Nobelpriset i fysik 2007

Presentation för
KUNGL.VETENSKAPSAKADEMIEN
av Börje Johansson

Fysikkommitténs slutliga förslag

Vid sin slutliga avvägning har Fysikkommittén funnit särskilt prisvärd upptäckten av fenomenet jättemagnetoresistans (GMR), som lagt grunden till en mängd nya vetenskapliga och teknologiska tillämpningar.

Kommittén har beslutat föreslå Kungl. Vetenskapsakademien att 2007 års Nobelpris i fysik utdelas gemensamt till

Albert Fert

Université de Paris - Sud, Orsay, Frankrike

och

Peter Grünberg

Forschungszentrum Jülich, Jülich, Tyskland

för upptäckten av jättemagnetoresistans

Nobelpriset i fysik 2007

Albert Fert (Paris) & Peter Grünberg (Jülich)

Giant Magnetoresistance of (001)Fe/(001)Cr Magnetic Superlattices

M.N. Baibich, J.M. Broto, **A. Fert**, F. Nguyen Van Dau, F. Petroff, P. Eitenne, G. Creuzet, A. Friederich, and J. Chazelas
Phys. Rev. Lett. **61**, 2472 (1988)

Enhanced magnetoresistance in layered magnetic structures with antiferromagnetic interlayer exchange

G. Binasch, **P. Grünberg**, F. Saurenbach, and W. Zinn
Phys. Rev. B **39**, 7 (1989)

Historik

On the Electro-dynamic Qualities of Metals:—

Effects of Magnetization on the Electric Conductivity of Nickel and of Iron.

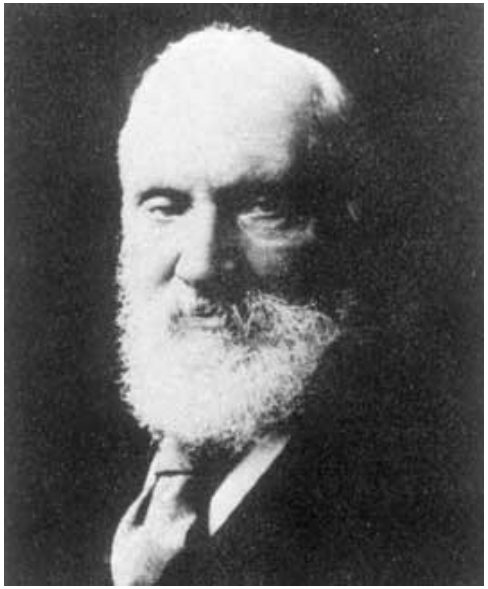
By Professor W. Thomson, F.R.S.

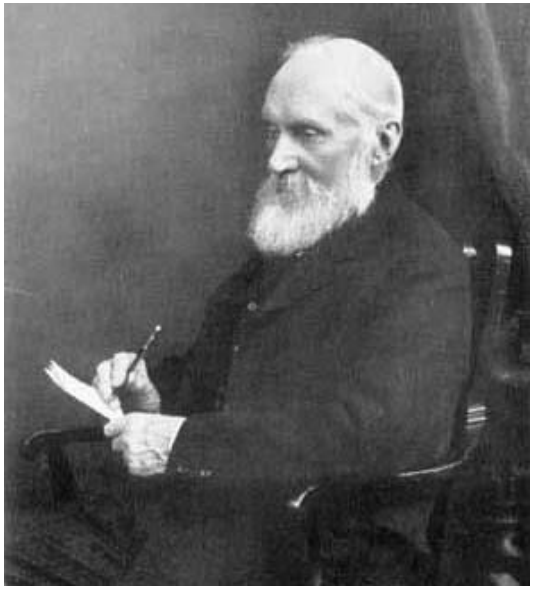
Received June 18, 1857.

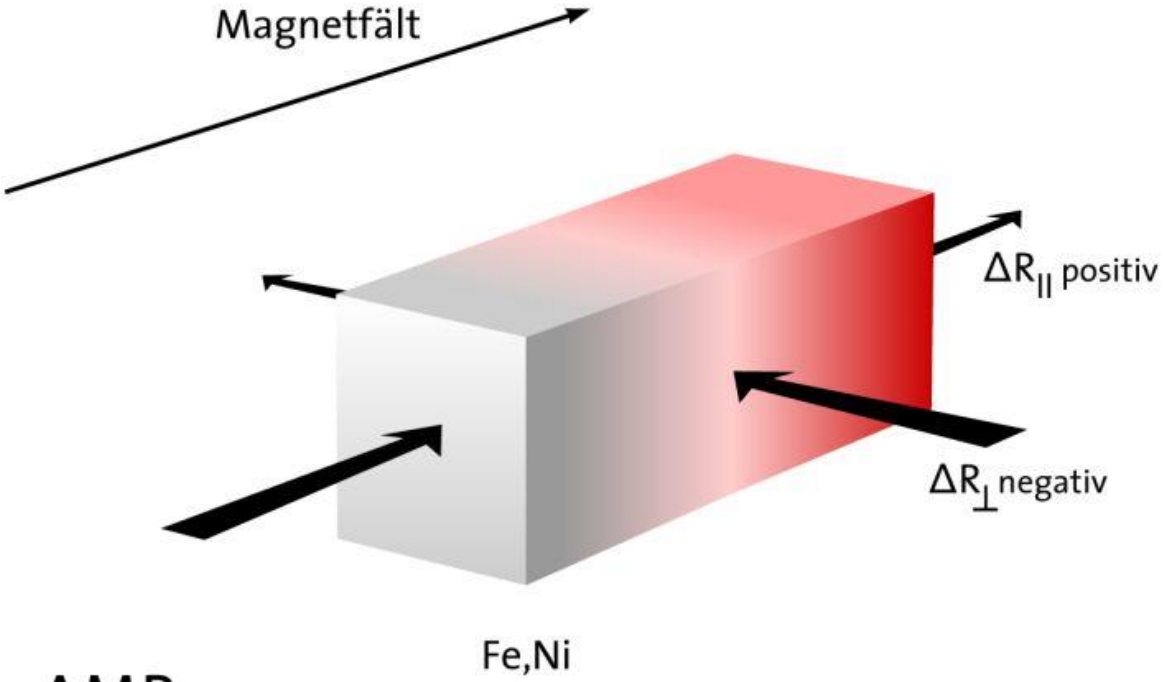
Proceedings of the Royal Society of London, Vol. 8, 1857, pp. 546-550.

Exactly 150 years ago W. Thomson (Lord Kelvin) measured the behavior of the resistance of iron and nickel in the presence of a magnetic field . He wrote:

"...I found that iron, when subjected to a magnetic force, acquires an increase of resistance to the conduction of electricity along, and a diminution of resistance to the conduction of electricity across, the lines of magnetization."







AMR
anisotrop magnetoresistans

Thomson, 1857
(Lord Kelvin)

RAPID COMMUNICATIONS

PHYSICAL REVIEW B VOLUME 39, NUMBER 7 1 MARCH 1989

Enhanced magnetoresistance in layered magnetic structures with antiferromagnetic interlayer exchange

G. Binasch, P. Grünberg, F. Saurenbach, and W. Zinn

Institut für Festkörperforschung, Kernforschungsanlage Jülich G.m.b.H., Postfach 1913, D-5170 Jülich, West Germany

(Received 31 May 1988; revised manuscript received 12 December 1988)

The electrical resistivity of Fe-Cr-Fe layers with antiferromagnetic interlayer exchange increases when the magnetizations of the Fe layers are aligned antiparallel. The effect is much stronger than the usual anisotropic magnetoresistance and further increases in structures with more than two Fe layers. It can be explained in terms of spin-flip scattering of conduction electrons caused by the antiparallel alignment of the magnetization.

VOLUME 61, NUMBER 21 PHYSICAL REVIEW LETTERS 21 NOVEMBER 1988

Giant Magnetoresistance of (001) Fe/(001) Cr Magnetic Superlattices

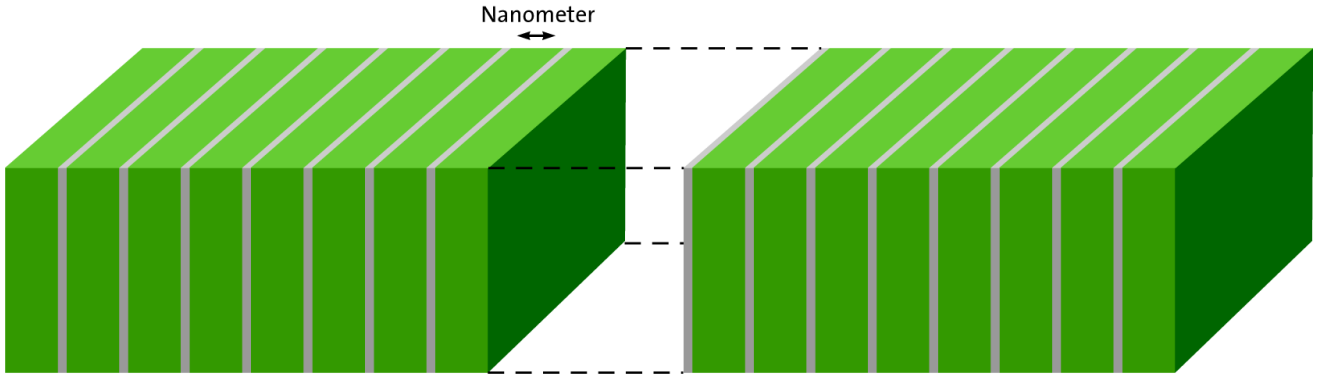
M. N. Baibich,[a] J. M. Broto, A. Fert, F. Nguyen Van Dau, and F. Petroff
Laboratoire de Physique des Solides, Université Paris-Sud, F-91405 Orsay, France

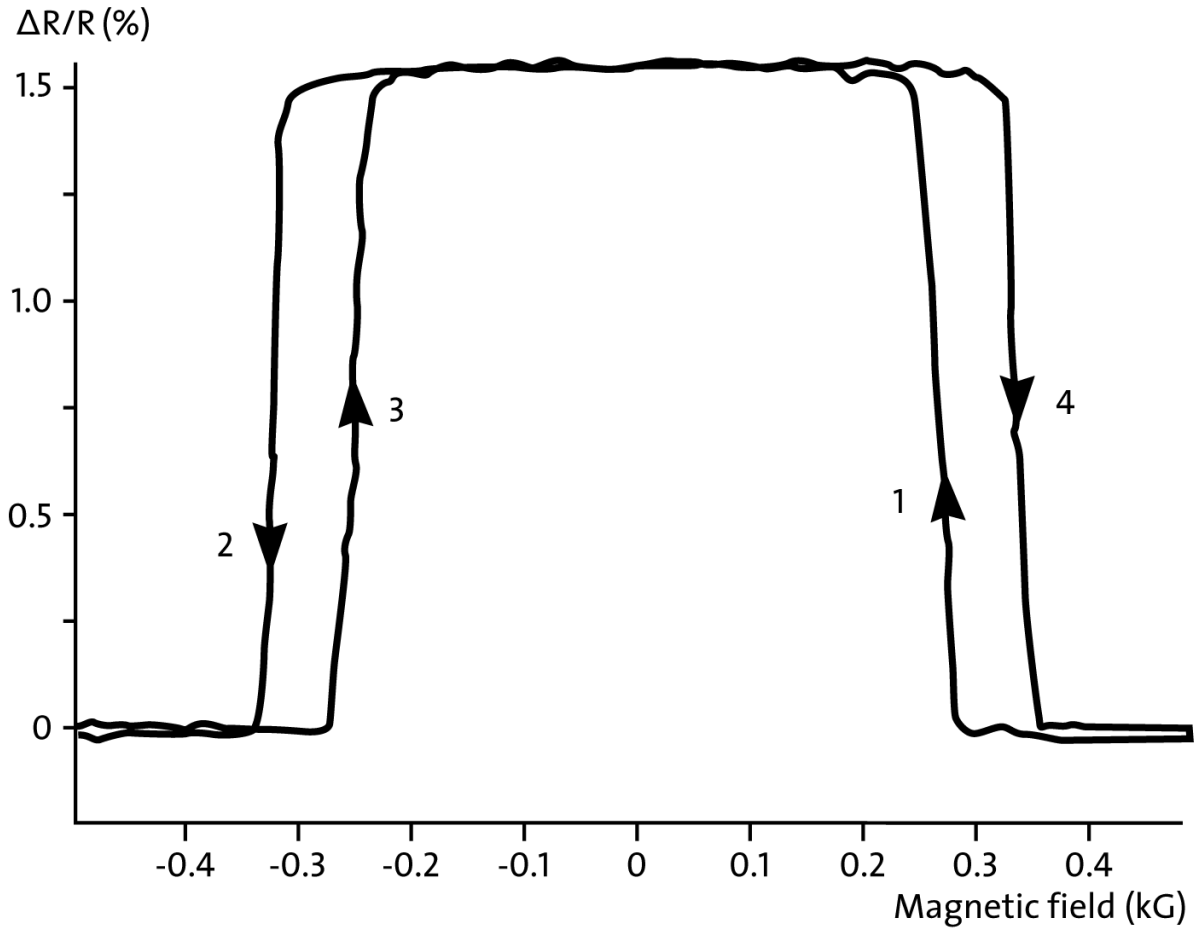
P. Eitenne, G. Creuzet, A. Friederich, and J. Chazelas
Laboratoire Central de Recherches, Thomson CSF, B.P. 10, F-91401 Orsay, France

