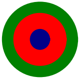
Ferromagnetics on the atomic level

Fe: [Ar] $3d^6\,4s^2$



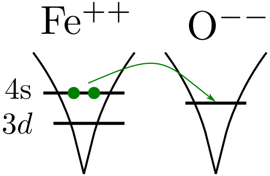
blue: inner core electrons

red: $3d$ shell electrons

green: $4s$ shell electrons

Due to intra-atomic exchange, the $3d$-shell ($L = 2$) electrons have total spin $S = 2$

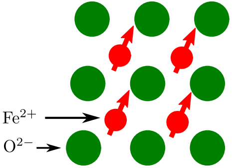
Ferromagnetic insulators



O: $1s^2\,2s^2\,2p^4$

$4s$ electrons transfer to the $2p$ shell of the O^{--} ion. $3d$ electrons stay on the Fe^{++} ion, which then has finite spin $\Rightarrow$ carries a magnetic moment.

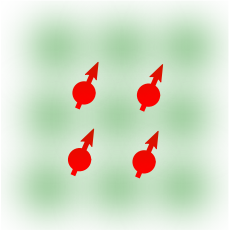
Ferromagnetic insulators



FeO, NiO, MnO, CoO etc: magnetic ions interact via the interatomic exchange.

MnO, CoO, CrO_2, Fe_2O_3 : have $T_c = 400–800\,K$. Industrially used for magnetic recording

Ferromagnetic metals. Fe: [Ar] $3d^6\,4s^2$

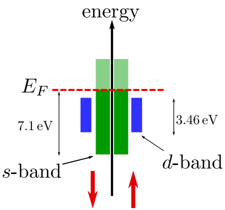


green: Fermi sea of s-electrons

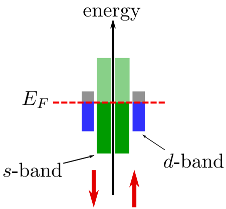
For readout of information, need to have spin-selective electric currents. Hence need ferromagnetic metals.

Band structure of ferromagnetic metals

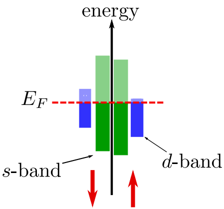
Cu: [Ar] $4s^1\,3d^{10}$



Ni: [Ar] $4s^2\,3d^8$
for $T > T_c$



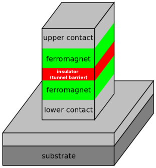
Ni: [Ar] $4s^2\,3d^8$
for $T < T_c$



s- and p-bands are wide, d-bands are narrow ($\Rightarrow$ DOS is large)

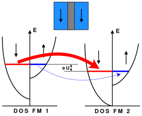
Due to exchange interaction, bands are spin split $\Rightarrow$ current is spin-polarized

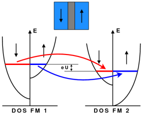
Tunnel magnetorezistance (TMR) junctions



Readheads of the magnetic hard drives:

Magnetizations of FM films can be controlled independently by external magnetic field. The voltage bias is applied using the control electrodes.





At zero bias voltage, electrons tunnel in both directions. With bias, the current has preferred direction. Due to exchange splitting, it's spin polarized.

If both electrodes are completely polarized, the junction operates as a switch $\Rightarrow$ *ferromagnetic half-metals*