Spin-dependent Tunneling Characteristics of Co2MnSi-based Magnetic Tunnel Junctions with $Co_{50}Fe_{50}$ Insertion Layers

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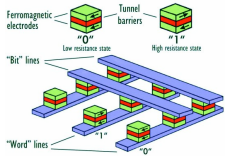
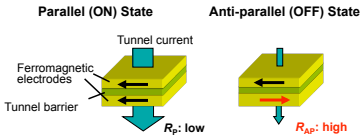
Introduction

Magnetoresistive Random Access Memory (MRAM)



- Non-volatile
- High speed
- High density
- Unlimited read/write endurance
- **Principal switching component: magnetic tunnel junctions**

Magnetic Tunnel Junctions (MTJs)



Key device parameter:

$$\text{TMR ratio} = \frac{R_{AP} - R_P}{R_P}$$

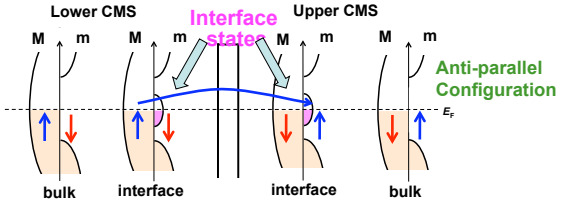
High spin-polarization is desirable to yield high TMR ratios

Heusler Alloy Half-Metallic Electrodes

- Complete spin polarization: only electrons of one spin involved in conduction
- Co_2MnSi (CMS) is a good candidate due to large energy gap for minority-spin electrons and high curie temperature

Purpose

- Previously demonstrated CMS/MgO/CMS MTJS with TMR ratios up to **236% at RT and 1135% at 4.2K** (Ishikawa et al., Appl. Phys. Lett. 2009)
- Large drop in TMR ratio at high T might be due to MgO/CMS in-gap interface states combined with magnon excitations



Purpose of this study is to understand this phenomenon in order to fabricate devices with higher TMR ratios

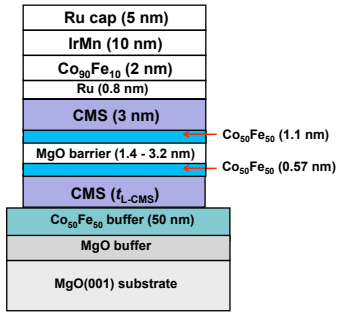
Methods

Approach

- Fabricate CMS-based MTJs with **interfacial insertion layers** in order to mitigate interfacial effects that tend to decrease TMR
- Measure and analyze the spin-dependent tunneling characteristics of these devices to elucidate tunneling paths

MTJ Fabrication

- MTJ layer structures were epitaxially grown on an MgO(001) substrate in a high vacuum chamber
- Layers deposited with magnetron sputtering and electron beam evaporation
- Samples processed using photolithography and argon ion milling



Results

TMR Characteristics

	TMR Ratio	
Layer structure	**RT**	**4.2 K**
MgO buff/CMS/MgO/CMS	**236%**	**1135%**
MgO buff/CoFe/MgO/CoFe	**250%**	**350%**
MgO buff/CoFe/MgO/CoFe/CMS	**450%**	**1135%**
MgO buff/CoFe buff/CMS/CoFe/MgO/CoFe/CMS	**413%**	**1523%**

- Presence of CMS dramatically improves TMR, indicating half-metallic characteristics
- Moreover, addition of insertion layers in CMS/MgO/CMS structures show further enhanced TMR

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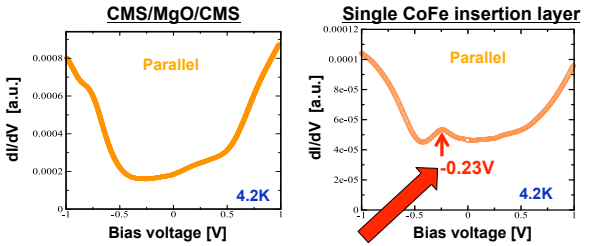
Results (cont.)

Tunneling Spectroscopy

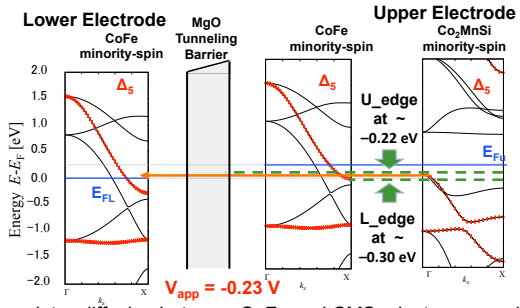


Peak at -0.23 V observed only in insertion layer MTJs

Discussion and Conclusion

Discussion

- Unique peak can be attributed to minority-to-minority tunneling path associated with the Δ5 symmetry (-0.22 eV to -0.30 eV)



- Low inter-diffusion between CoFe and CMS: electrons supplied by CMS, and tunnel to lower electrode through CoFe
- Suggests that CoFe's primary role is to weaken magnon effects

Conclusion

- Demonstrated high TMR ratios up to 450% for CMS-based MTJs with $Co_{50}Fe_{50}$ insertion layers
- Tunneling spectroscopy confirmed that CMS acted as half-metallic spin-source while $Co_{50}Fe_{50}$ weakened magnon excitations
- **Future work:**
  - Understanding drop in TMR in double insertion layer MTJs
  - Further optimizing interfaces to enhance TMR