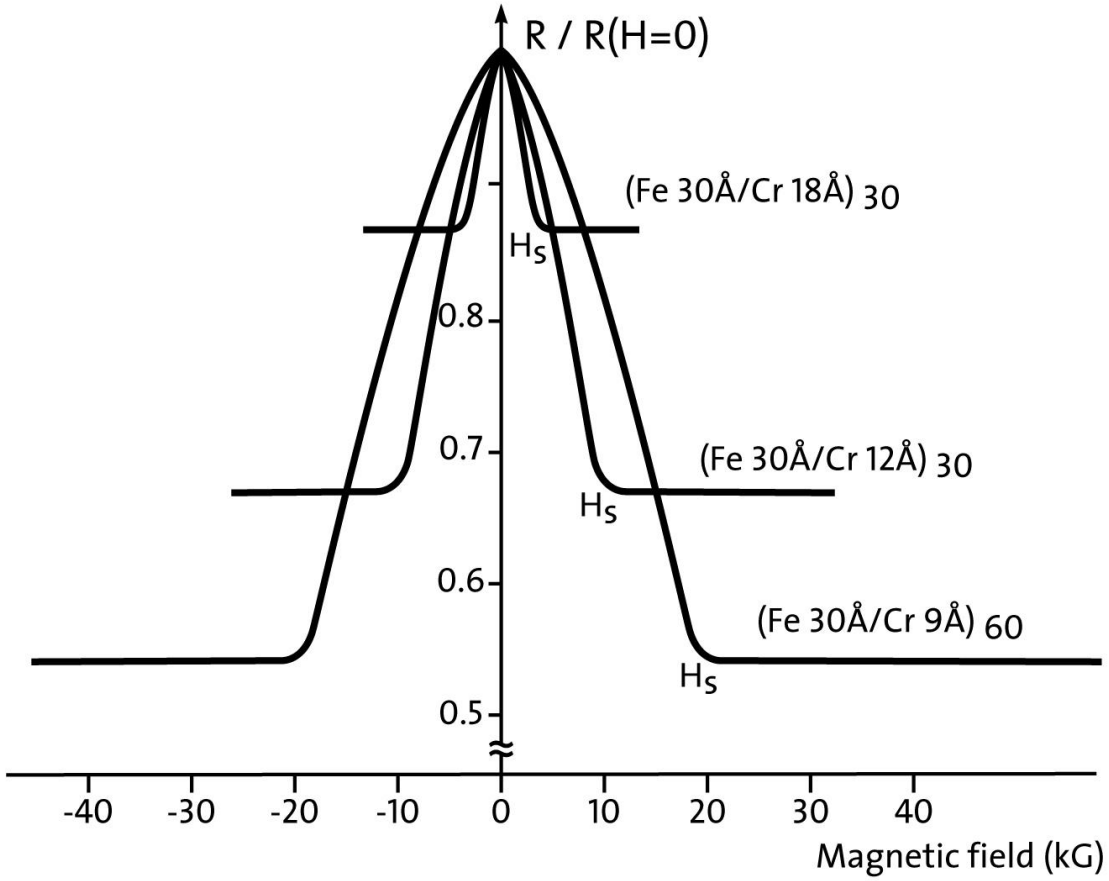
(Received 24 August 1988)

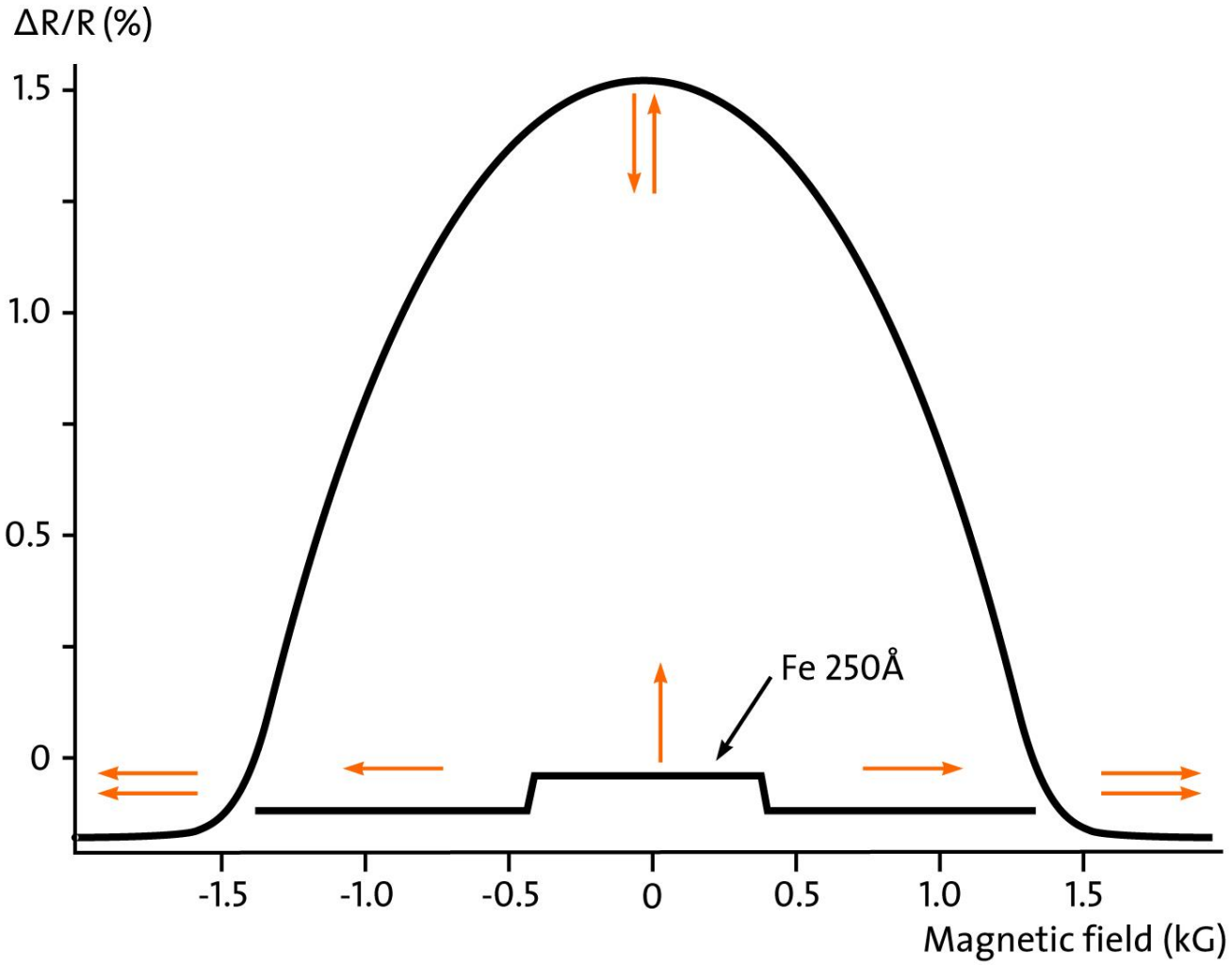
We have studied the magnetoresistance of (001)Fe/(001)Cr superlattices prepared by molecular-beam epitaxy. A huge magnetoresistance is found in superlattices with thin Cr layers: For example, with $t_{Cr}=9$ Å, at $T=4.2$ K, the resistivity is lowered by almost a factor of 2 in a magnetic field of 2 T. We ascribe this giant magnetoresistance to spin-dependent transmission of the conduction electrons between Fe layers through Cr layers.

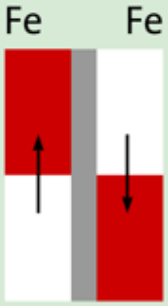
PACS numbers: 75.50.Rr, 72.15.Gd, 75.70.Cn


Nanometer

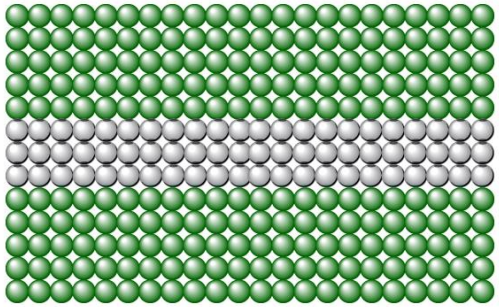

ΔR/R (%)
1.5
1.0
0.5
0
1
2
3
4
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
Magnetic field (kG)

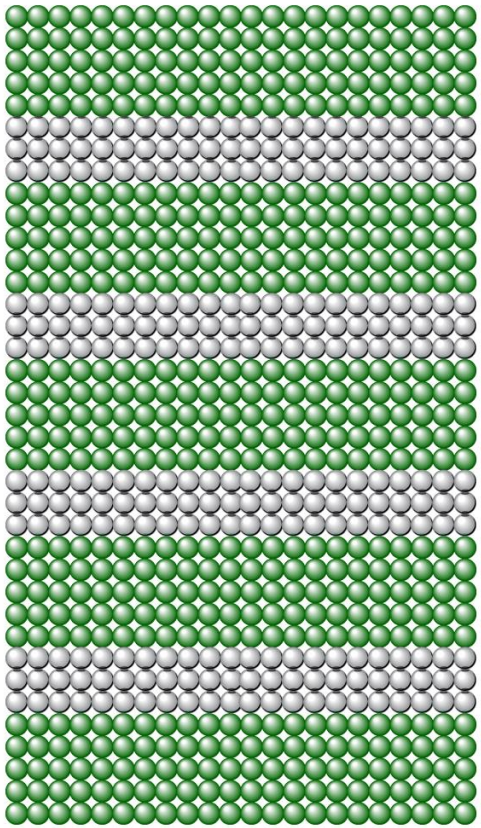

R / R(H=0)
(Fe 30Å/Cr 18Å) 30
Hs
0.8
0.7
(Fe 30Å/Cr 12Å) 30
Hs
0.6
(Fe 30Å/Cr 9Å) 60
Hs
0.5
-40
-30
-20
-10
0
10
20
30
40
Magnetic field (kG)


ΔR/R (%)
1.5
1.0
0.5
0
Fe 250Å
-1.5
-1.0
-0.5
0
0.5
1.0
1.5
Magnetic field (kG)

