Spin-Resolved Quantum Conduction

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Outline

1. Introduction
2. Ohm's Law vs Quantum Mechanics
3. Quantum Conduction
4. Spin-Resolved Quantum Conduction
5. Summary

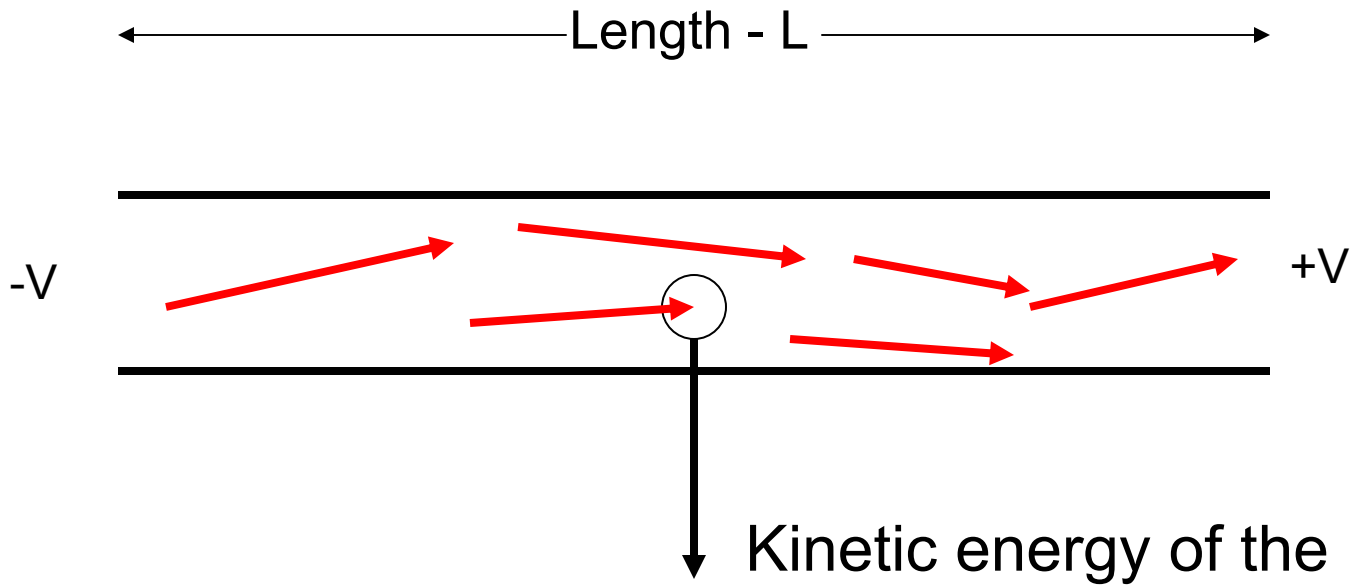
Introduction

1. What is the conduction though a single atom, and how can you measure it?

