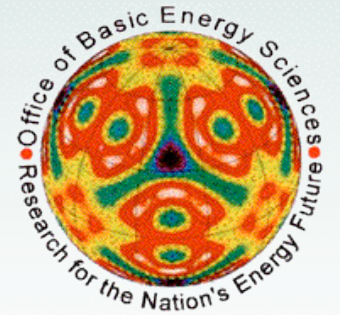
Resonant Spin-Dependent Tunneling Through Metallic Quantum Well States

X.-G. Zhang, Zhongyi Lu, and Sokrates Pantelides

Center for Computational Sciences &

Computer Science and Mathematics Division

Oak Ridge National Laboratory



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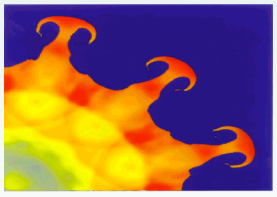

Mathematical, Information, and Computational Sciences Division

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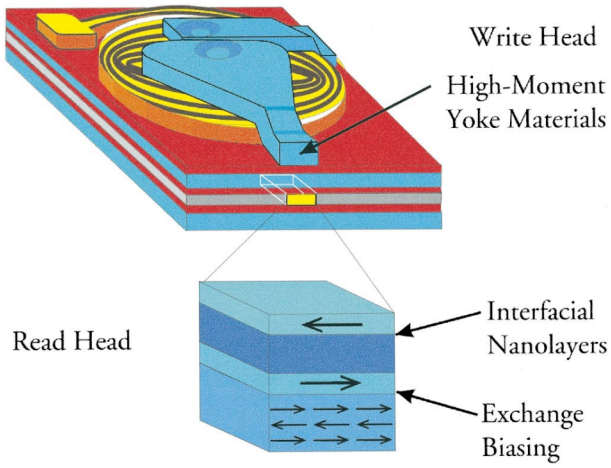
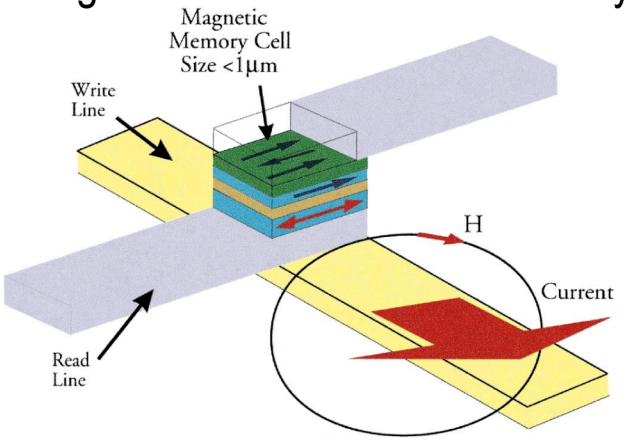
UT-BATTELLE