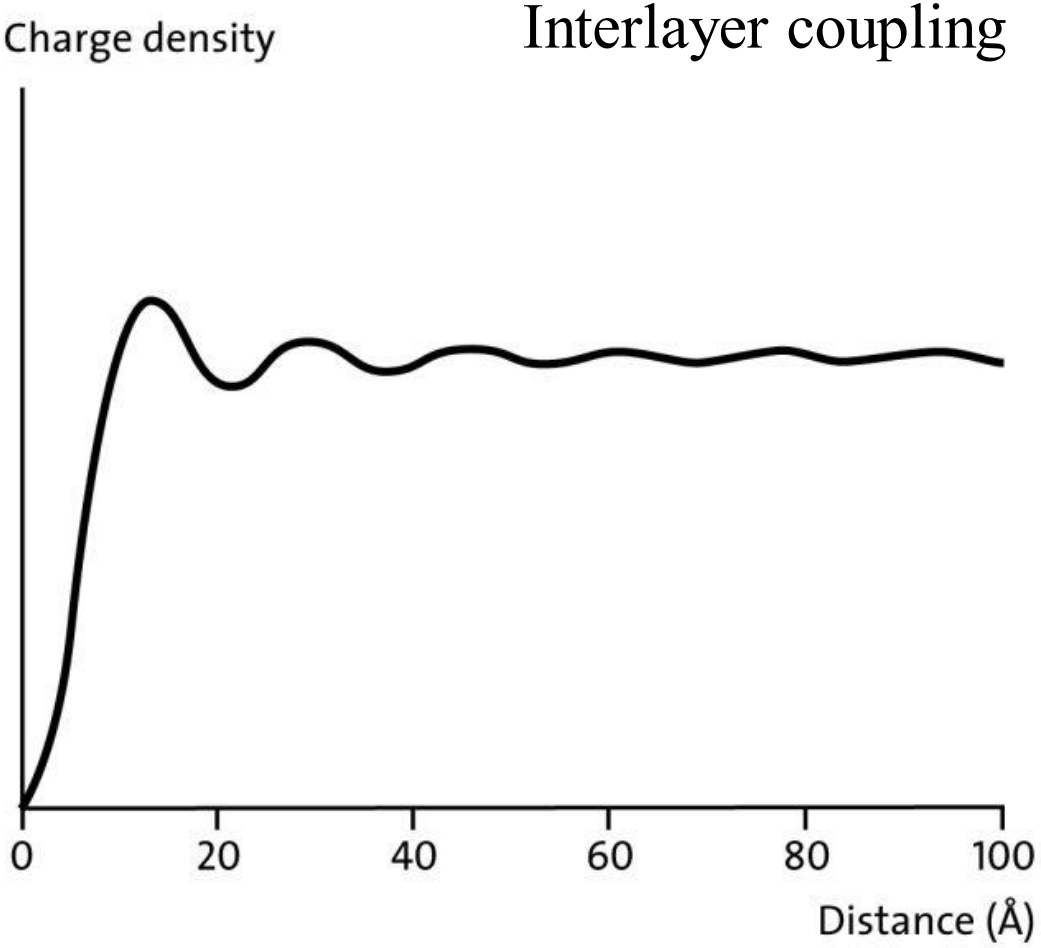


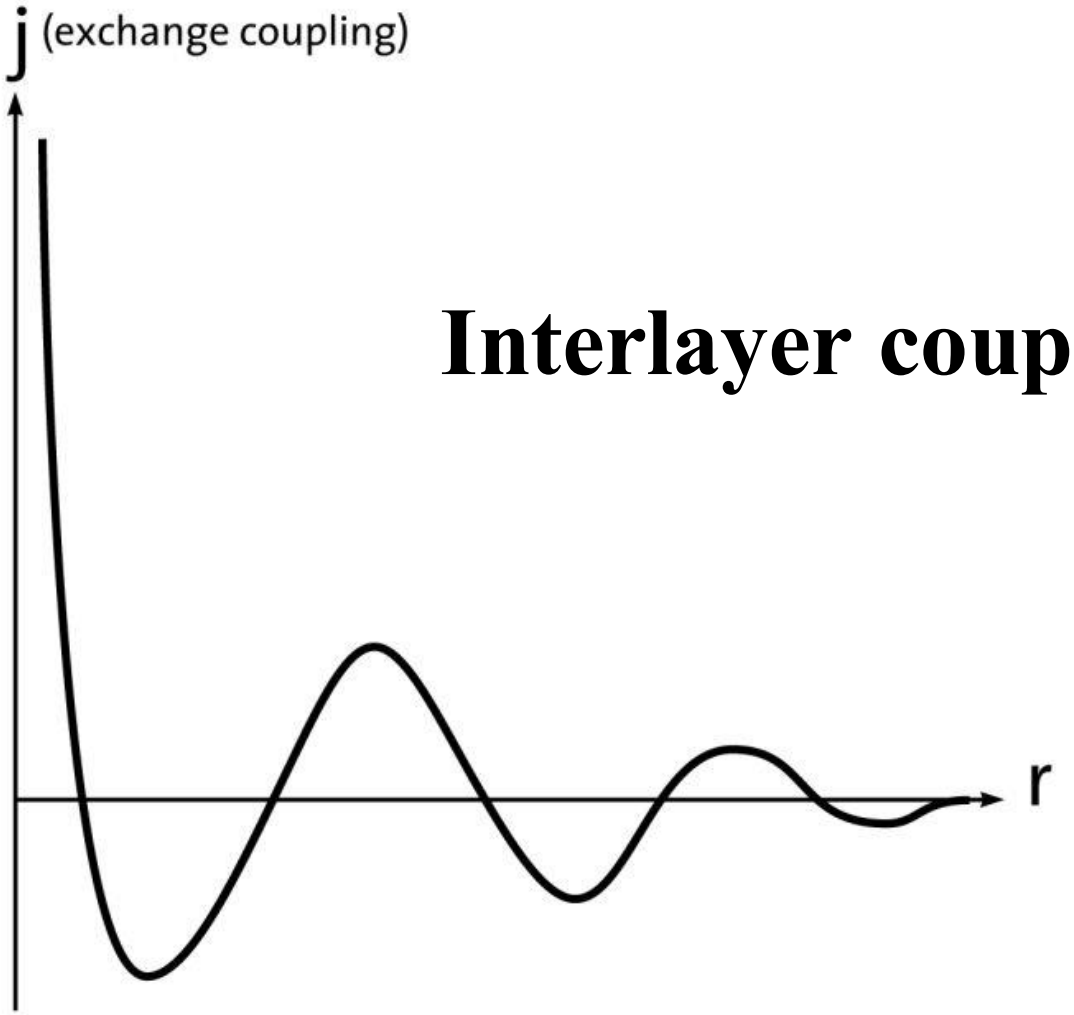
Ferromagnet (electron spin, magnetic moment)