2. How does ferromagnetic behavior effect conduction in atomic sized systems?

Ohm's Law vs Quantum Mechanics

Ohm's Law measures the average of the scattering events

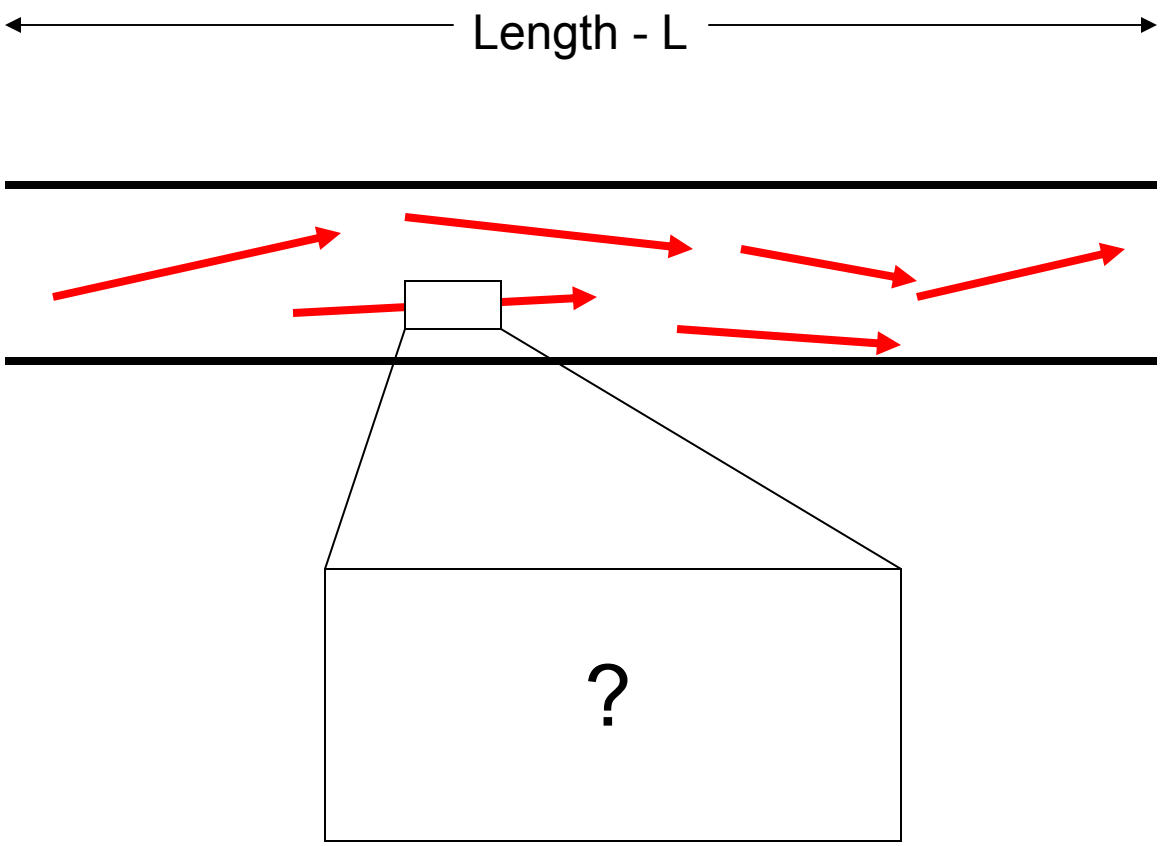


Mean Free Path - λ

$L >> \lambda$

