Magnetic Tunnel Junctions Based on CrO$_2$ and Co Electrodes with Epitaxial SnO$_2$ Barriers

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**ABSTRACT:** Magnetic tunnel junctions (MTJs) have been fabricated using epitaxial half-metallic chromium dioxide (CrO$_2$) films with a Co counter-electrode. A heteroepitaxial layer of SnO$_2$ is grown on top of the CrO$_2$ layer to form the tunneling barrier. Positive magnetoresistance (MR) is observed in these junctions with a maximum value of 14% at 10 K. An additional field-dependent behavior is observed in the MTJs with SnO$_2$, barrier thicknesses in the range of 2-6 nm that is quite unique. A spontaneous voltage is developed in these junctions without the application of any bias current when the magnetic electrodes are switched from a spin-parallel to antiparallel configuration. Equivalently, the effect may be viewed as a magnetoresistance which becomes infinite at zero bias. The developed voltage increases with decreasing temperature, reaching ~50µV at 10 K. Spin-dependent electrochemical potential shifts at the interfaces resulting from diffusive spin currents is considered to be a likely source for the observed magnetovoltage effect.


**Epitaxy of CrO$_2$-SnO$_2$ heteroepitaxial structures**
- Prepared by CVD with CrO$_3$ and SnI$_4$ as precursors
- SnO$_2$ grows epitaxially on CrO$_2$
- Dislocations at the interface for thick SnO$_2$ films due to the large lattice mismatch (9%)
- SnO$_2$ crystalline quality is worse than that of CrO$_2$

**Observation of MV effect**
- Spontaneous voltage shift with spin orientation switching
- Approaches infinite MR at low biases
- Vanishes fast with temperature
- Appears for certain barrier thicknesses

**Possible reasons**
- Chemical potential shift due to diffusive spin currents
- Unequal population of spin-up and spin-down electrons
- Shifts in spin-resolved chemical potentials and a potential drop at the interface
- Magnetoelectric
  - CrO$_2$ is magnetoelectric and AFM (T$_N$ ~ 307K); some compounds of SnO$_2$ (ITO etc.) are piezoelectric.
  - However, a strong temperature dependence is not expected.

**Summary:**
- Fabricated MTJs based on CrO$_2$-Co with epitaxial SnO$_2$ as the barrier
- Up to 14% TMR was observed at 10 K
- TMR can be reversed by varying the barrier thickness and bias
- A spontaneous voltage generation was observed for junctions with certain barrier thicknesses, which leads to nominally infinite MR at zero bias.