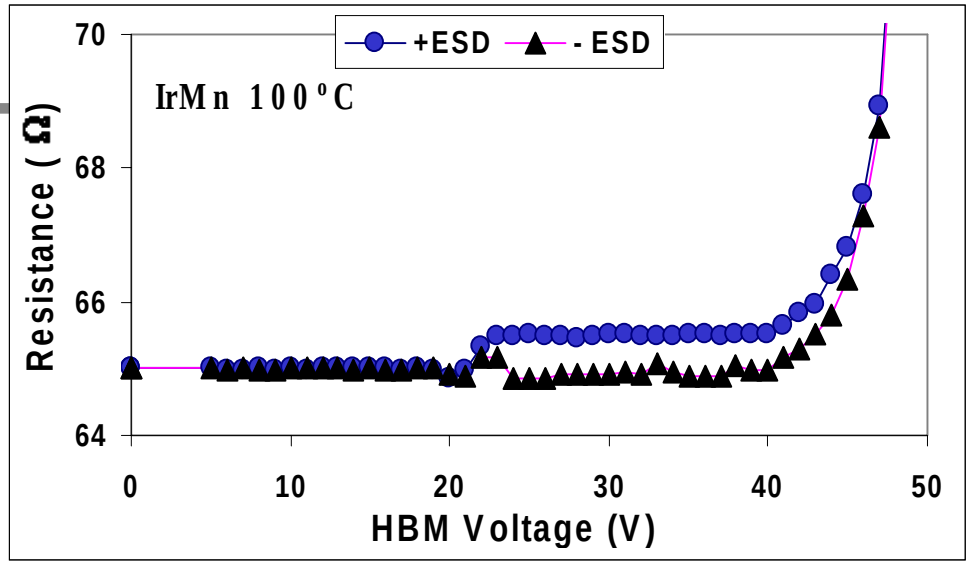
- Magnetic damage at 22 V_{HBM} : pinned layer reversal with transfer curve slope reversal
- 28 to 50 V_{HBM} : pinned layer toggles back and forth between reset and reversed states
- *Reset amplitude ~ initial amplitude*
- ~40 V_{HBM} : permanent resistance increase and amplitude loss