Kinetic energy of the moving electron is altered by **phonons**, **electrons**, or **defects**

Ohm's Law vs Quantum Mechanics



$\lambda = 0.5$ nm for metals

Conduction in Atomic Sized Systems – Quantum Conduction

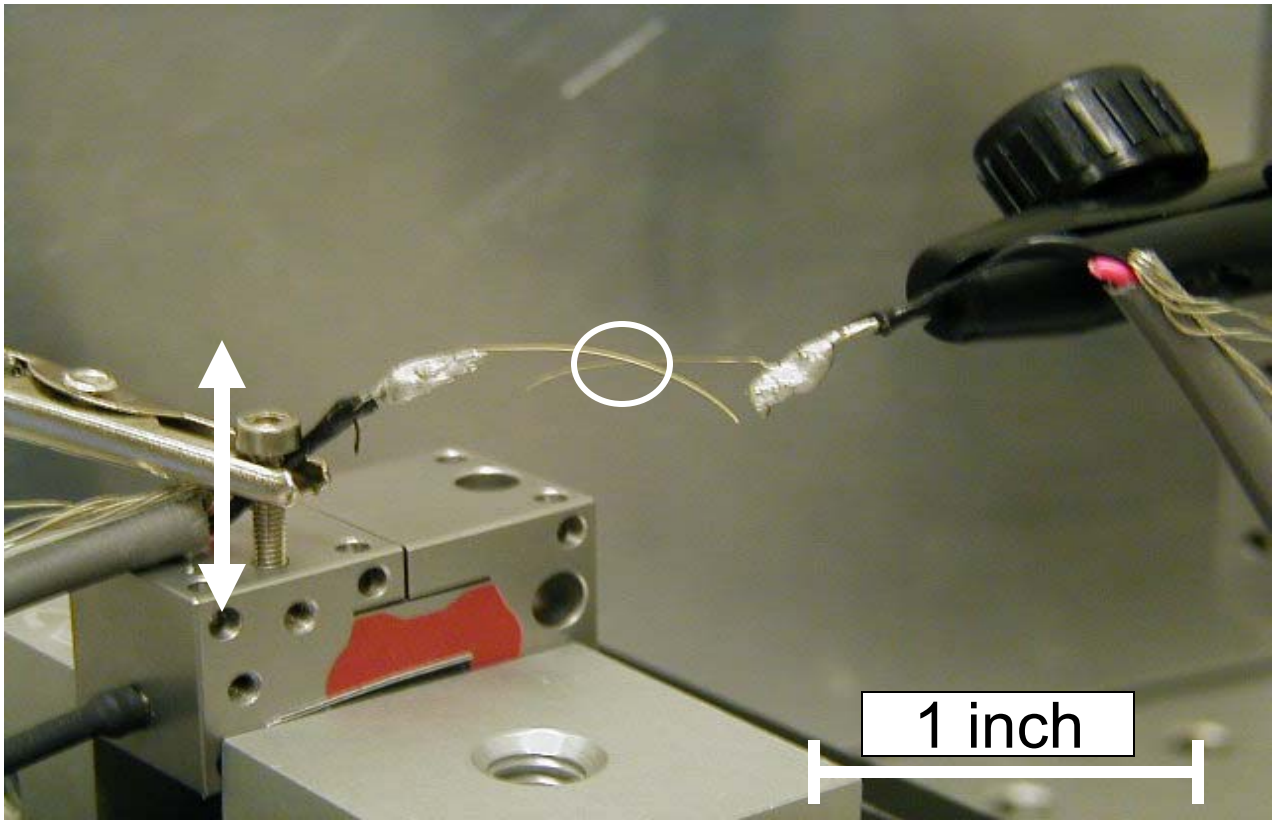
1. Wire Length ~ Mean Free Path
2. Assume no scattering – eliminate the classical sources of resistance