Magneto-transport in spin-valve

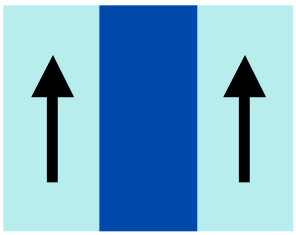
Recording head

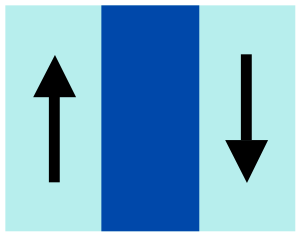


Magnetic Random Access Memory

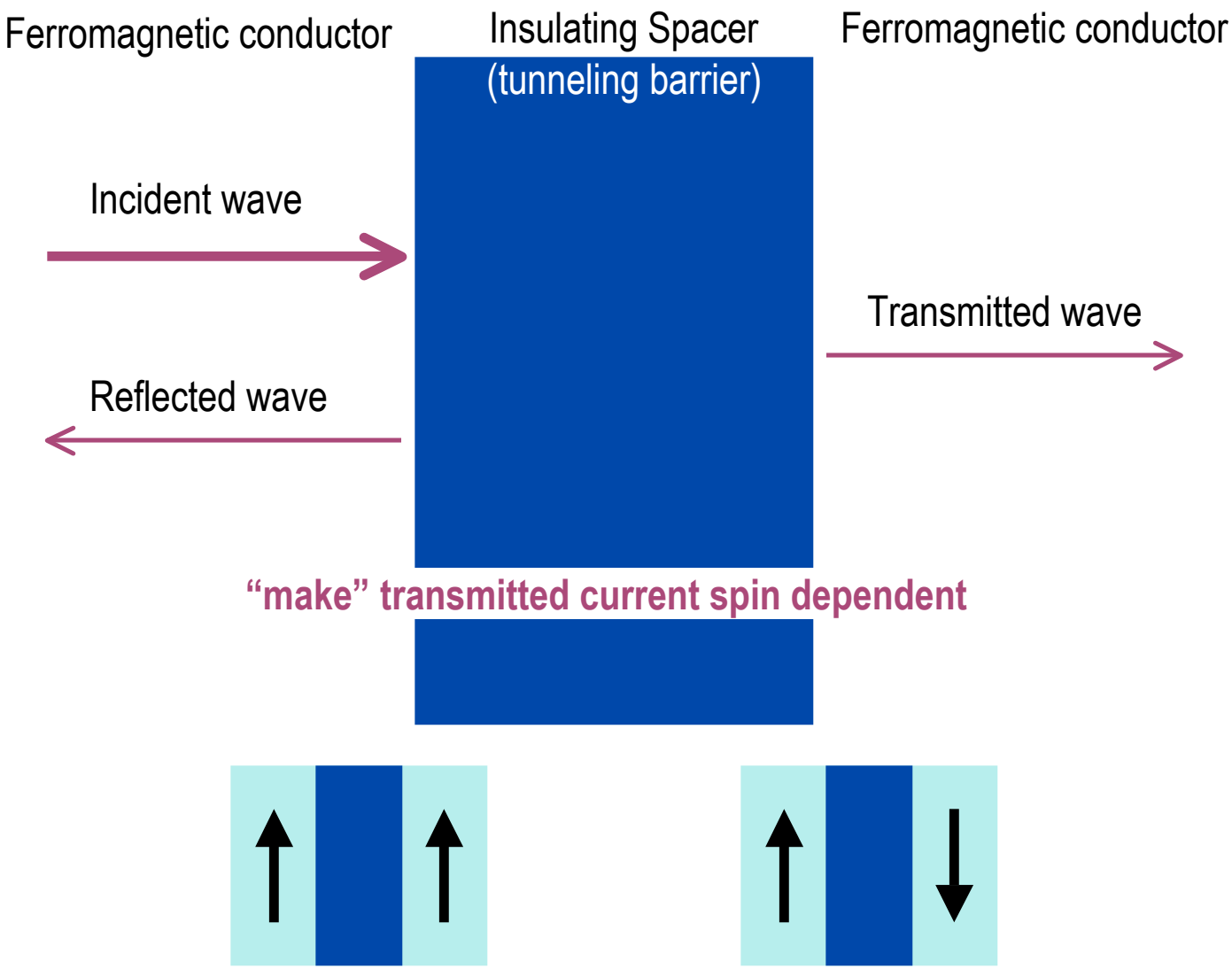


Detect decrease in resistance when moments in two ferromagnetic layers are aligned





Spin-dependent tunneling



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Quantum size effect in magnetic tunnel junctions with ultrathin Fe(001) electrodes

T. Nagahama[a)]
Nano-electronics Research Institute, AIST, Umezono 1, Tsukuba, 305-8568, Japan; CREST-Japan Science and Technology Corporation, Honmachi 4-1-8, Kawaguchi, Saitama, Japan; and Joint Research Center for Atom Technology, Higashi 1-1-4, Tsukuba, 305-8562, Japan