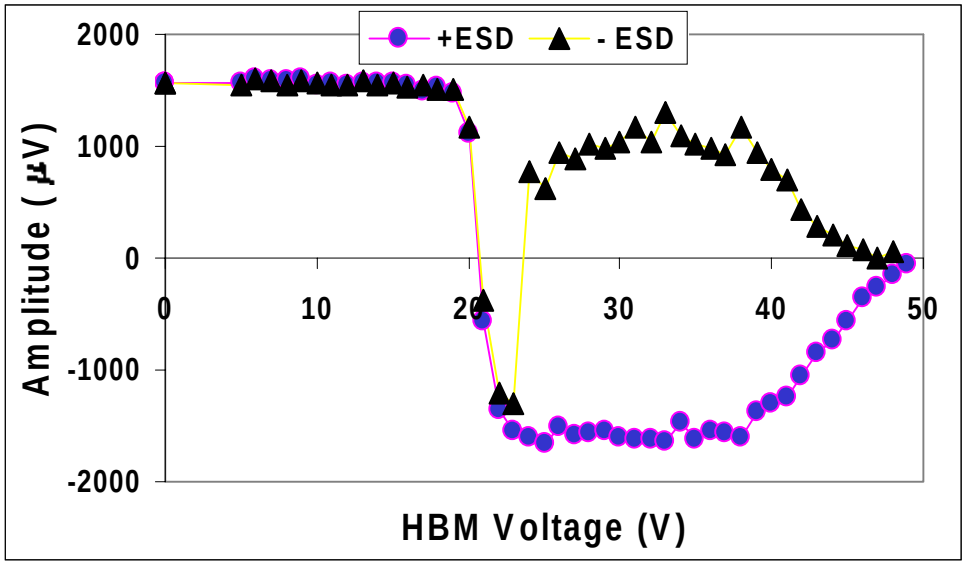




IrMn:
+5 mA: 100 ºC

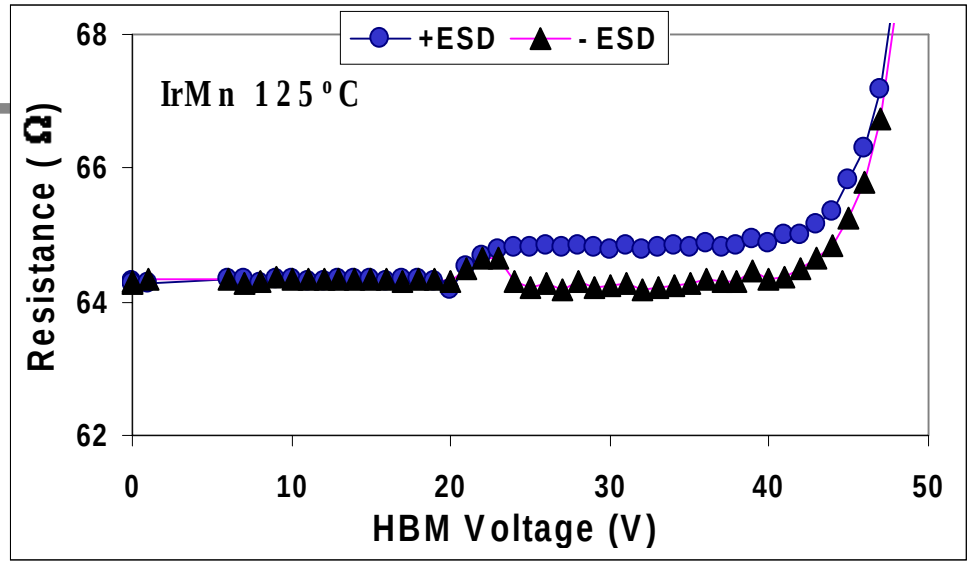
- Magnetic damage at 21 V_{HBM}
- 24 to 40 V_{HBM} : pinned layer toggles back and forth
- *Reset amplitude < initial amplitude*
- ~40 V_{HBM} : permanent resistance increase

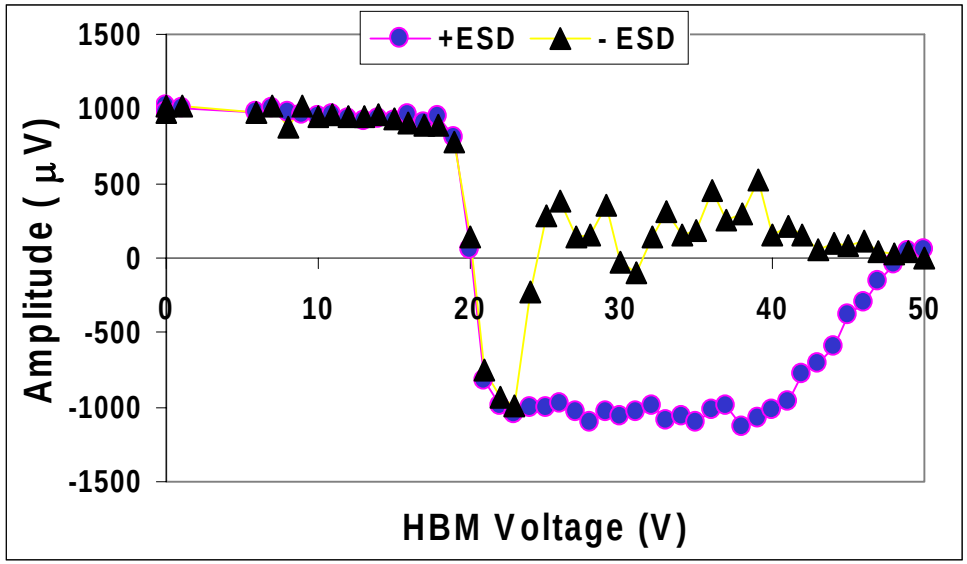




IrMn: +5 mA:125 ºC

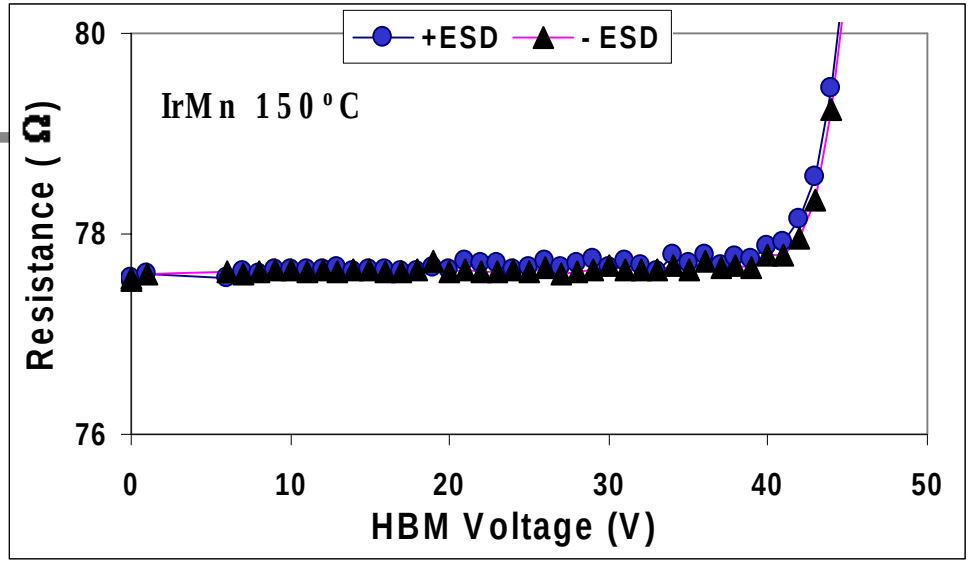
- Magnetic damage at 20 V_{HBM}
- 24 to 40 V_{HBM} : pinned layer toggles back and forth
- *Reset amplitude < initial amplitude*
- ~40 V_{HBM} : permanent resistance increase