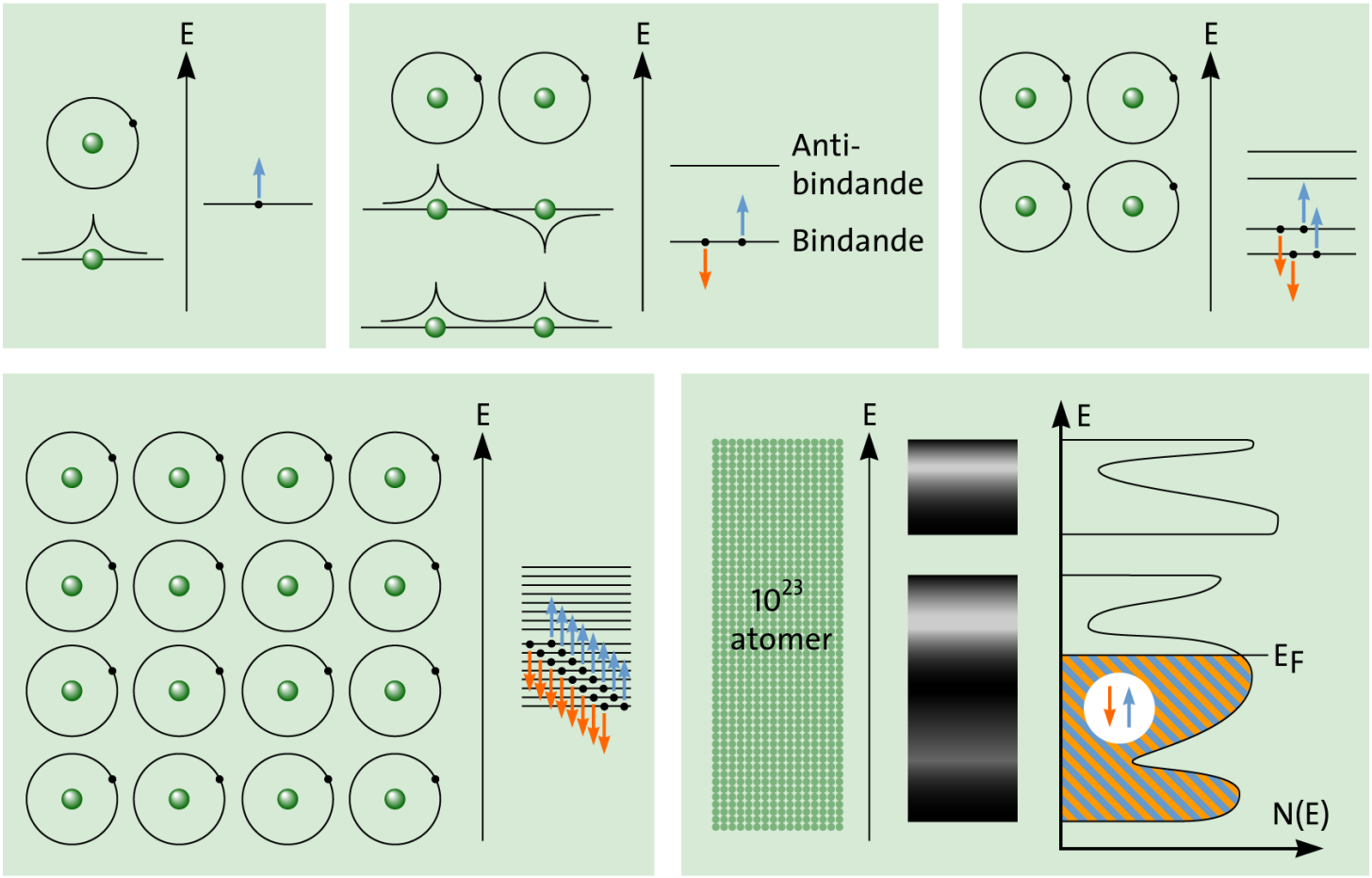


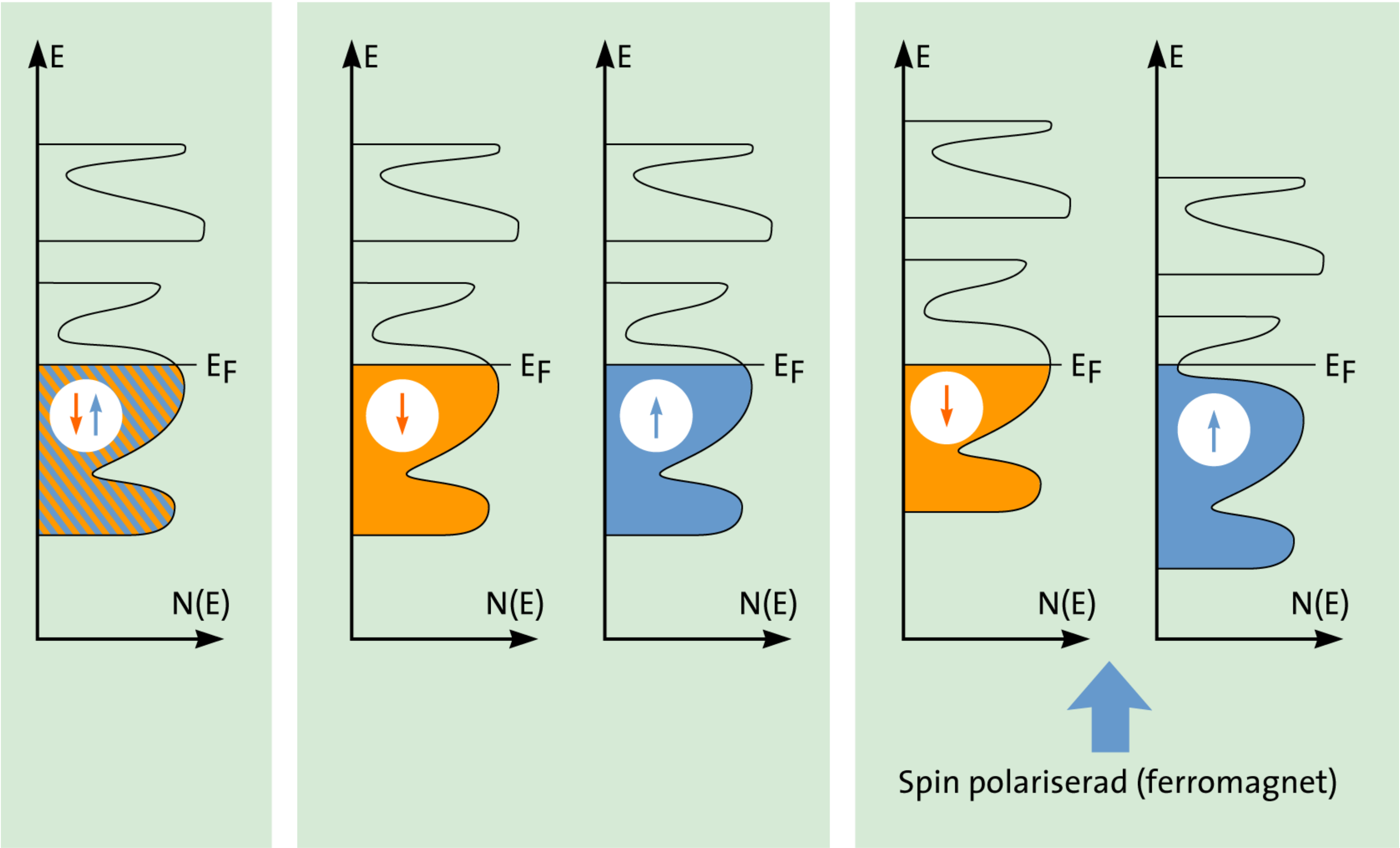
Interlayer coupling

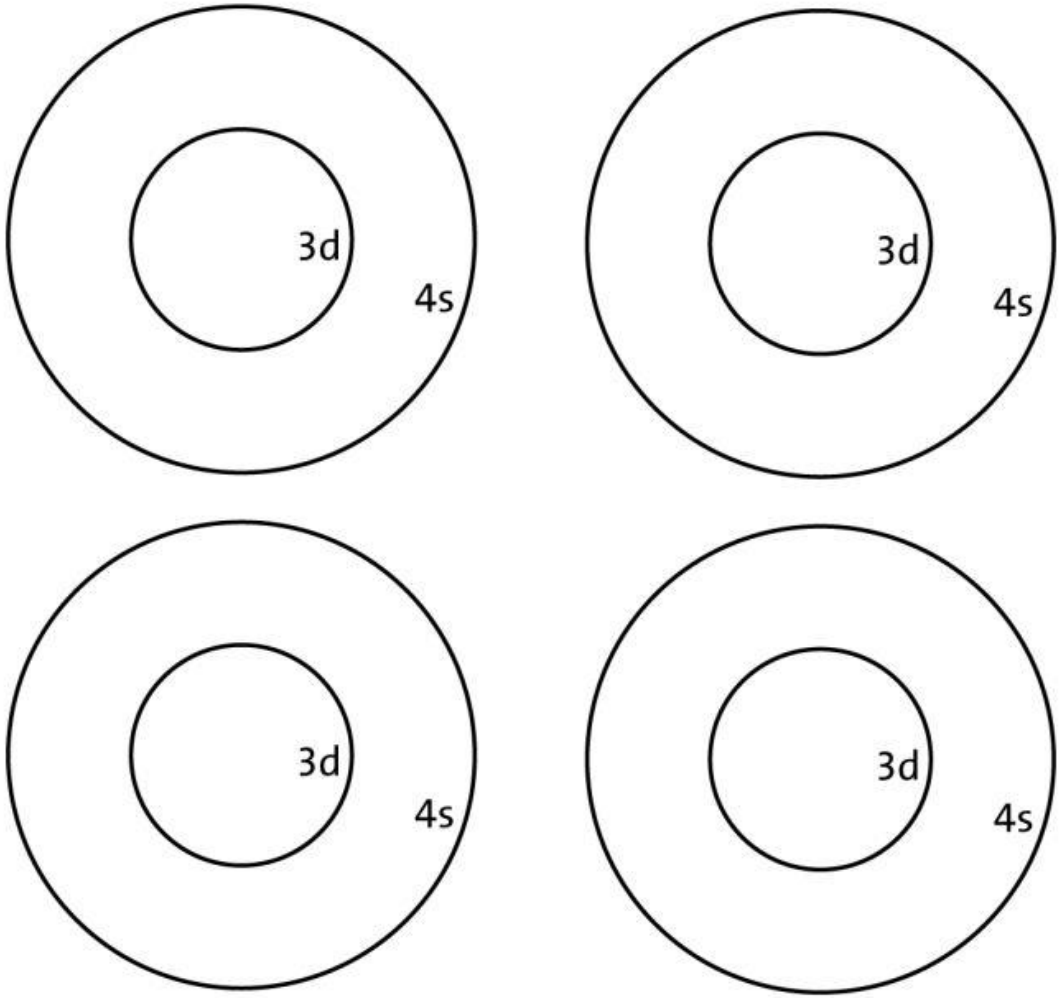


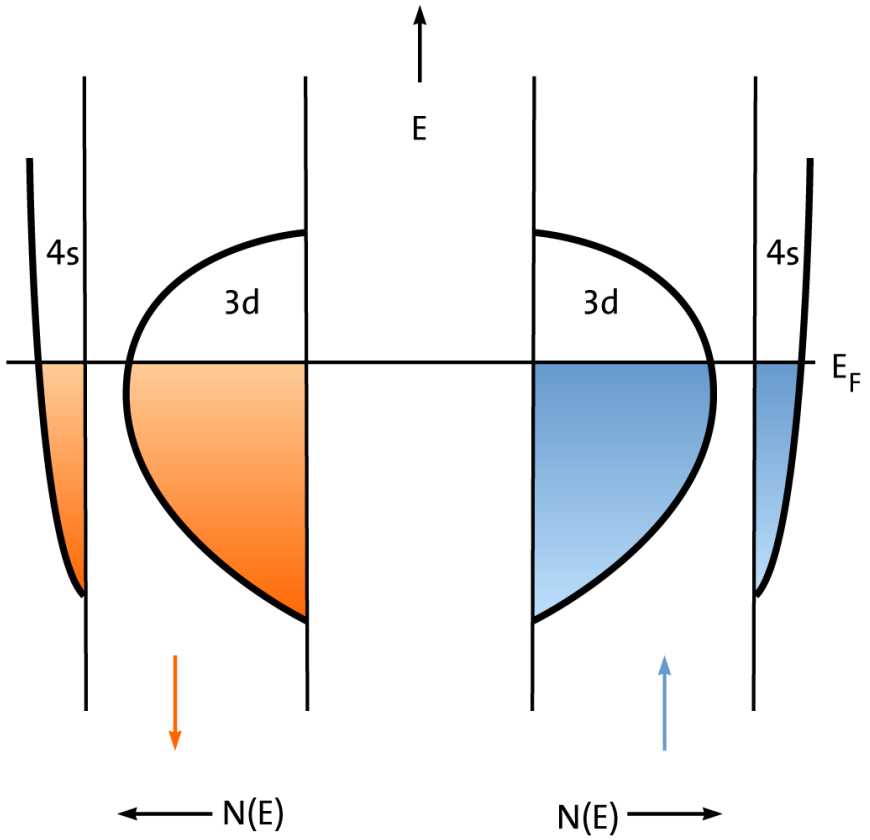


Interlayer coupling

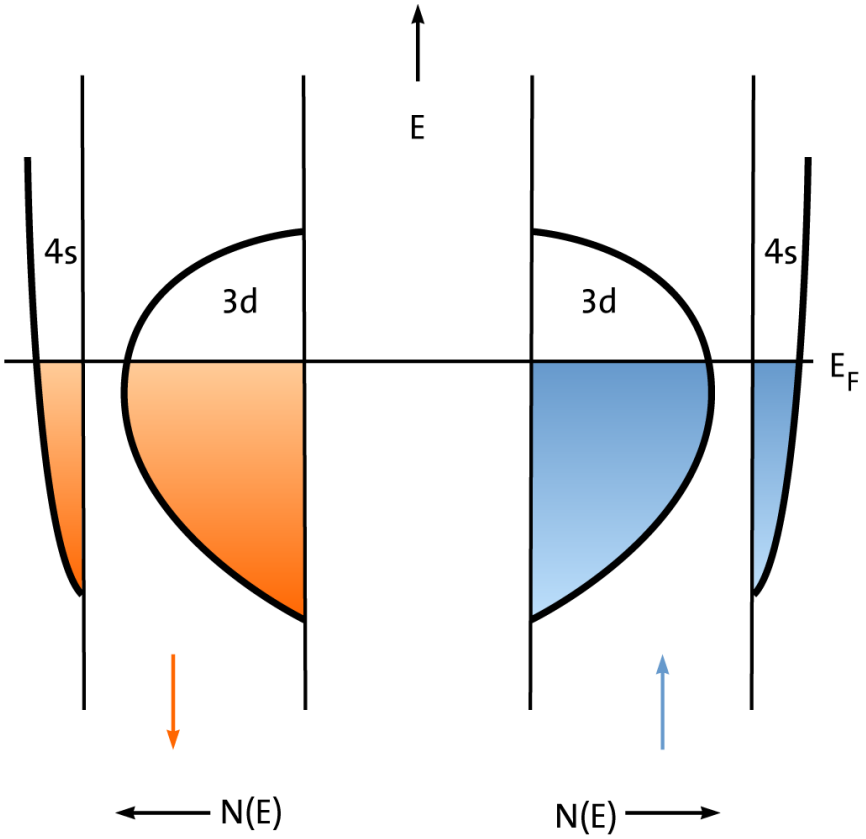

E
E
Anti-
bindande
Bindande
E
E
E
10^{23}
atomer
E
E
E_F
N(E)


E
E$_F$
N(E)
E
E$_F$
N(E)
E
E$_F$
N(E)
E
E$_F$
N(E)
E
E$_F$
N(E)
Spin polariserad (ferromagnet)