S. Yuasa
Nano-electronics
Science and Techn

Y. Suzuki
Nano-electronics
and Technology C
Center for Atom T

E. Tamura
Angstrom Technol

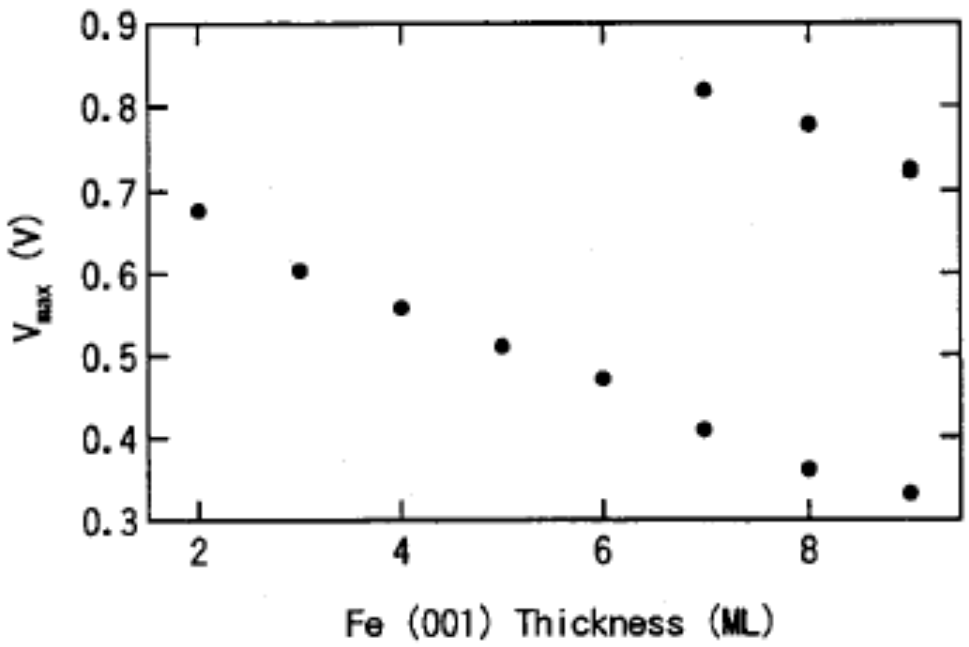
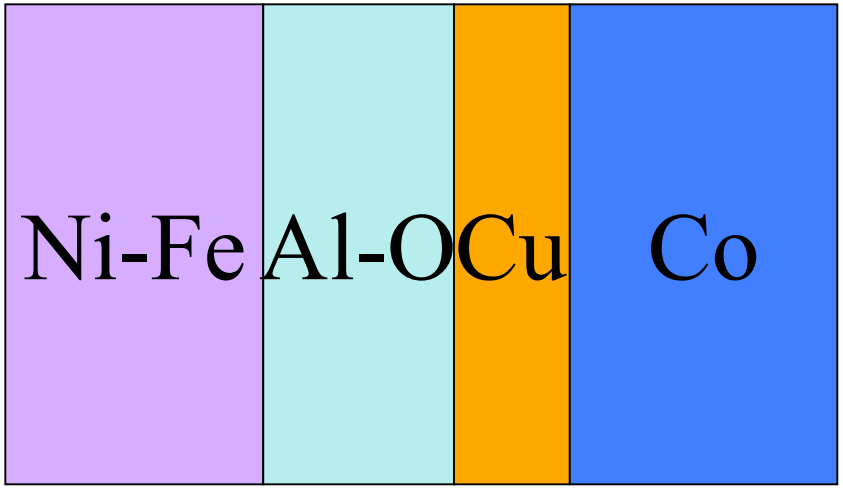
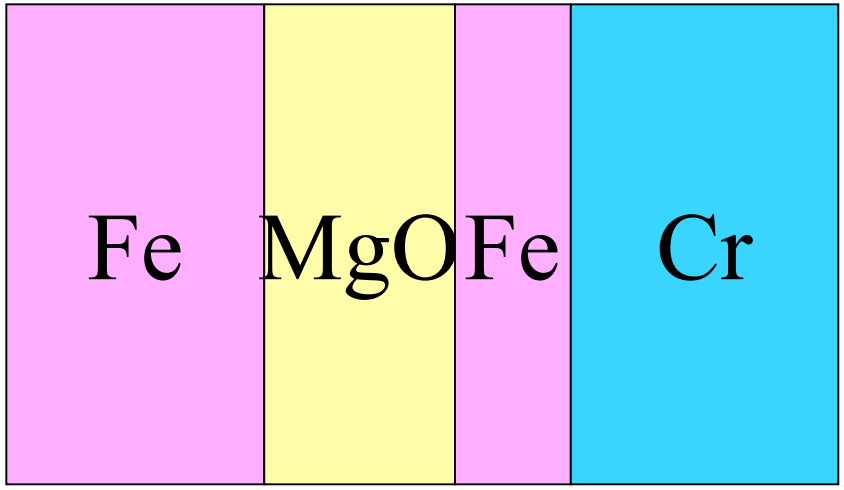


FIG. 2. Bias voltage at which the differential conductivity shows maxima, shown as a function of electrode thickness. MTJs with an electrode thicker than 6 ML show two maxima.