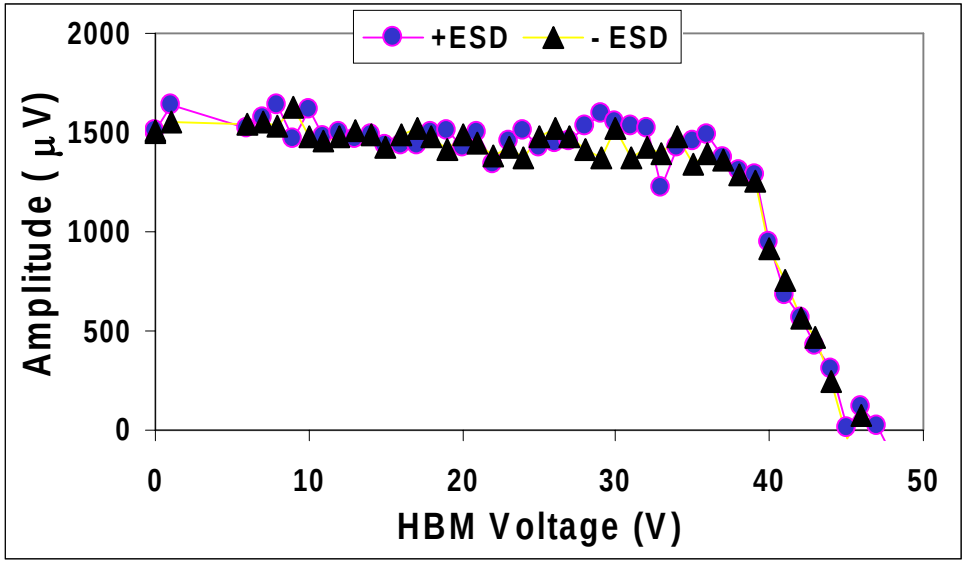




IrMn:
+5 mA:150 ºC

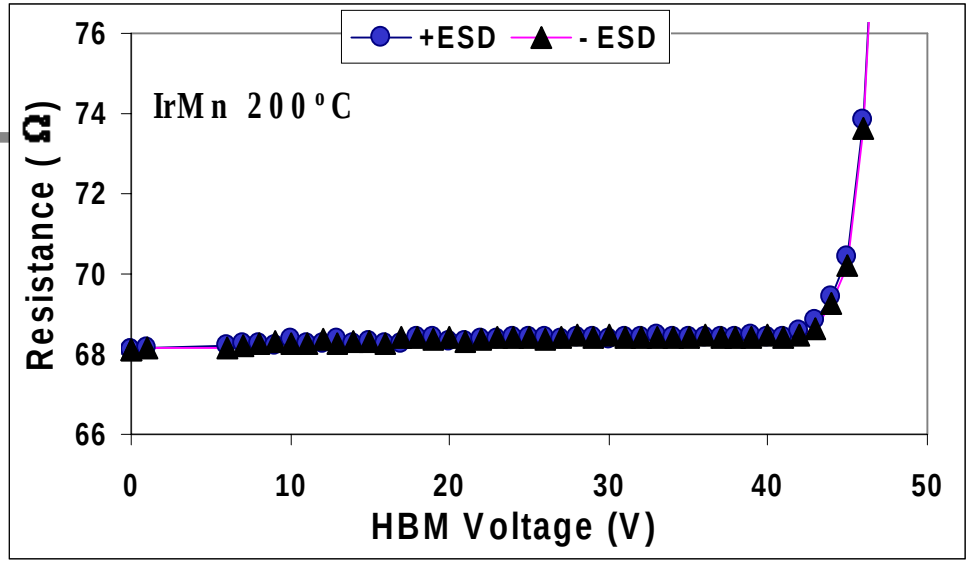
- Dramatically different magnetic behavior from that seen at lower temperatures!
- No pinned layer reversal or toggling of the pinned layer!
- ~40 V_{HBM} : same permanent resistance increase