$G_o = 2e^2/h = 7.72 \times 10^{-5}$ S

$R_o = 12{,}949\ \Omega$

- **Conduction is a step-wise function**
- **The resistance of a 'perfect' conductor is not zero!**

Formation of Atomic Wires

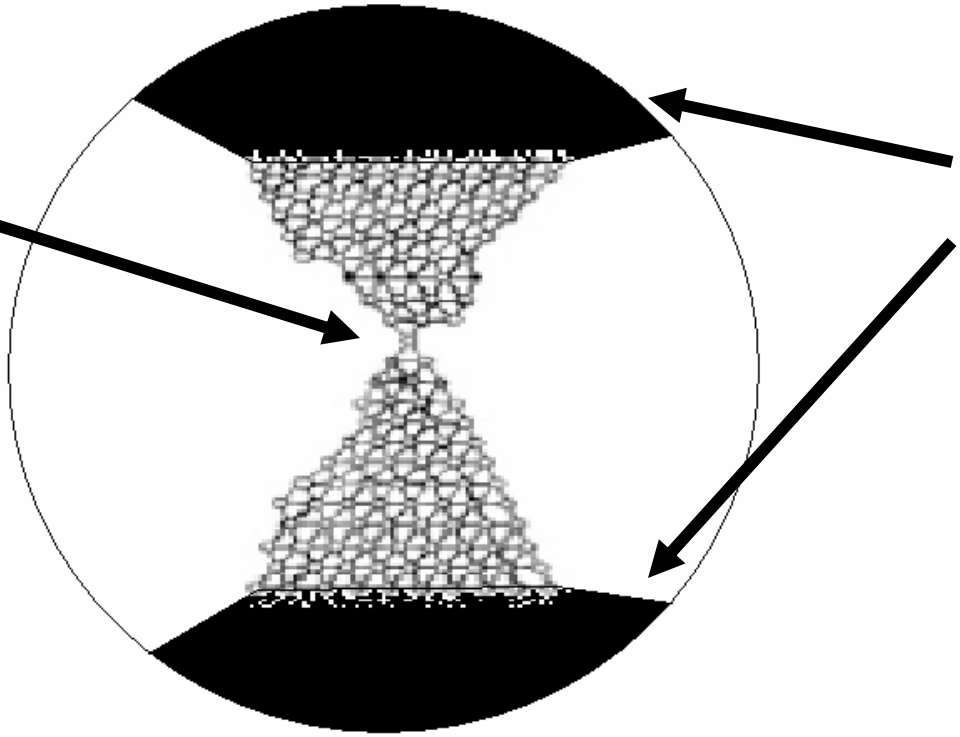


Two gold wires: 50 micron diameter, ~2 cm long