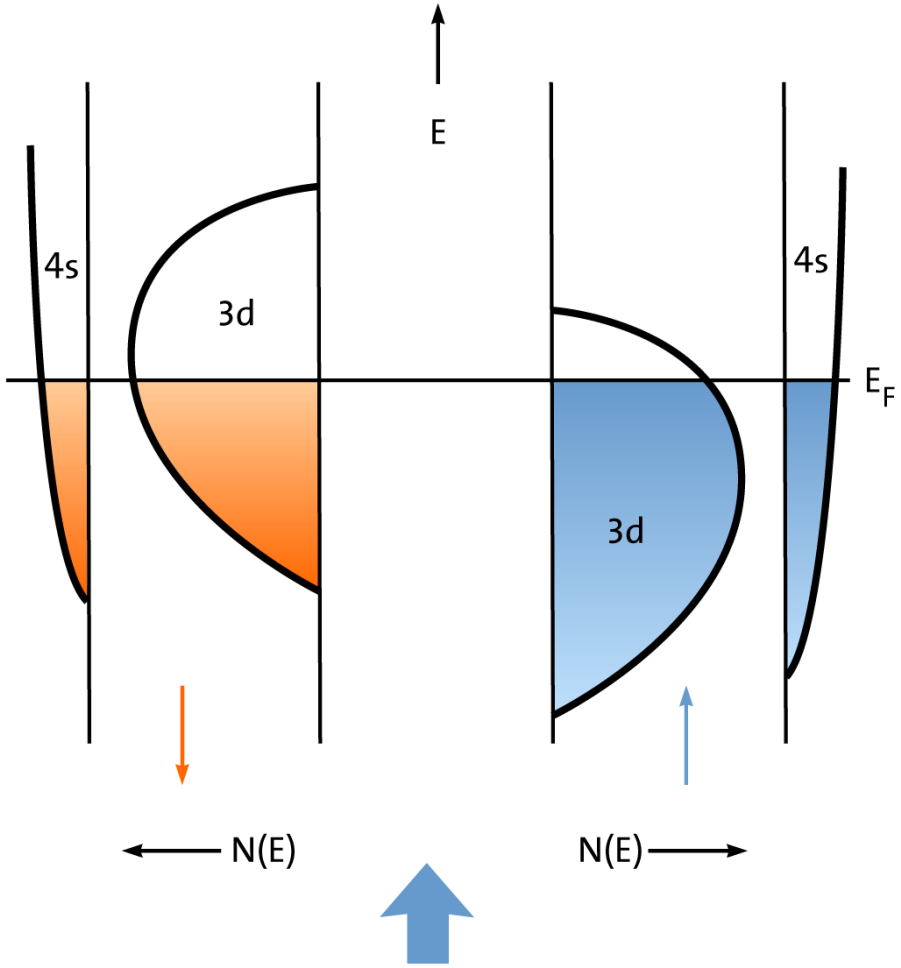

3d
4s
3d
4s
3d
4s
3d
4s

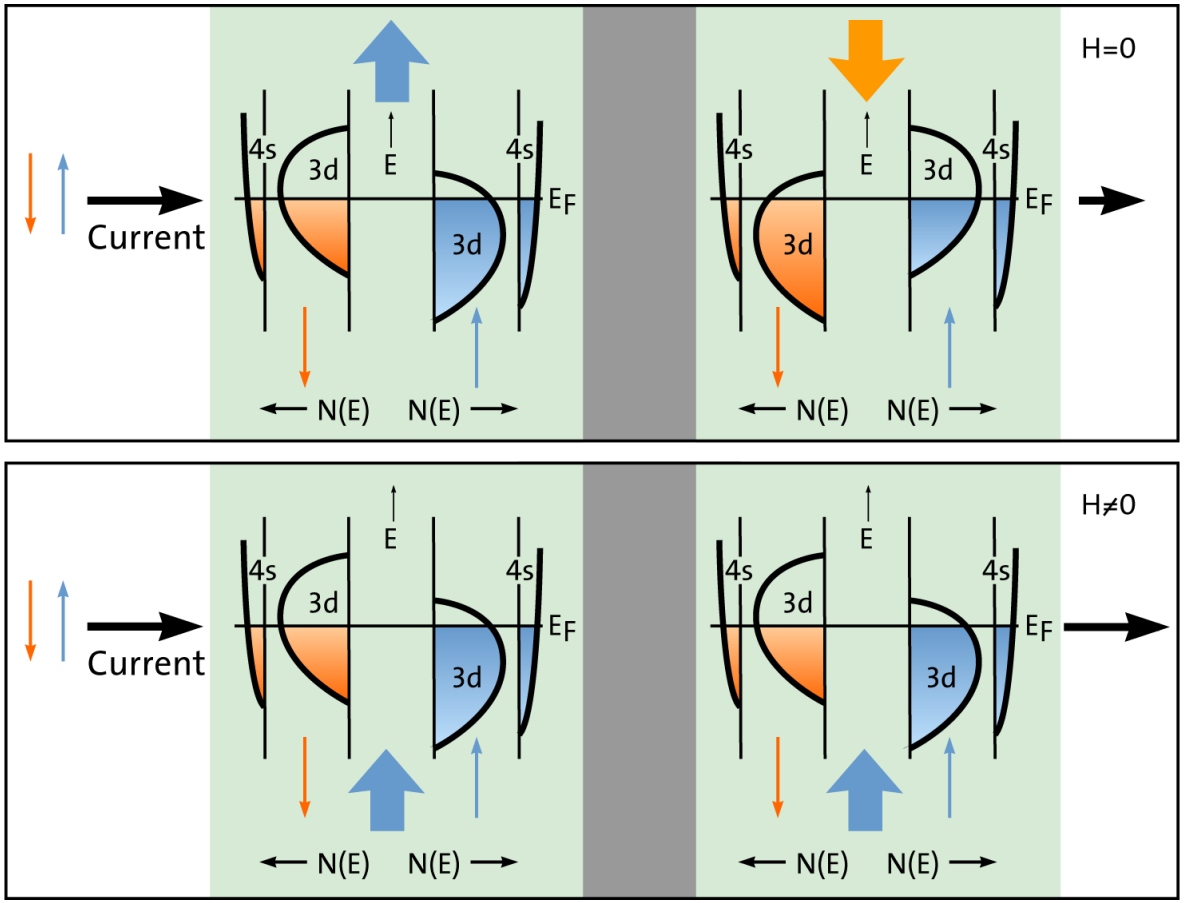

E
4s
3d
3d
4s
E_F
N(E)
N(E)

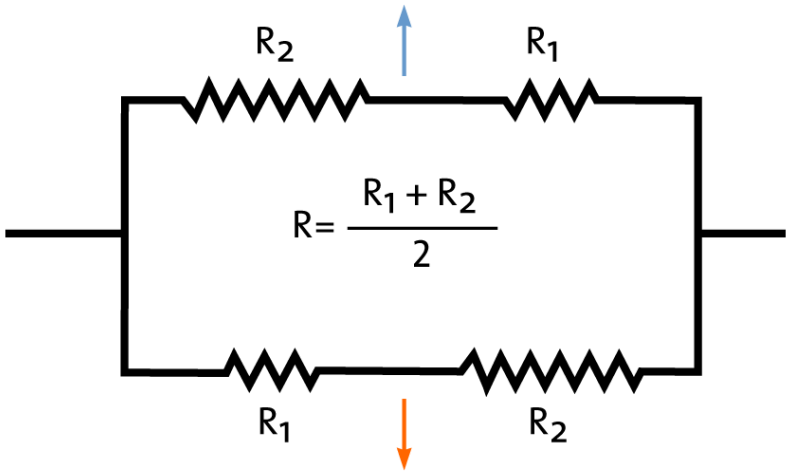
Resistans



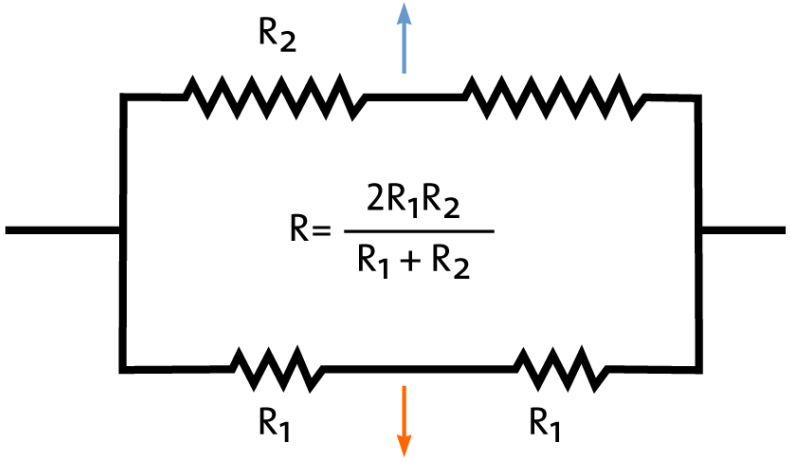
Resistans *spinn upp* elektroner
Resistans *spinn ner* elektroner



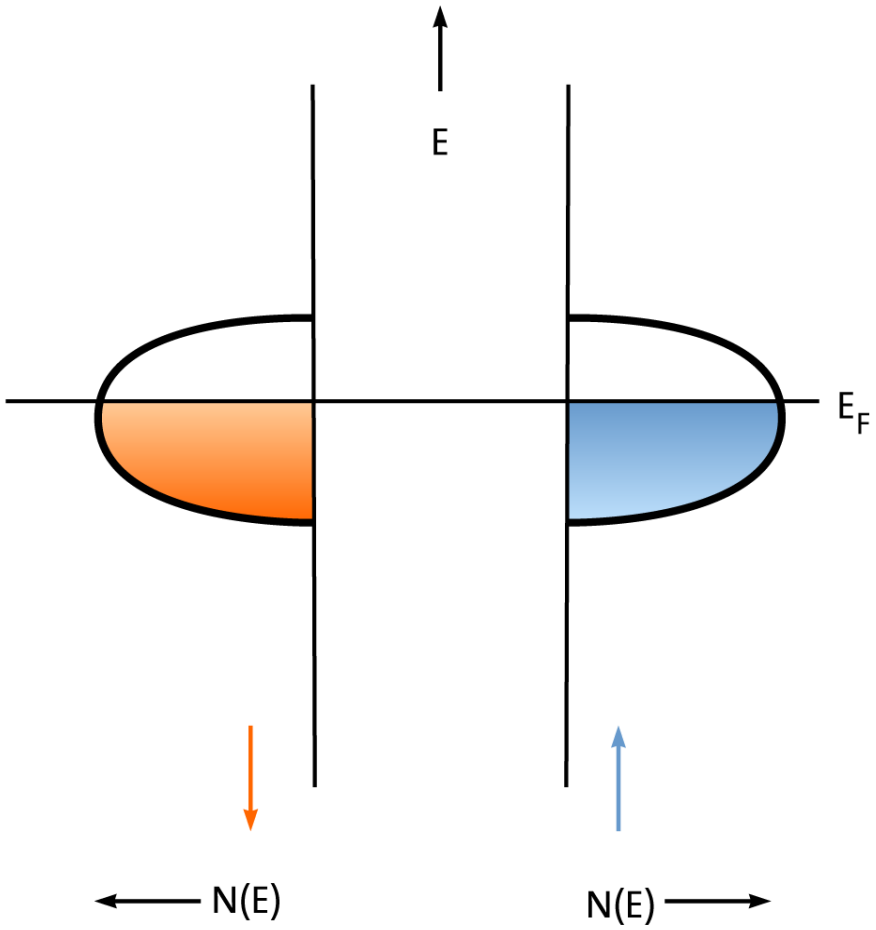

H=0
Current
4s
3d
E
4s
E_F
3d
N(E)
N(E)
4s
E
3d
4s
E_F
3d
N(E)
N(E)
H≠0
Current
4s
E
3d
4s
E_F
3d
N(E)
N(E)
4s
E
3d
4s
E_F
3d
N(E)
N(E)



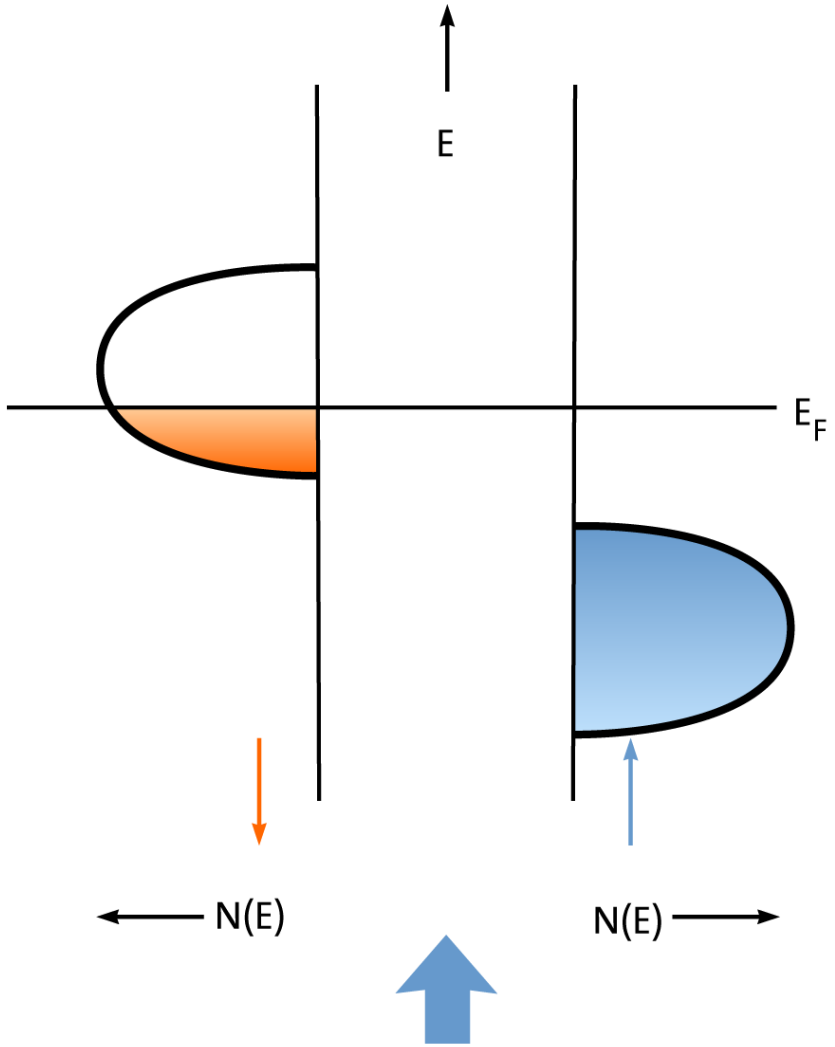
$$\Delta R = -(1/2)(R_2 - R_1)^2/(R_2 + R_1)$$