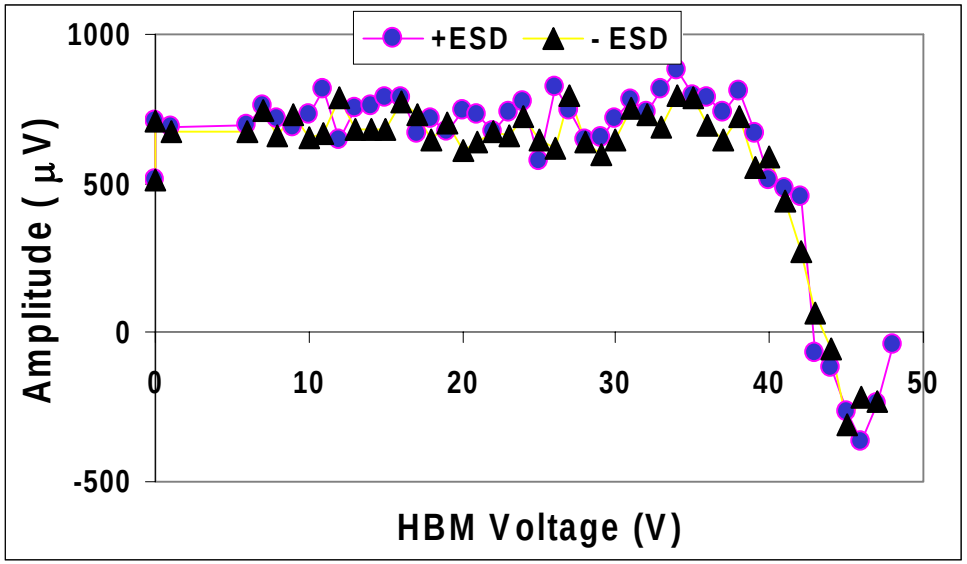




IrMn:
+5 mA: 200 ºC

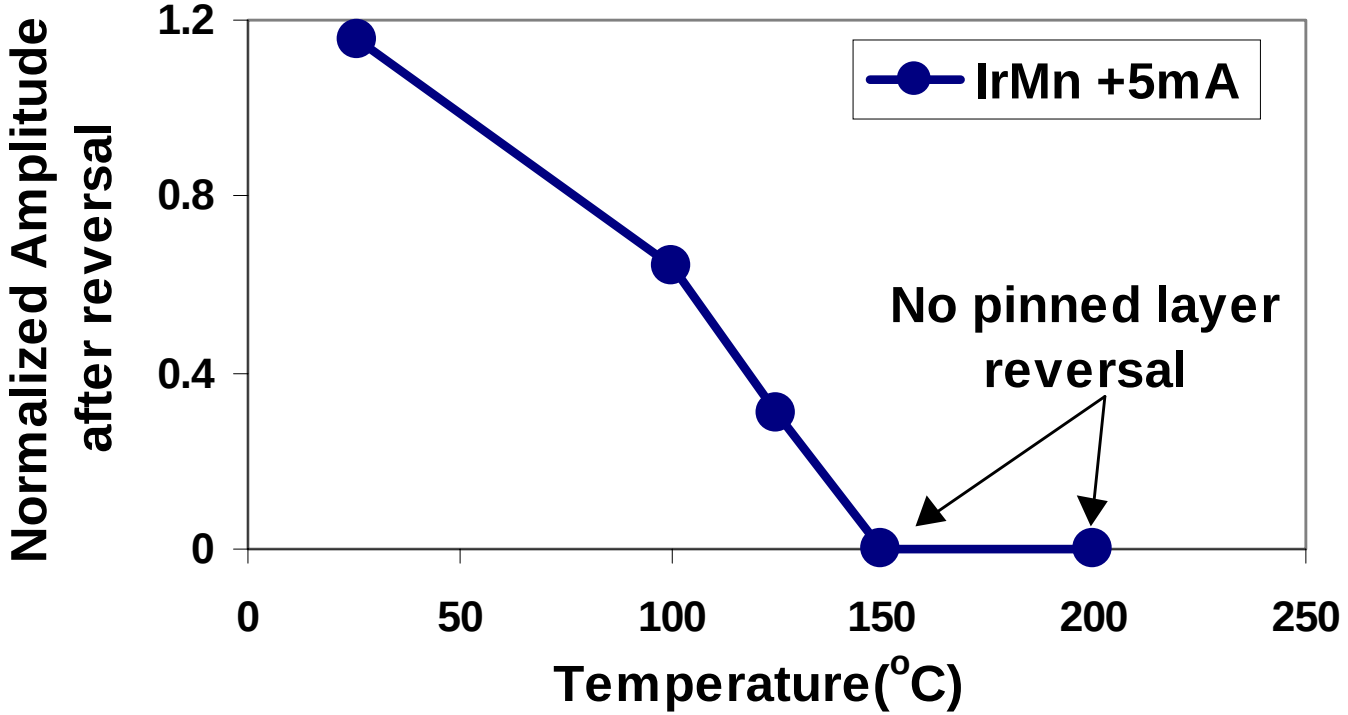
- **No pinned layer reversal or toggling of the pinned layer!**
- ~40 V_{HBM} : same permanent resistance increase
- Transfer curves showed more instability and amplitude variation