Piezo-oscillator

Mechanically Controlled Break Junction

Surface Atoms Bond – Form wire upon separation



Gold Wires

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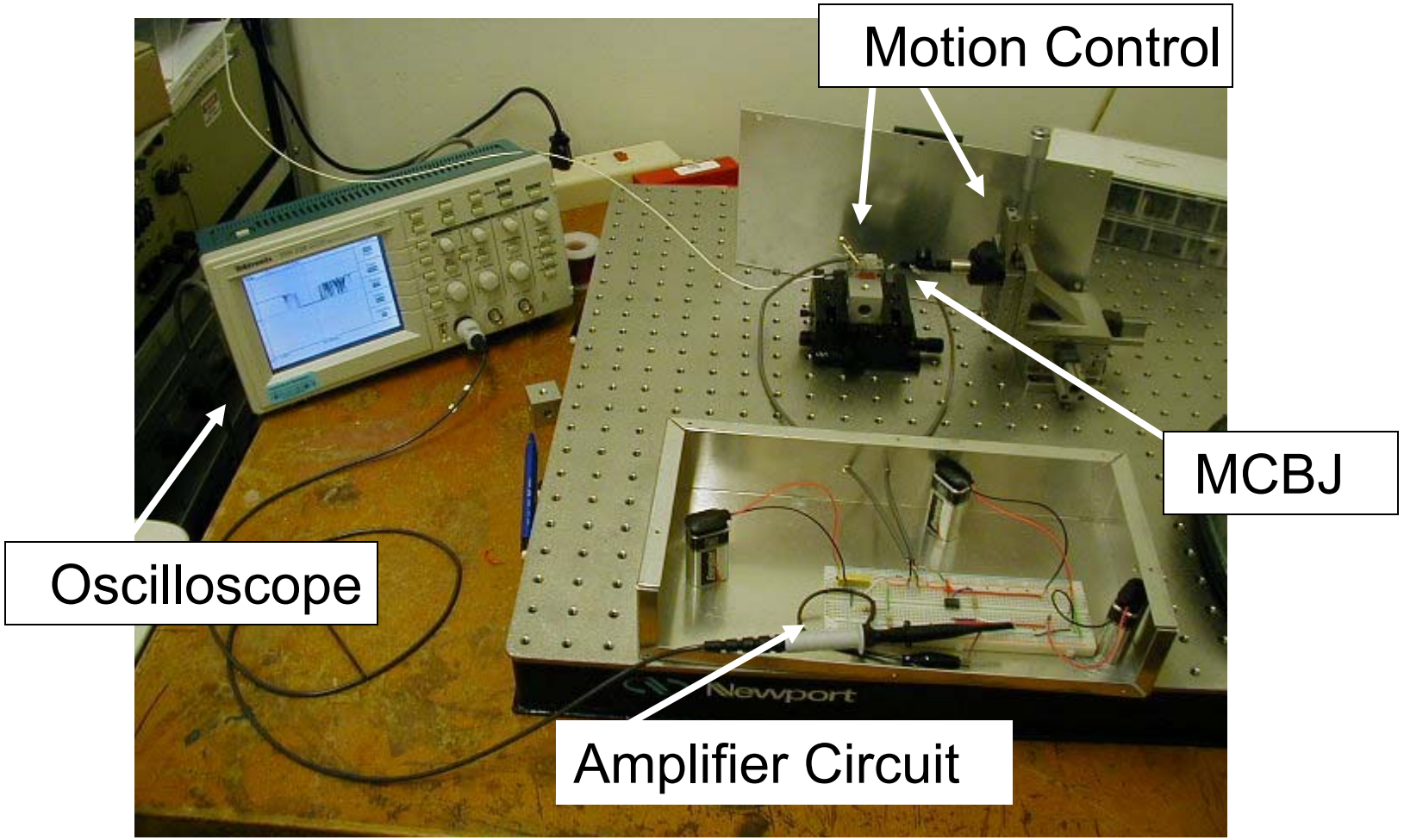
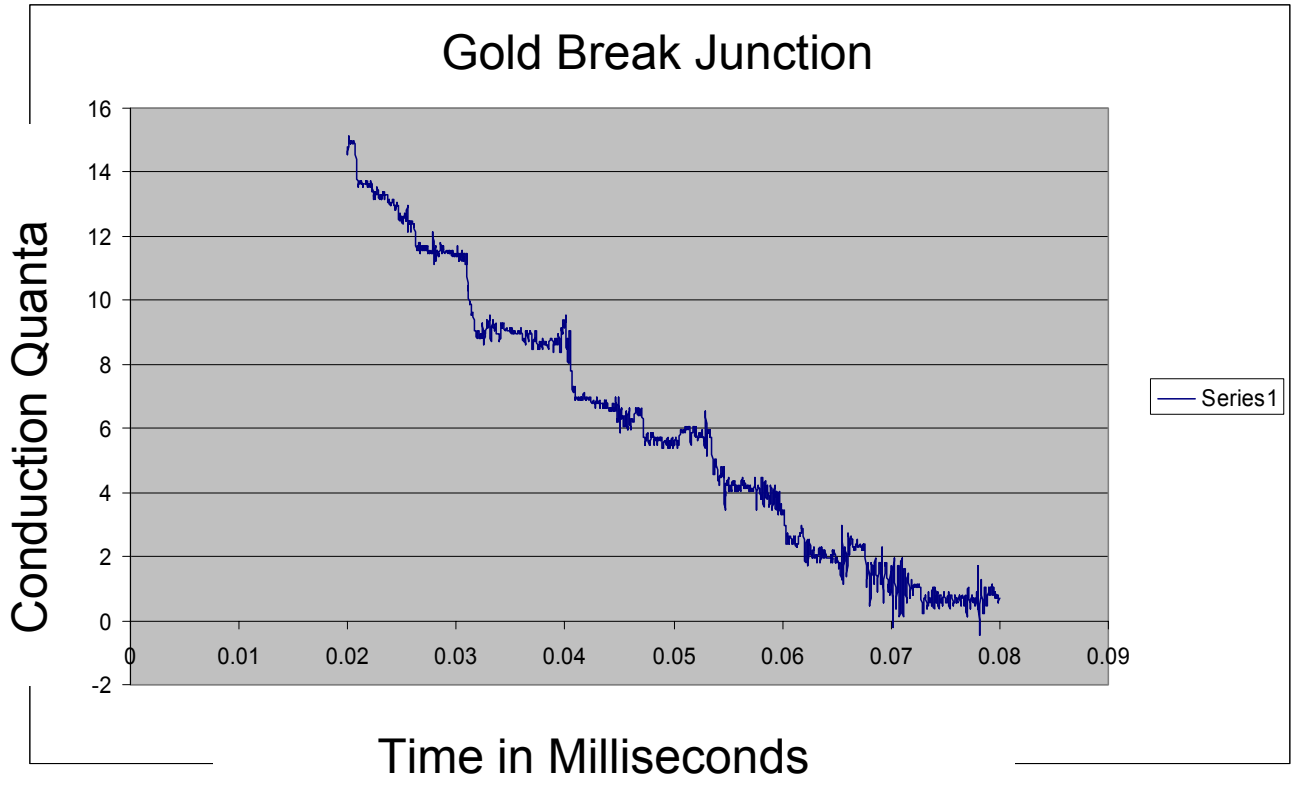
Experimental Set-Up