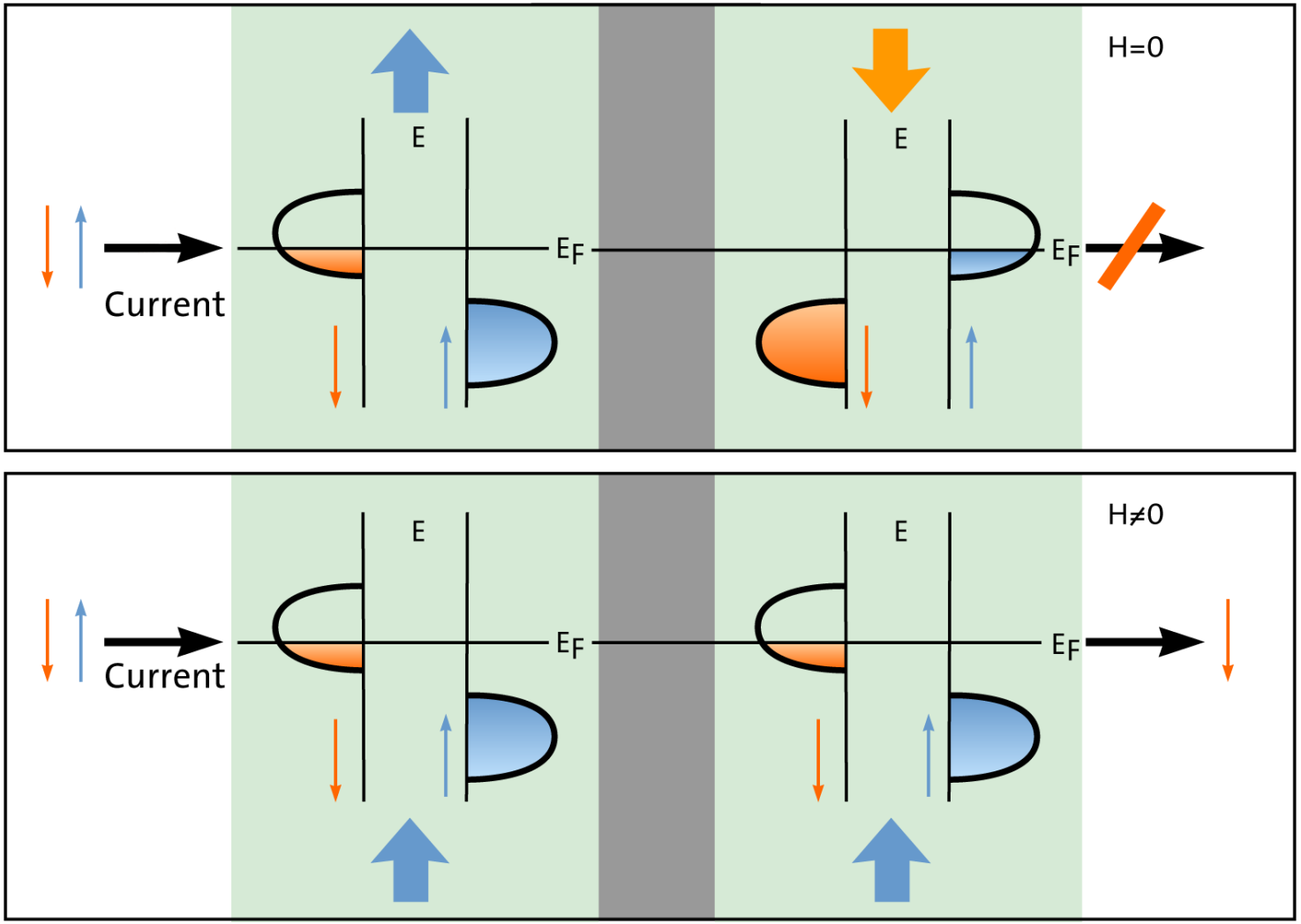


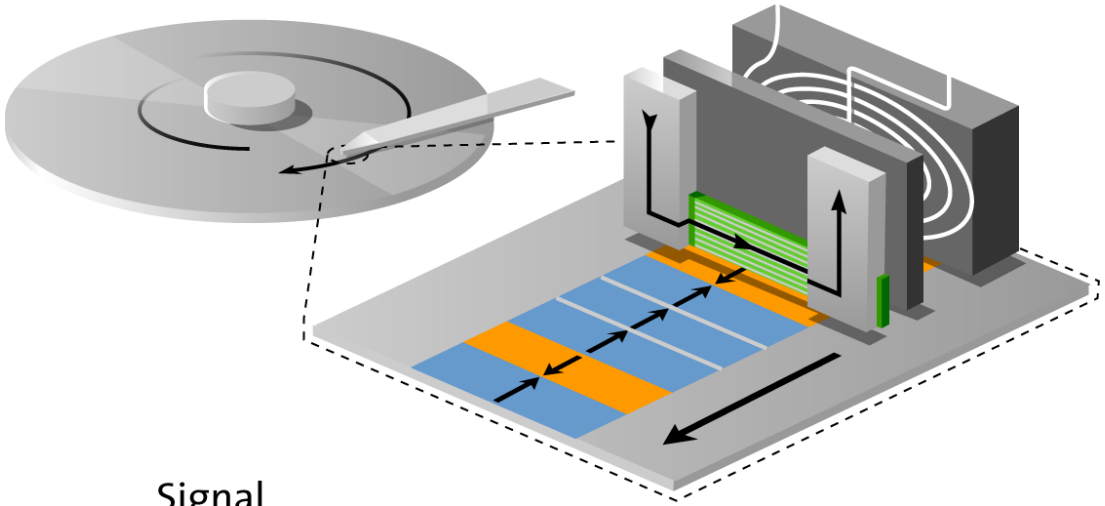
Half-metallic ferromagnet (CrO_2)

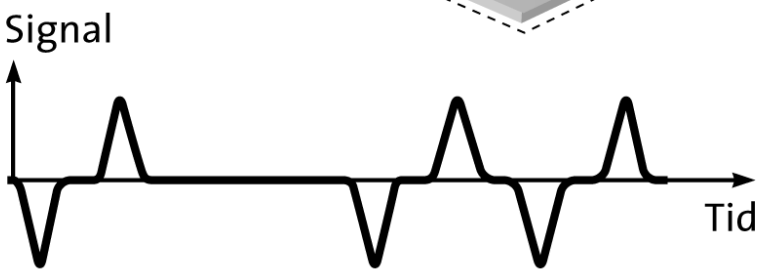


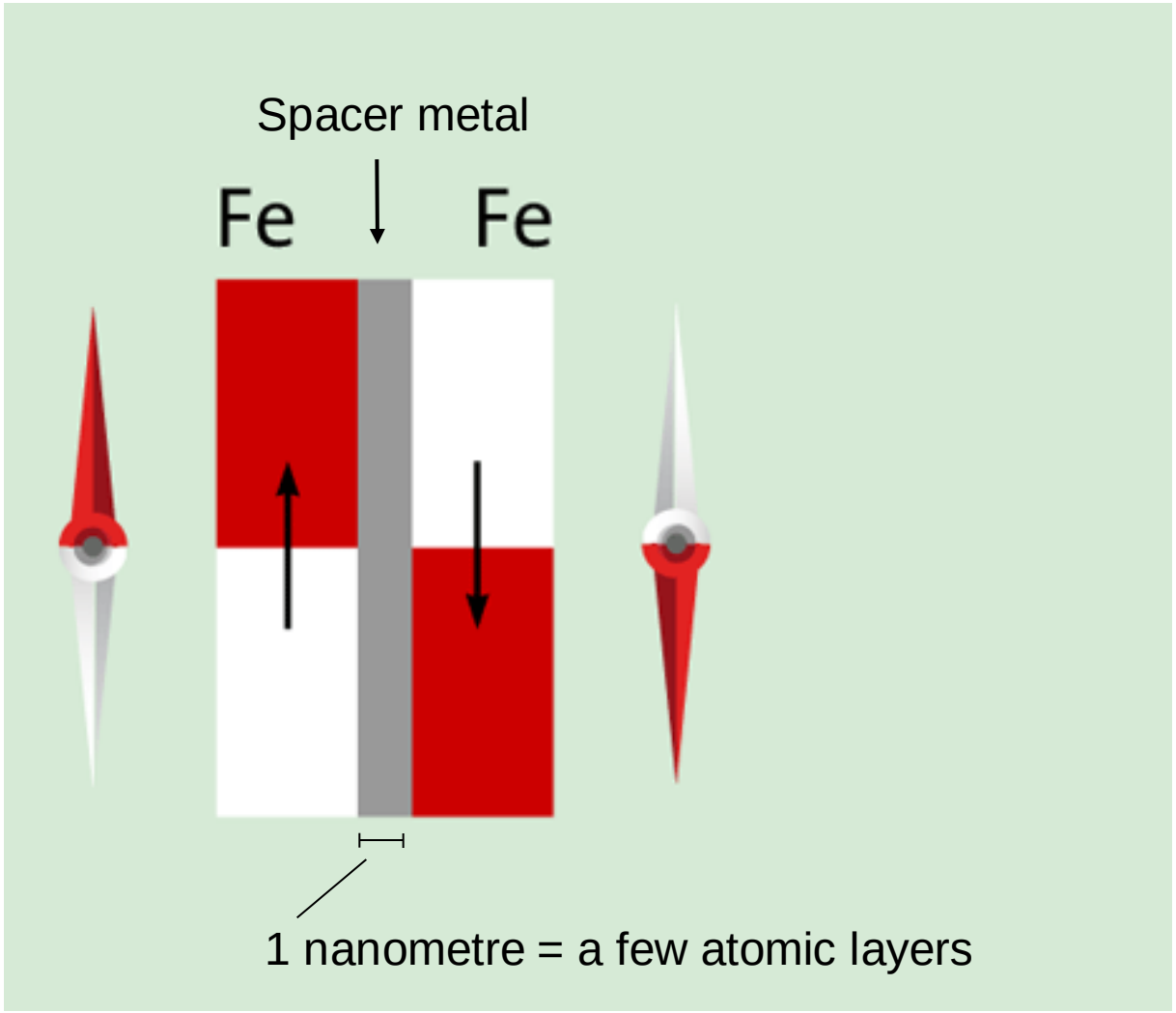
Half-metallic ferromagnet(CrO_2)