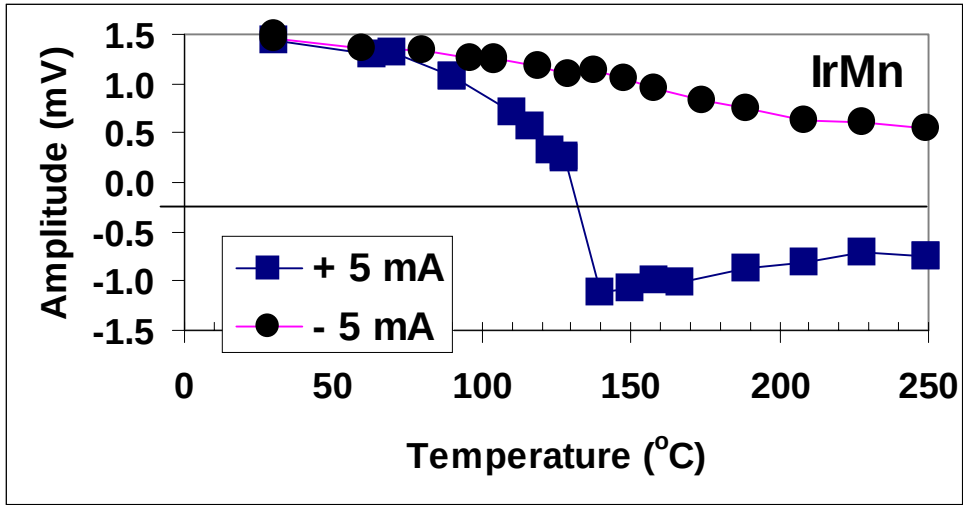
Summary of +5 mA data for IrMn

- No significant change in resistance failure voltage with temperature
- No change in onset of pinned layer reversal for T<125C
- Amplitude after reversal was reduced for T<125C
- ***Disappearance of pinned layer reversal* for T > 150 °C**



IrMn: Amplitude vs. temperature with bias current on

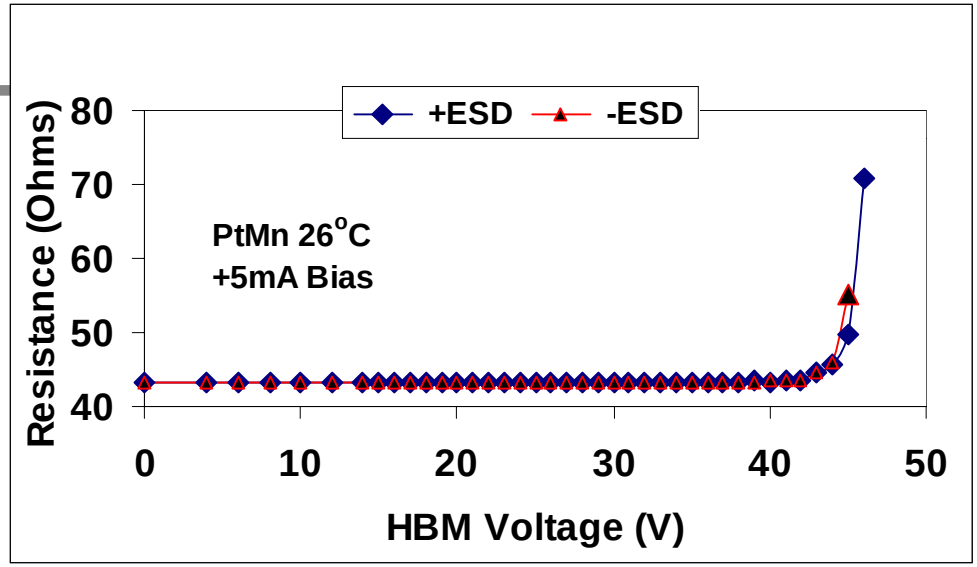
- *Positive bias current reverses the pinned layer above ~130 °C*
- *Negative bias current at >130 °C resets any pinned layer reversal due to ESD*
- *Above 130 °C turning the bias current on sets or resets the pinned layer*