Choices of Resonant Tunnel Junctions





Nonmagnetic QW layer

- Long MFP
- QW states cannot be switched

Amorphous barrier layer

- Wider selection of electrodes
- All states tunnel with same rate

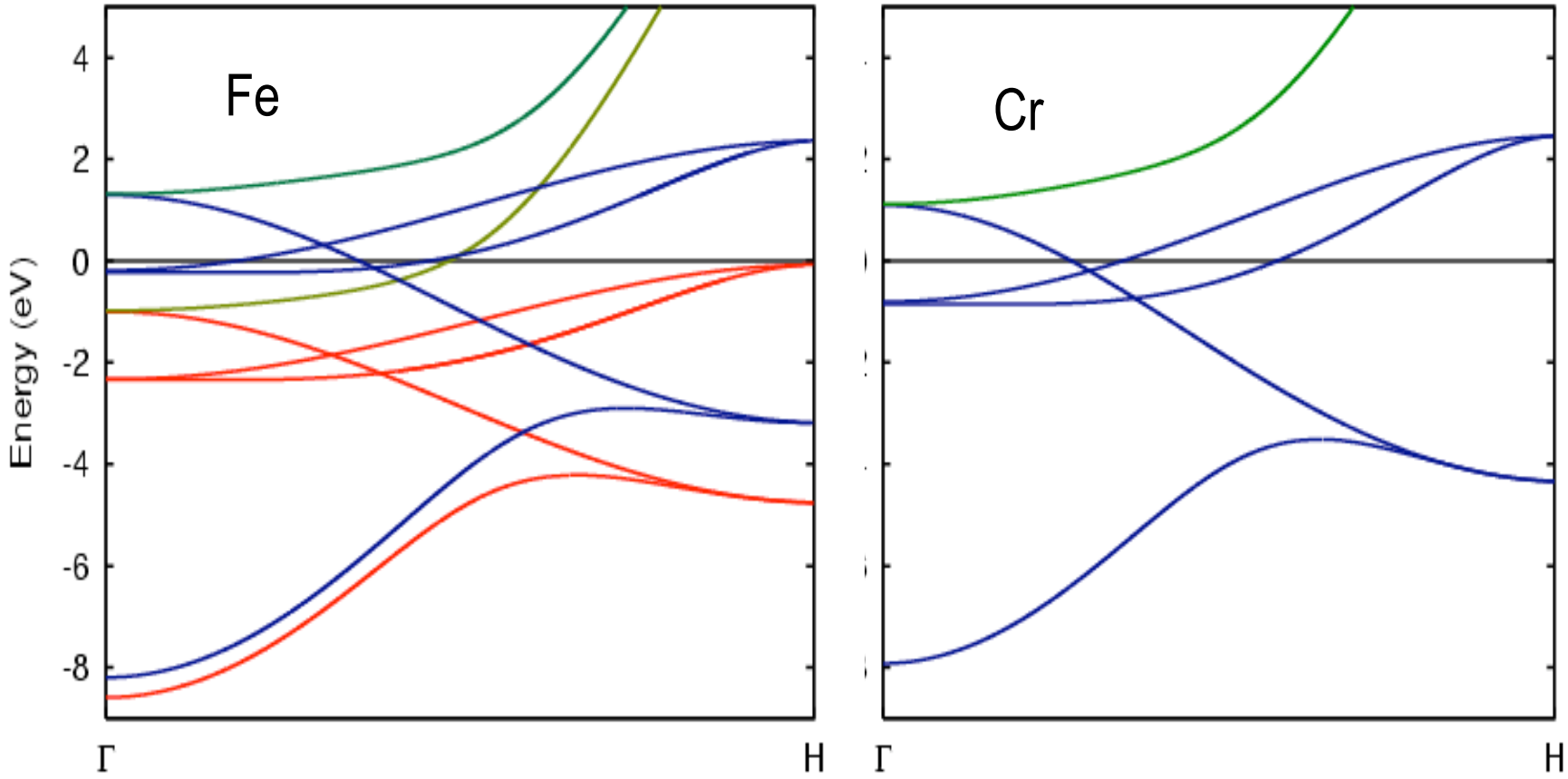
Magnetic QW layer

- Short MFP
- QW states are spin-dependent

Epitaxial barrier layer (MgO)