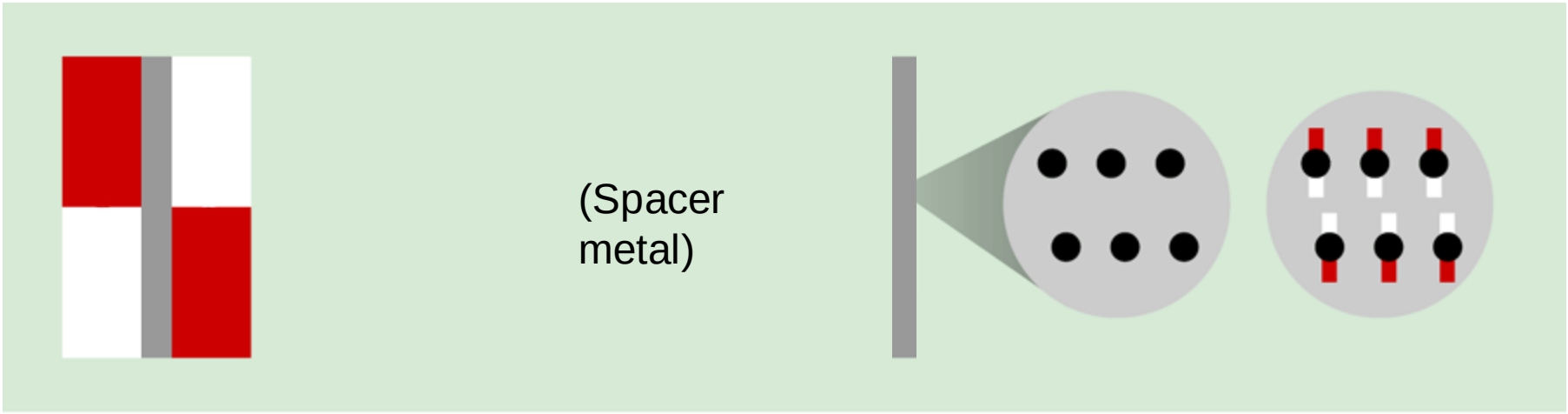


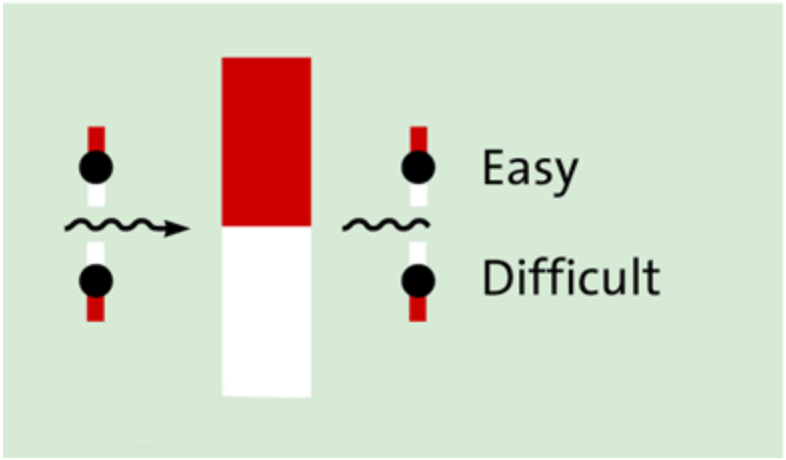

H=0
E
E
Current
E_F
E_F
H≠0
E
E
Current
E_F
E_F

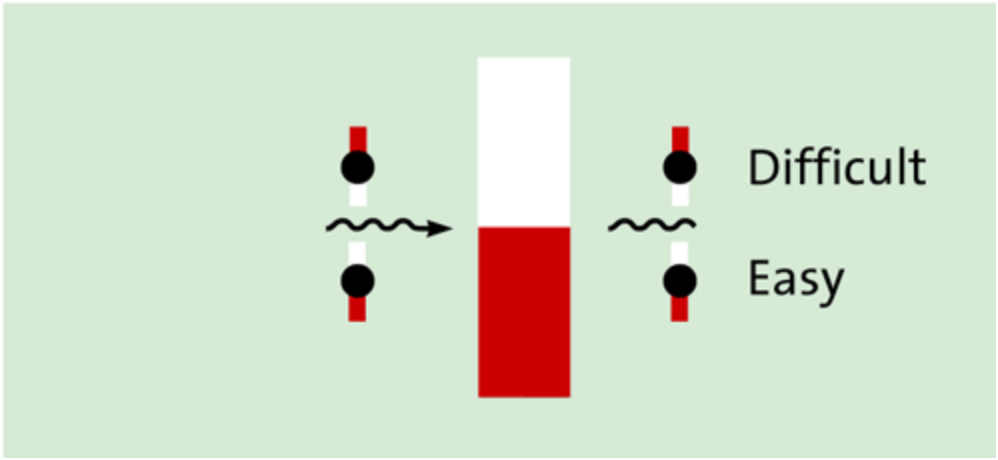



Signal
Tid

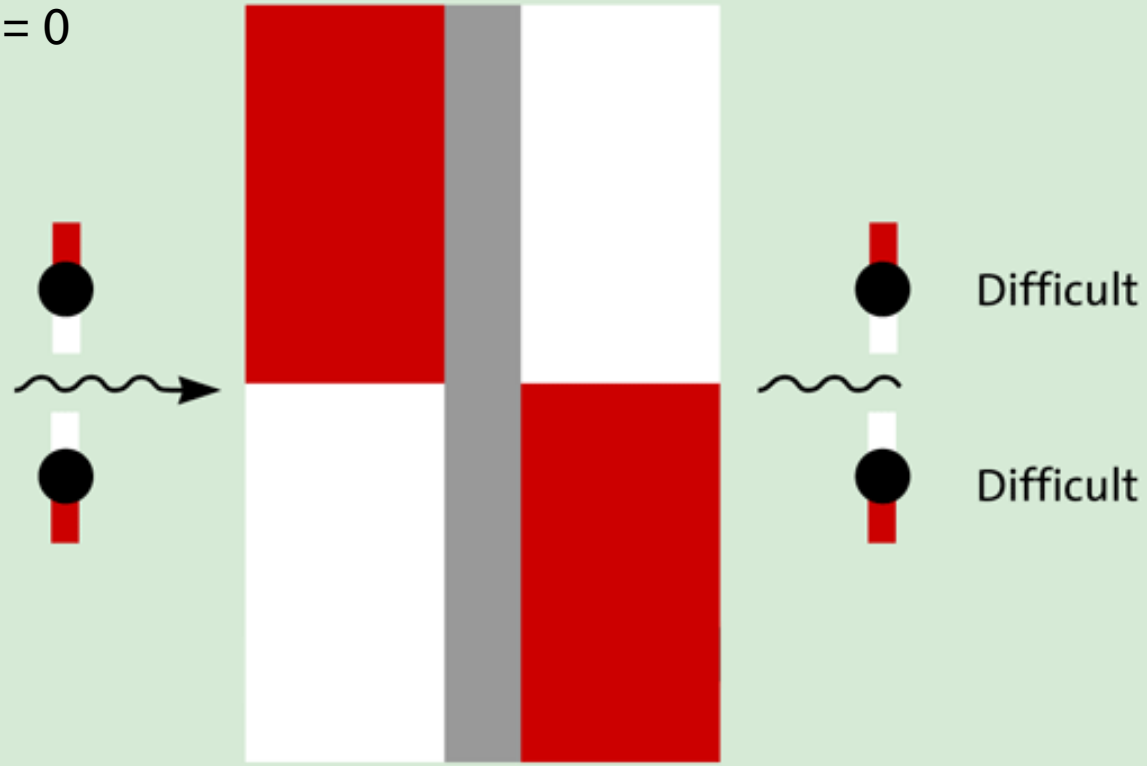

Spacer metal
Fe
Fe
1 nanometre = a few atomic layers


(Spacer
metal)