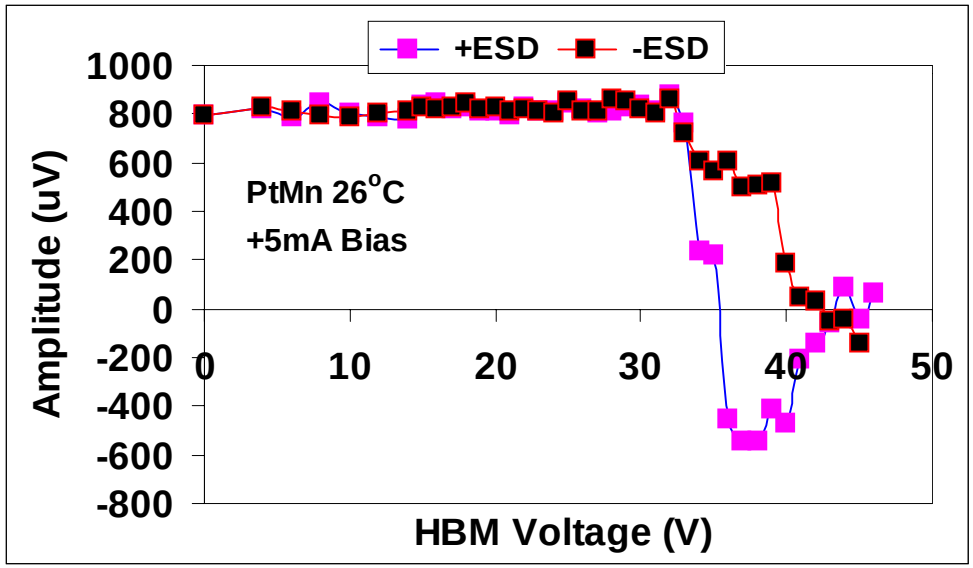


Negative amplitude means slope reversal

PtMn: +5mA 26 ºC

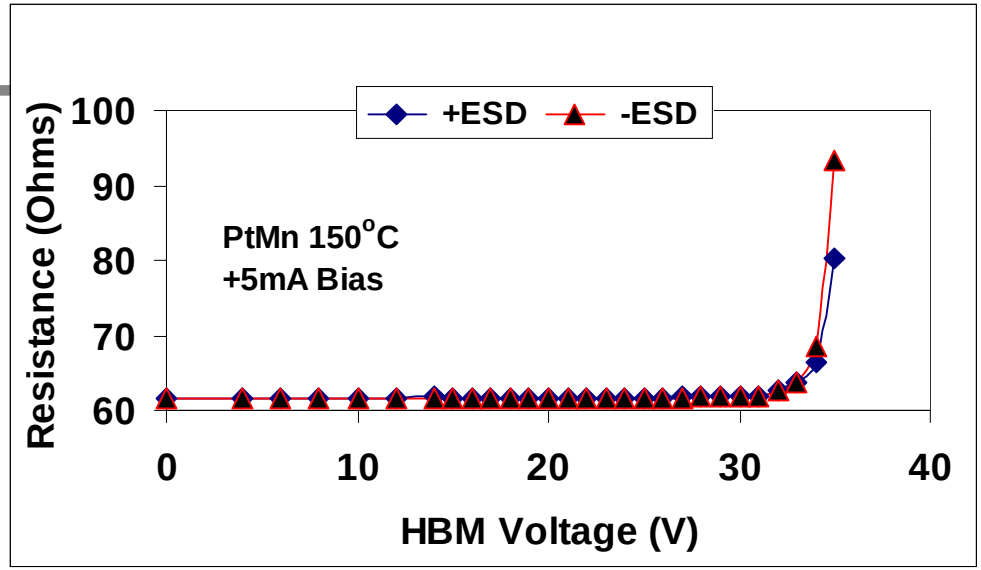
- Magnetic damage at 34 V_{HBM}
- Pinned layer reversal with transfer curve slope reversal at 36 V_{HBM}
- 36 to 43 V_{HBM} : pinned layer toggles back and forth between reset and reversed states
- ~43 V_{HBM} : permanent resistance increase and amplitude loss