- Limited choice of electrodes
- Δ_1 state dominates tunneling

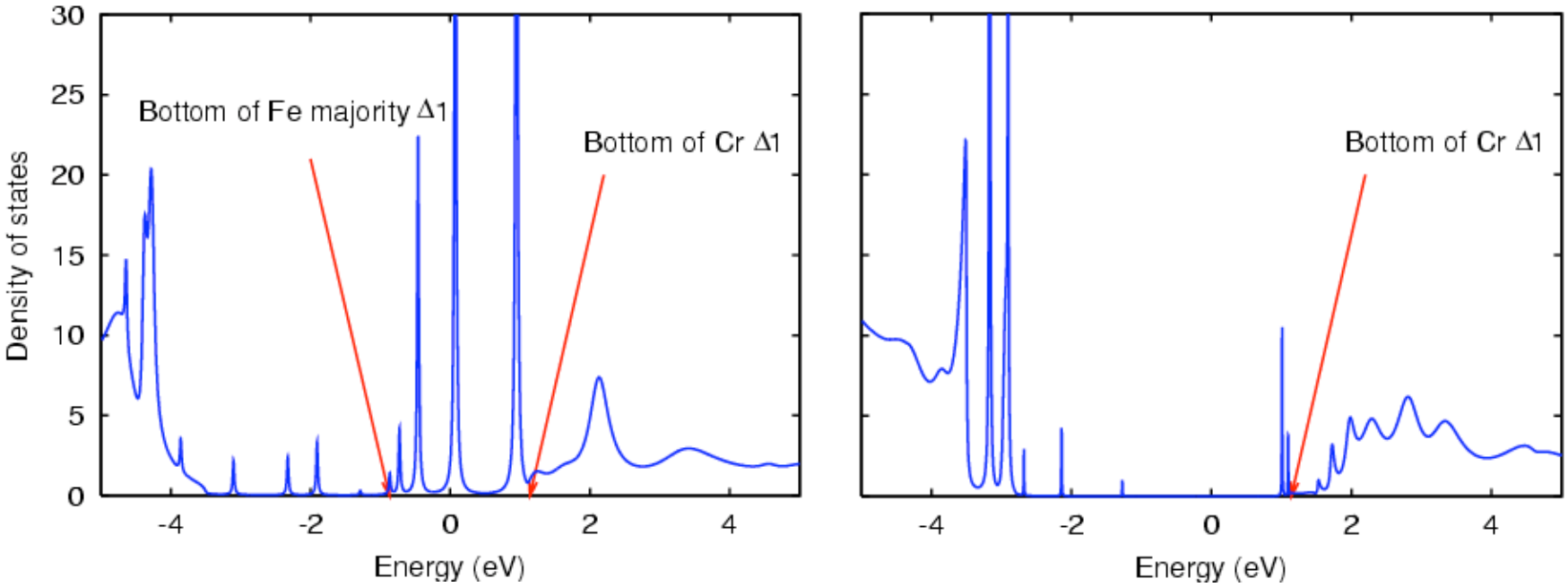
Quantum well states in Fe have Δ_1 symmetry