Conduction Curves in Break Junctions

As the MCBJ is stretched, the number of atoms in the constriction is reduced to 0



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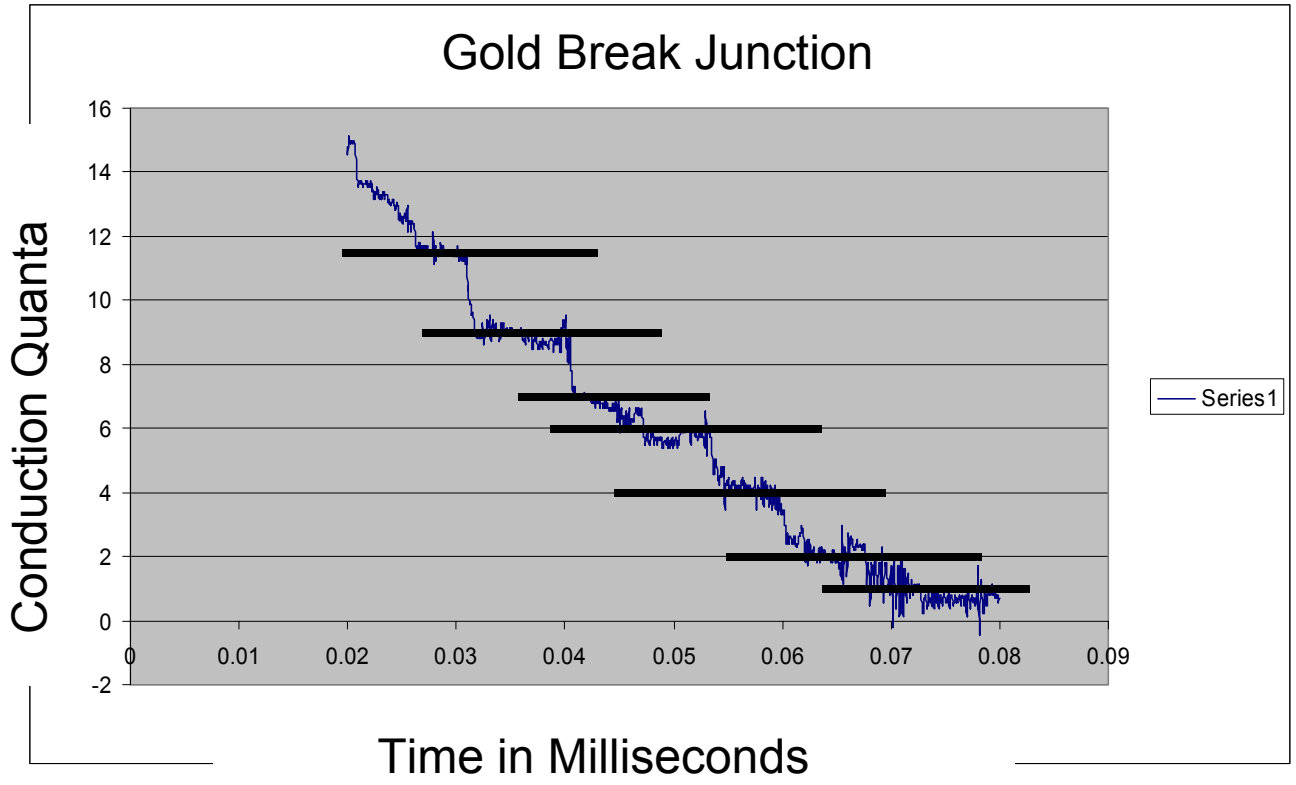
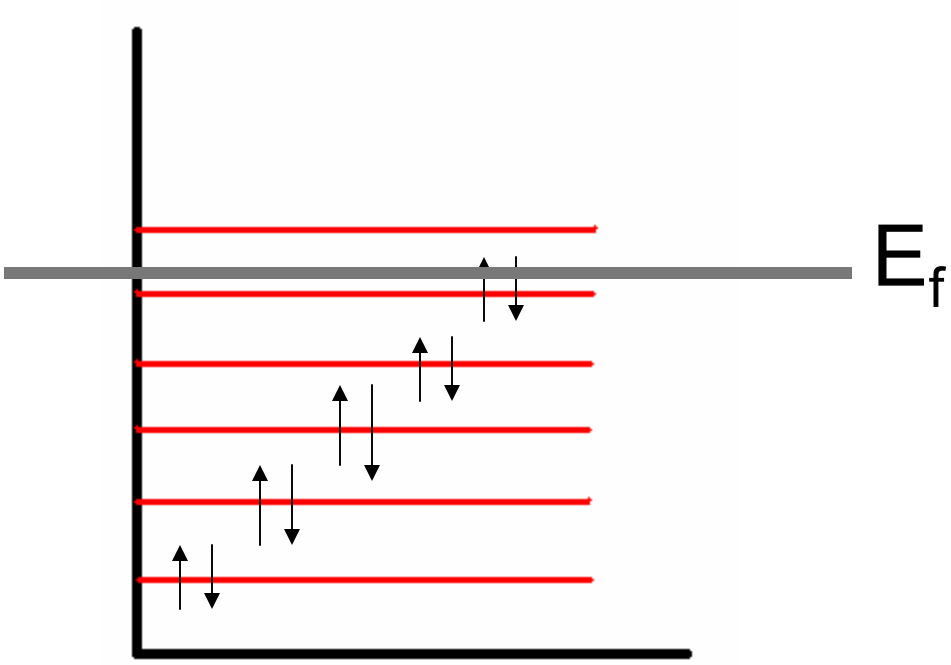