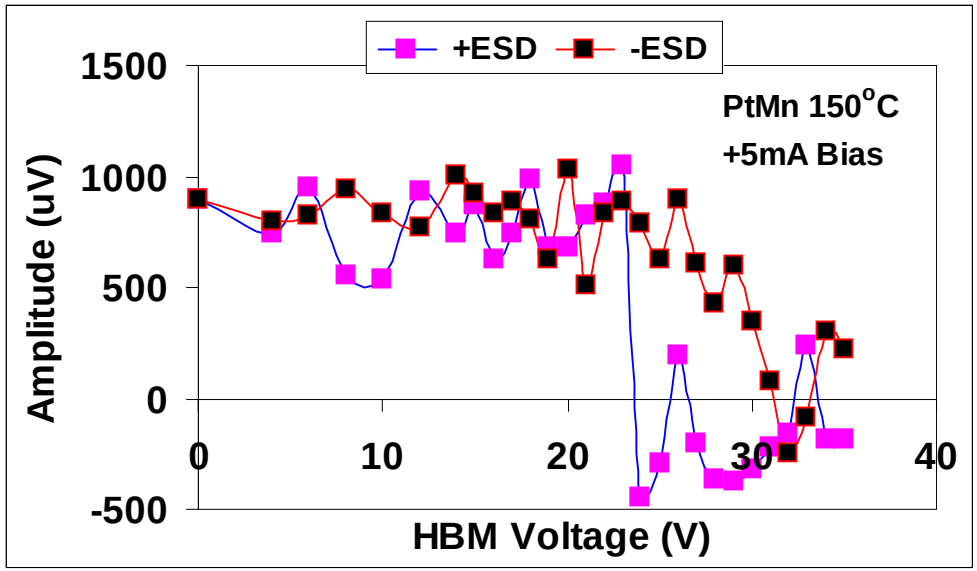




PtMn: +5mA 150 ºC

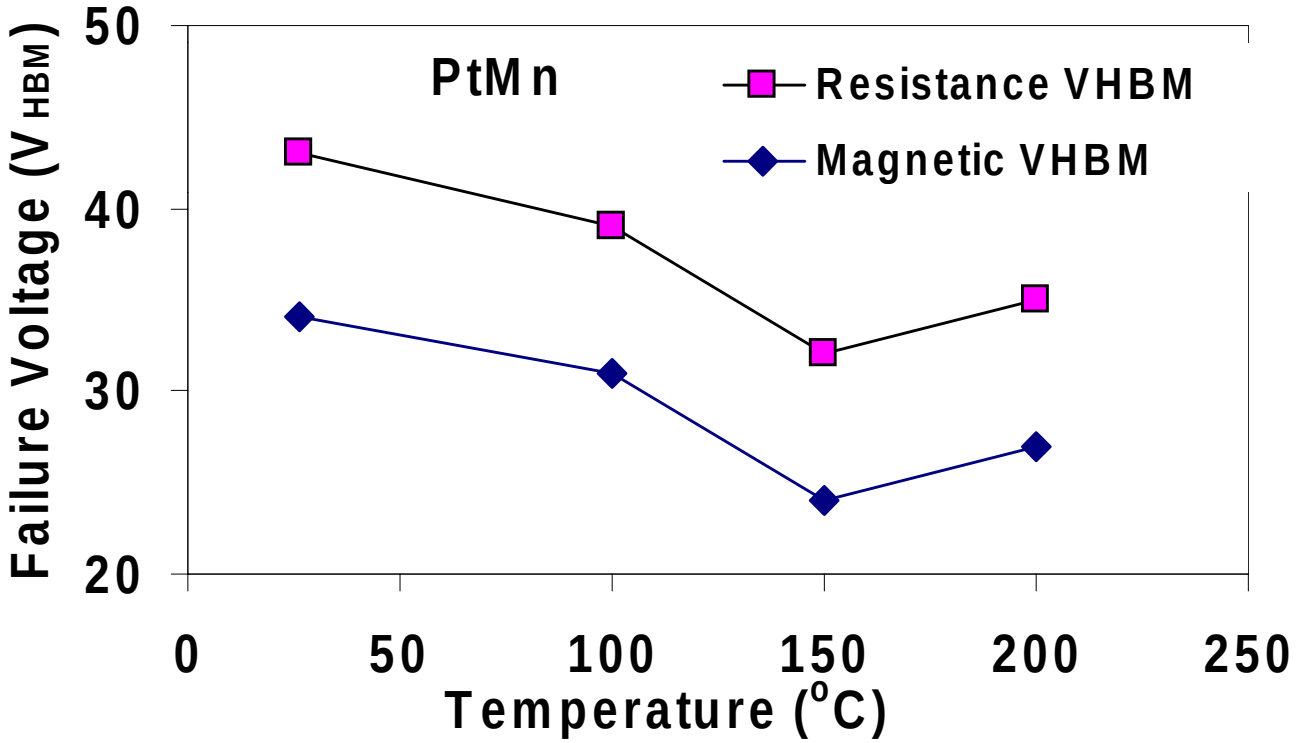
- Magnetic damage at 24 V_{HBM}
- 24 to 32 V_{HBM} : pinned layer toggles back and forth
- ~32 V_{HBM} : permanent resistance increase
- Significant amplitude instability