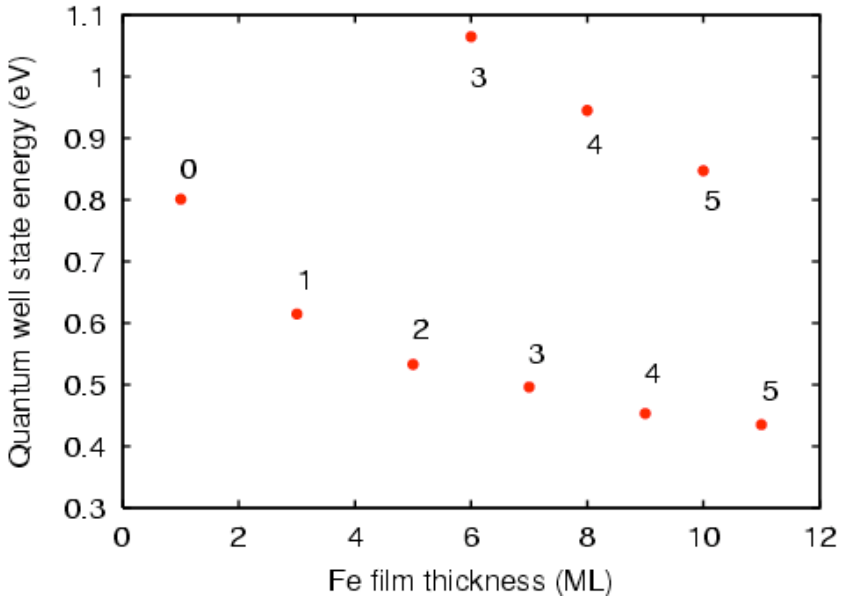
s-partial DOS at $k_{//}$=0 for Fe film in Fe/MgO/FeO/8Fe/Cr