Ferromagnetic Quantum Conduction

Non-magnetic – Each state is occupied by **two** electrons of opposite spins



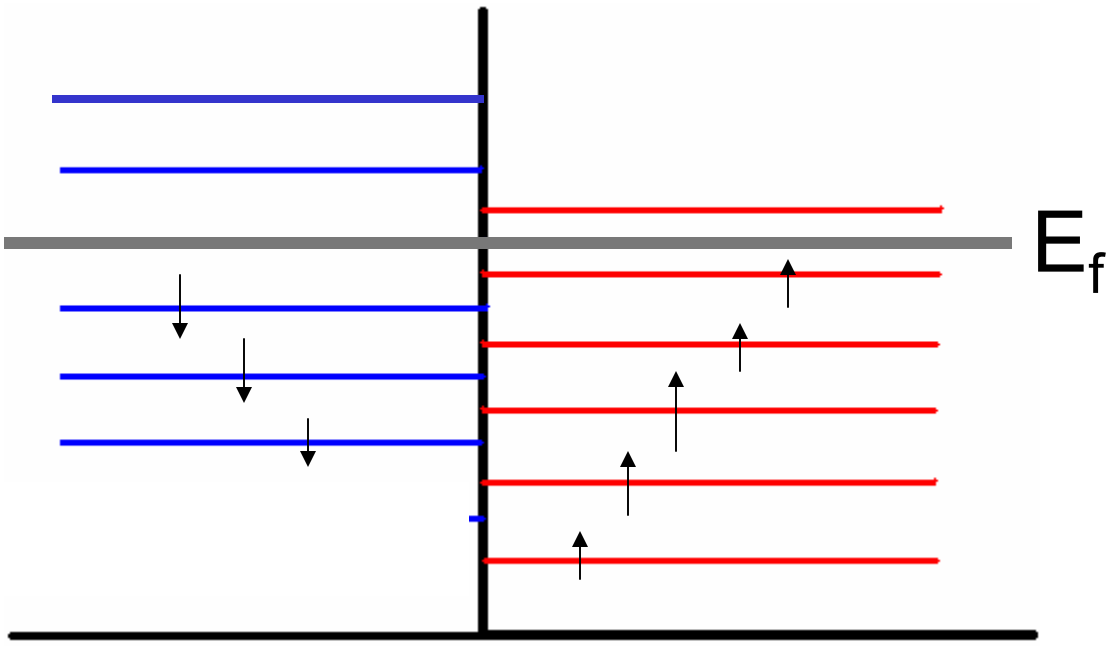
Ferromagnetic Quantum Conduction

Ferromagnet

1. Each state splits

2. Energy between states is cut in half

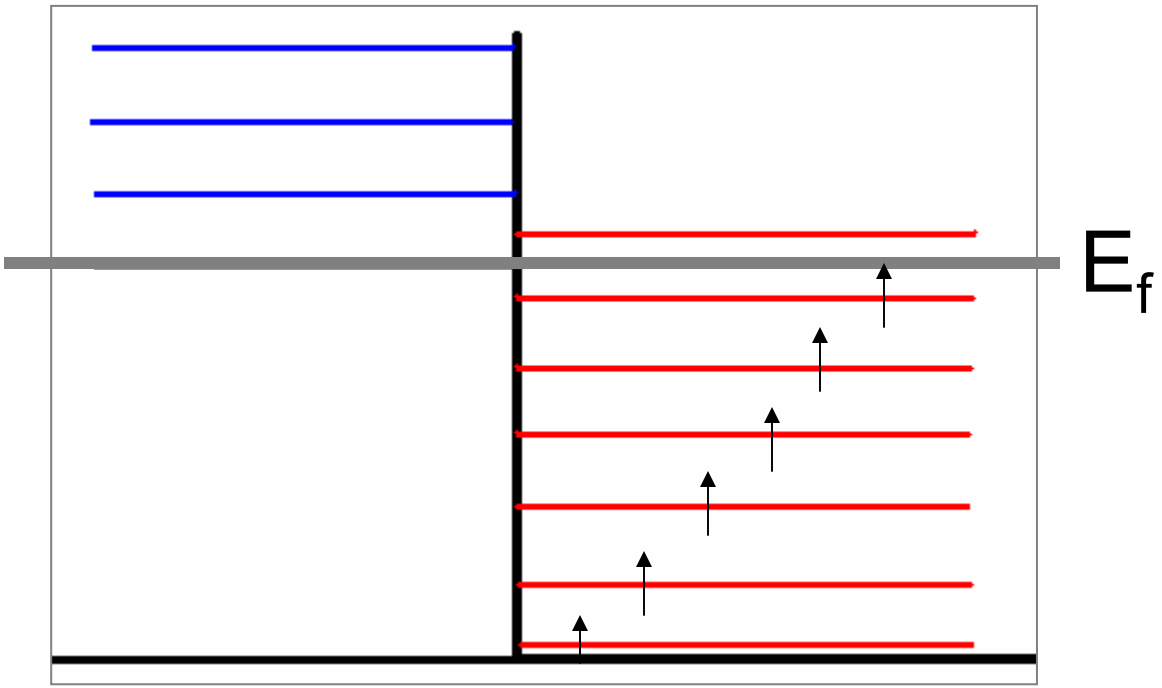
3. There are majority and minority spins



Cut G_o in half → R_o = 25,898 Ω

Half Metallic Ferromagnets

1. Complete Band Splitting
2. Conduction of one spin only
3. %100 Spin Polarized



Examples:

CrO_2

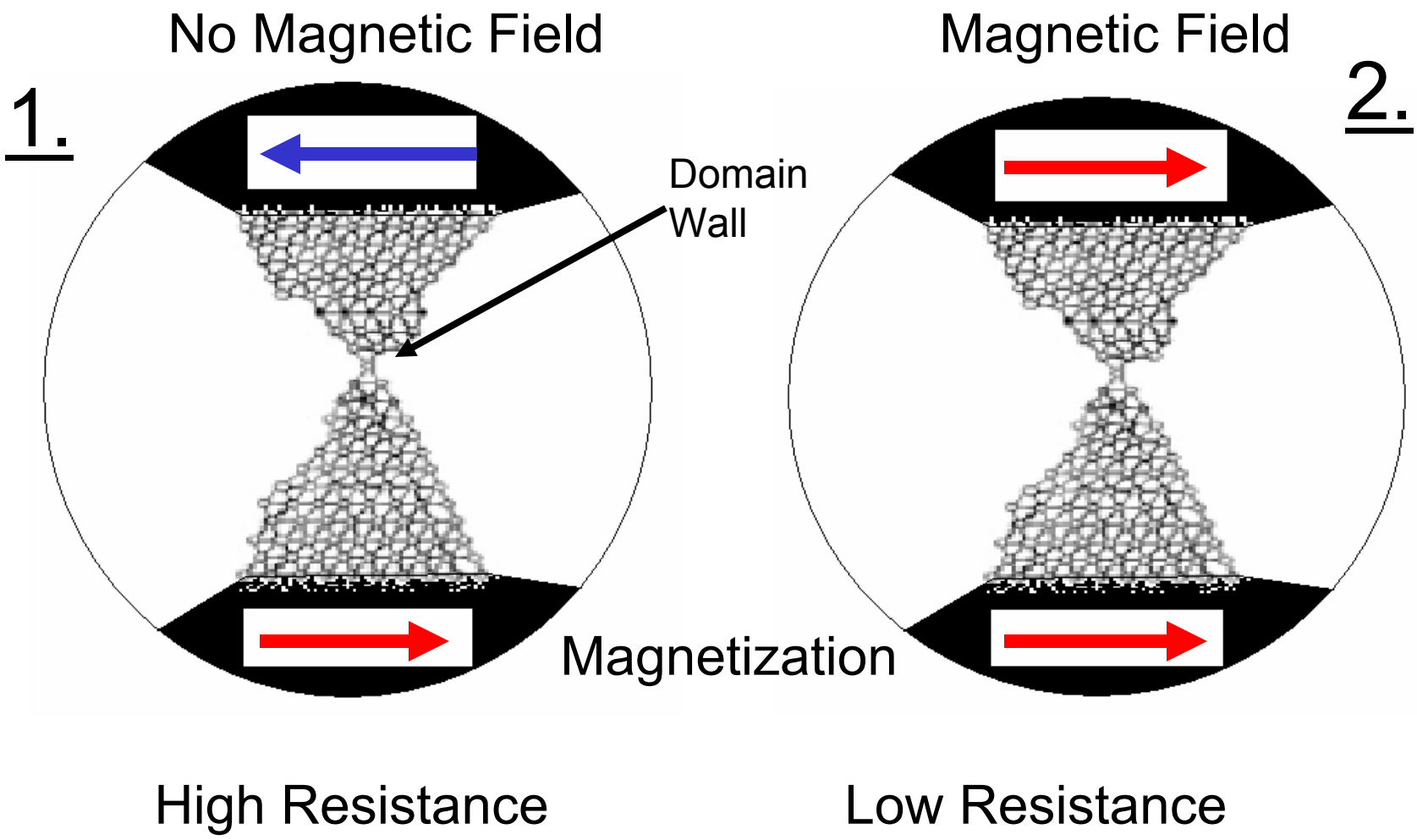
NiMnSb

$La_{0.7}Sr_{0.3}MnO_3$

Magnetoresistance

1. Electrical Resistance from Magnetic Domain Walls or resistance due to spin-flipping
2. Is the physical phenomena central to nearly all of today's computer devices – high MR, better devices
3. Increases with percent spin polarization, and decreases with size.

Huge Magnetoresistance in Half-Metallic MCBJ's?



Summary

You can measure the conductance through atomic sized conductors with a simple experiment and break junctions

Break Junctions, although not useful for applications, are an excellent tool for learning the fundamental properties of materials on the nanoscale

There is still time to provide a unique addition to this field

Acknowledgements

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