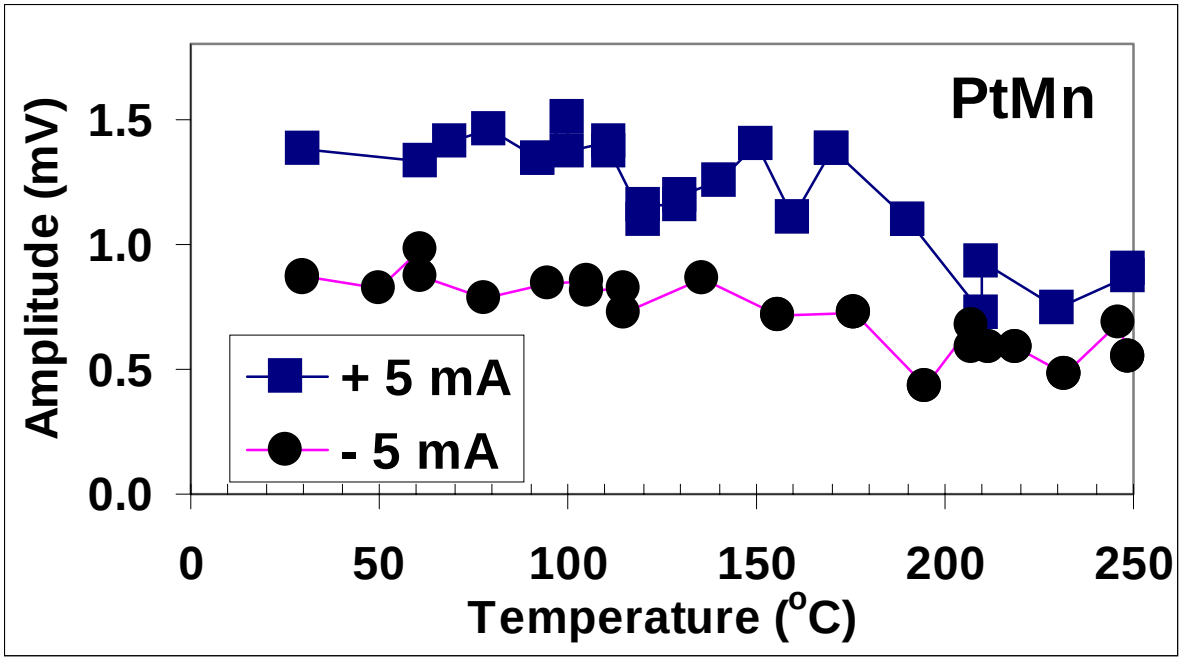


Summary of data for PtMn

- Magnetic and resistance failure voltage decrease with temperature



PtMn: Heating with bias current



- *No slope reversal due to bias current as PtMn design is heated with bias current on*
- *Dramatically different from IrMn design*

Conclusions

- QST/ESD/hot finger setup permits study of GMR heads as a function of temperature and ESD

- Characterization of ESD behavior at higher temperatures has produced some unexpected results
  - expected a simple decrease in magnetic failure voltage vs. temperature
  - measured no decrease in failure voltage in IrMn heads
    - » "stable" two-state ***pinned-layer reversal behavior disappeared*** above 150 ^{o}C in IrMn Heads due to bias current masking
  - PtMn Heads exhibit decrease in failure voltage vs. Temp
    - » Function of increased head resistance or proximity to blocking temp?

Conclusions

- Different head designs produce significantly different results
- Important and interesting to measure the ESD failure levels of GMR heads as a function of temperature