5 QW states in majority channel

1 QW state and a resonance in minority channel

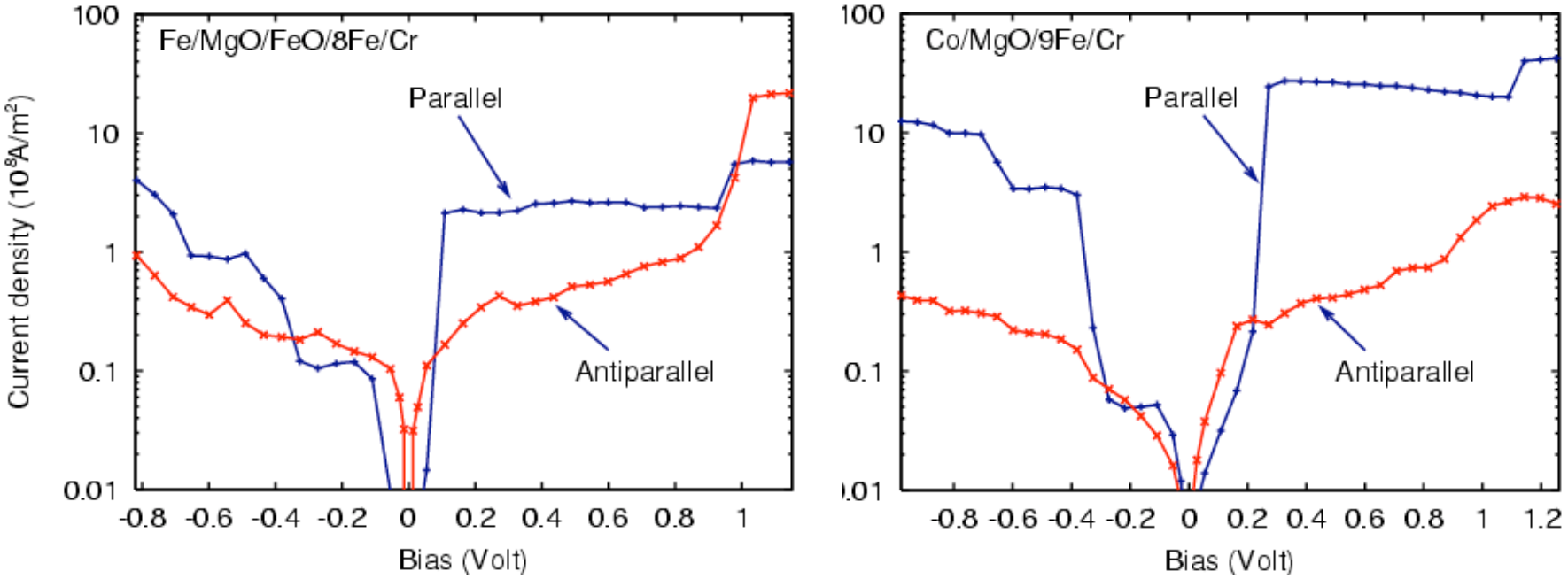


Energy and number of nodes of QW states



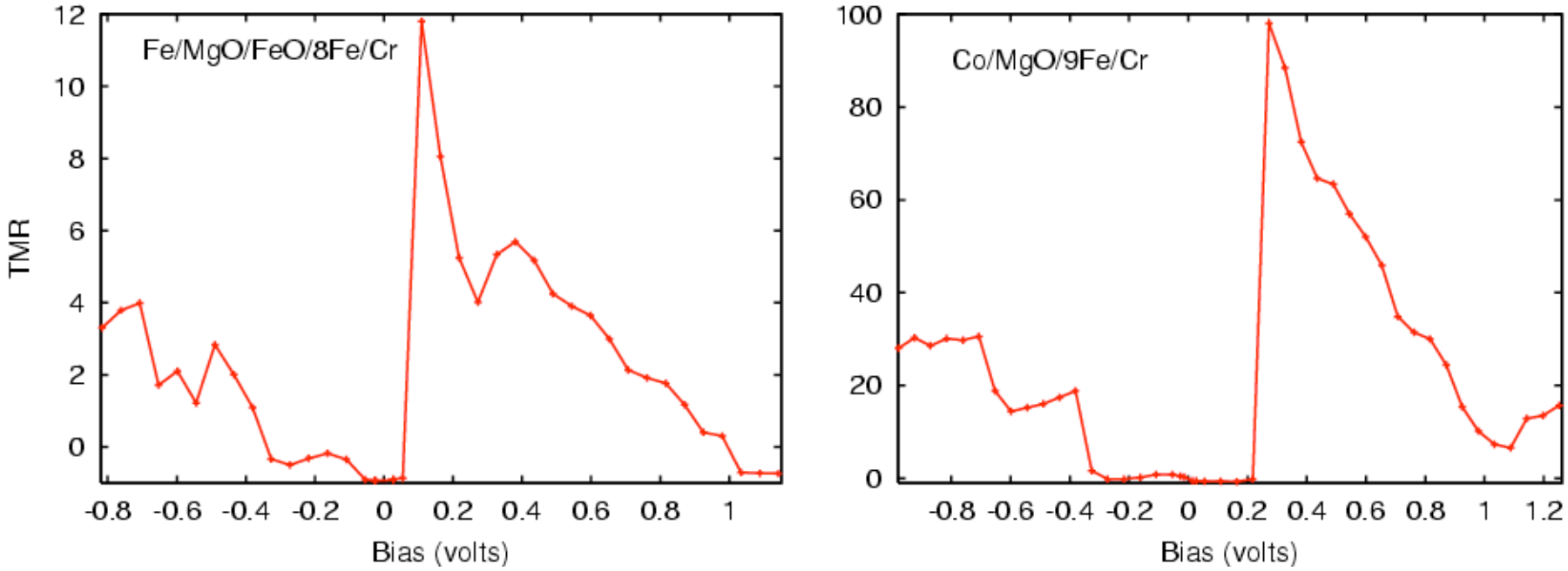
- Nearly perfect agreement with experiment in positions and thickness dependence
- Resonances from Γ-bar rather than X-bar as earlier speculated
- Different positions for even and odd layers – experimental data averaged over both

I-V Curves



- Tunnel current jumps by 1 to 2 orders of magnitude at resonances
- Larger effect at positive biases
- Majority current flat between resonances – all current flows through QW states

TMR



- Large negative TMR at small bias
- Large positive TMR from QW resonances
- TMR negative again at minority spin QW resonance

Conclusions

- *Large resonant tunneling through metallic QW states predicted in Fe/MgO/FeO/Fe/Cr and Co/MgO/Fe/Cr*
- *Tunneling current from QW states above Fermi energy (positvie bias) much greater than from QW states below Fermi energy*
- *Majority spin QW states contribute to a large positive TMR, minority spin QW states contribute to a large negative TMR*
- *Due to long MFP of minority spin electrons, resonant tunneling through minority spin QW states may be easier to observe, but requires larger bias windows and thicker films*

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