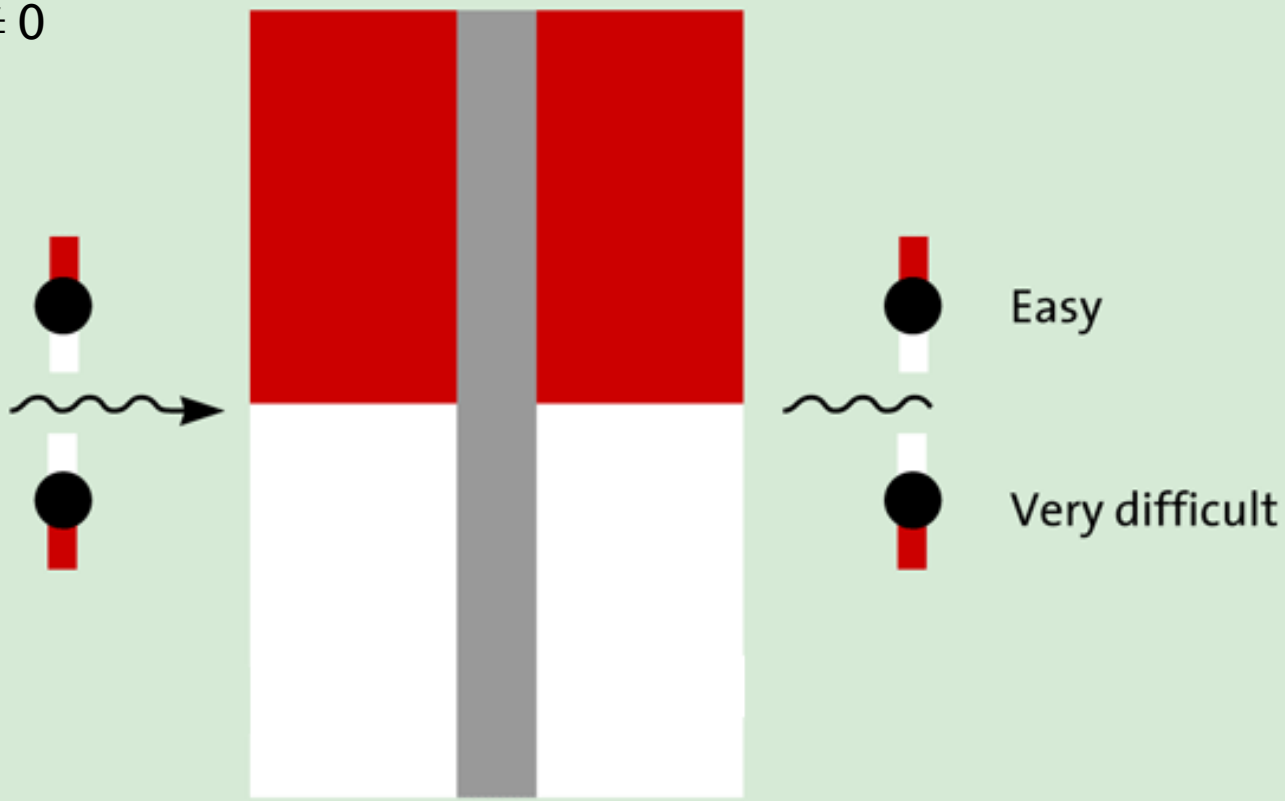

Easy
Difficult


Difficult
Easy

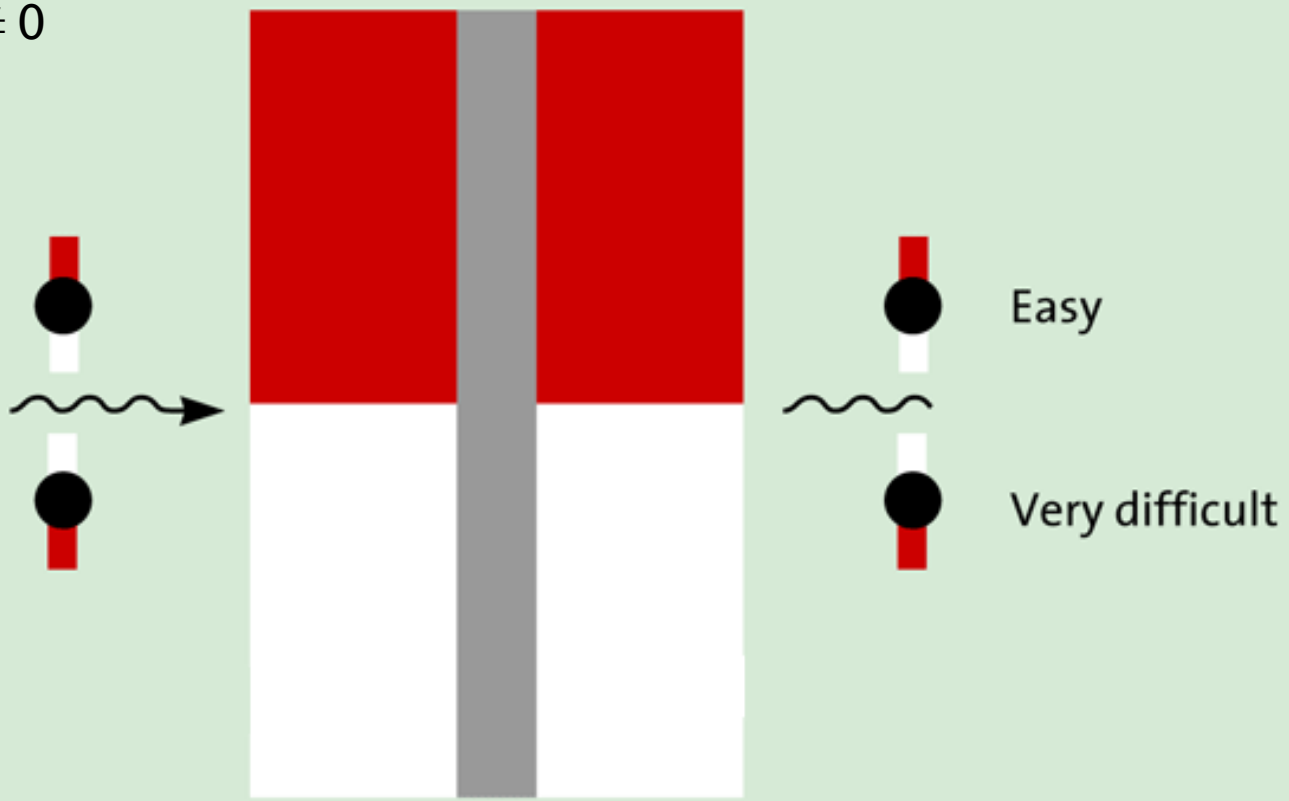
Magnetic field = 0



Magnetic field $\neq 0$



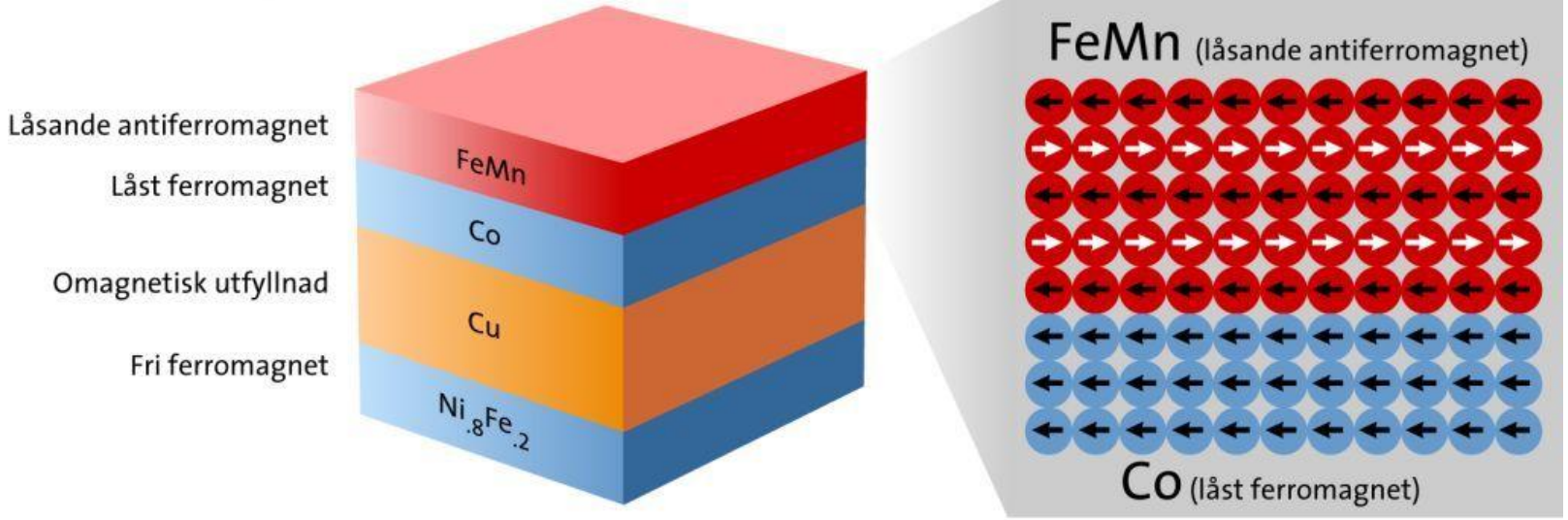
Magnetic field $\neq 0$

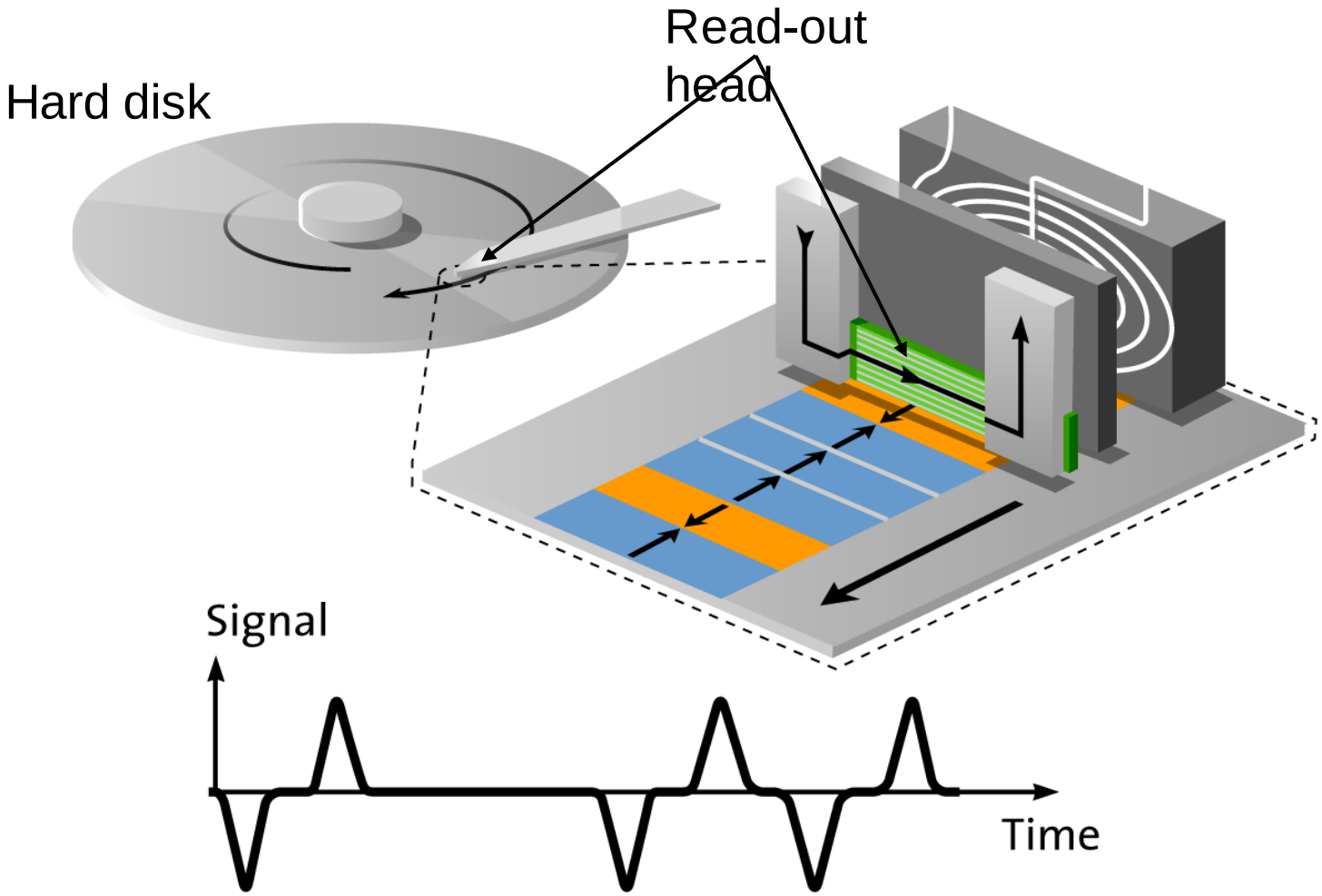


Magnetic field $\neq 0$ => Easy

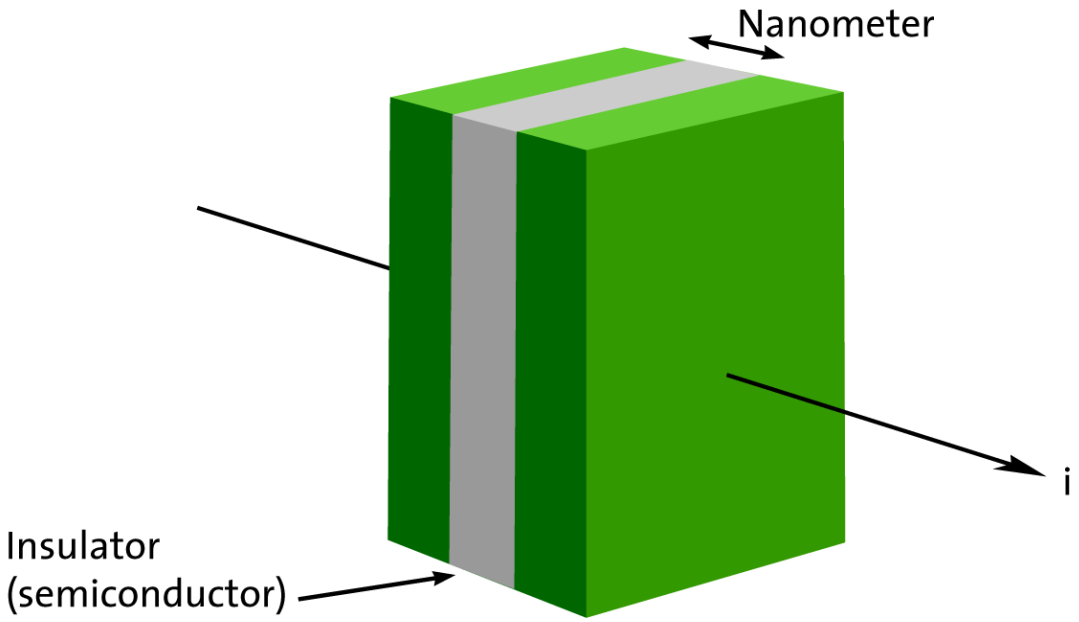
Magnetic field = 0 => Difficult

Spinnventil

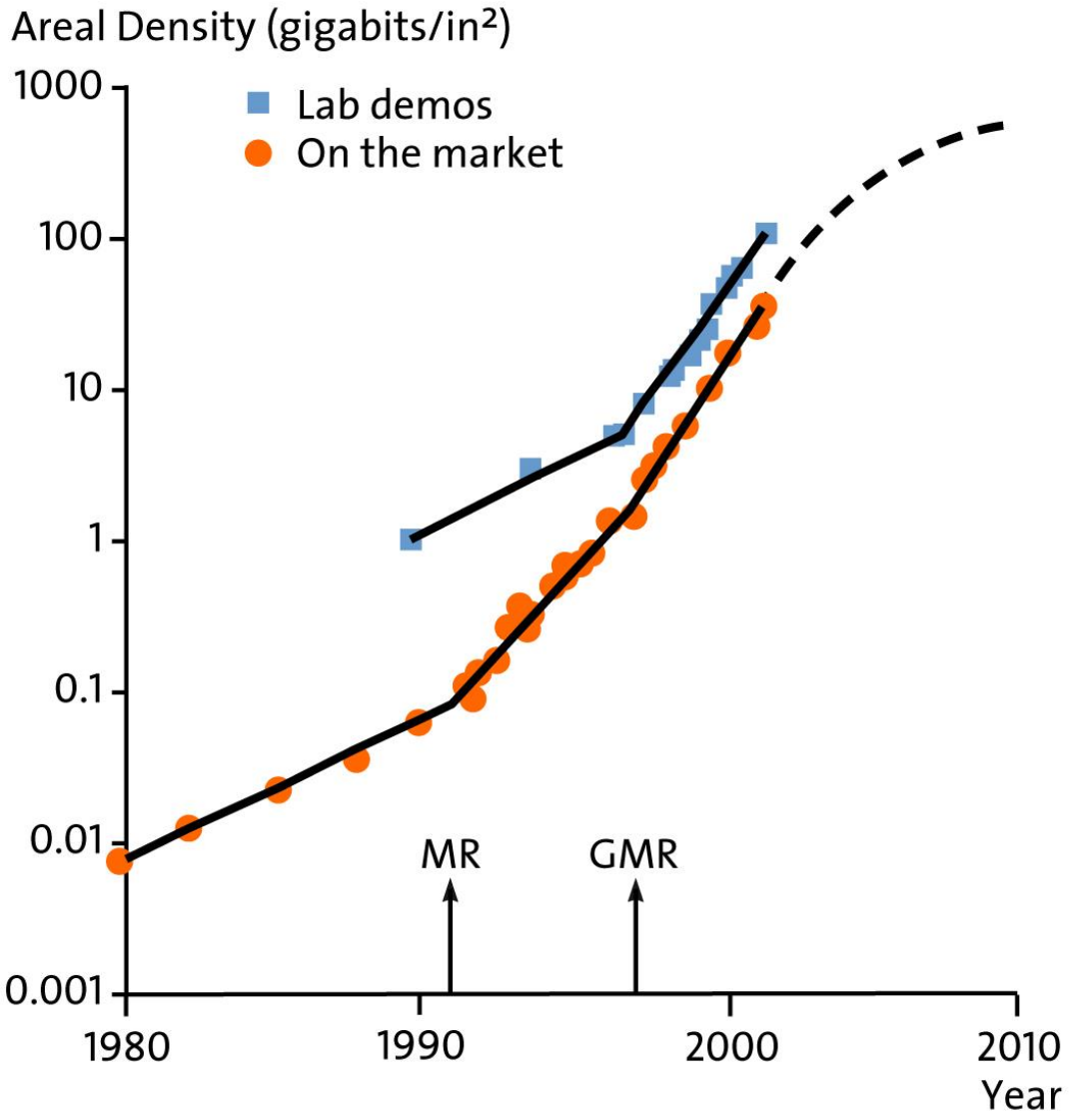


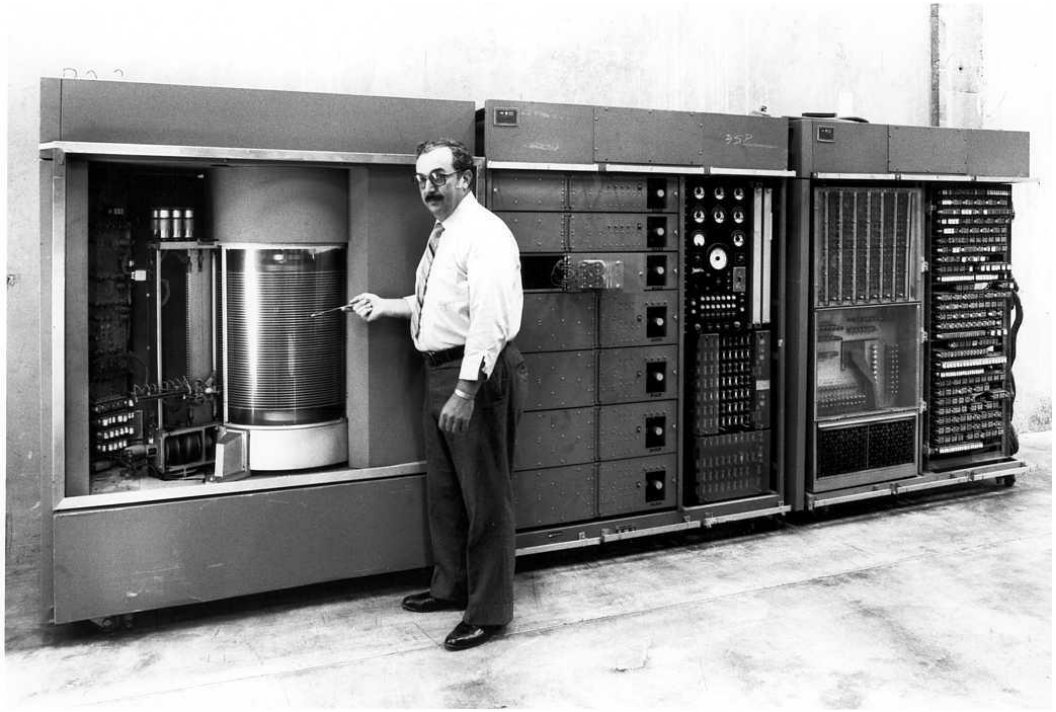

Hard disk
Read-out head
Signal
Time

Tunneling magnetoresistance (TMR)

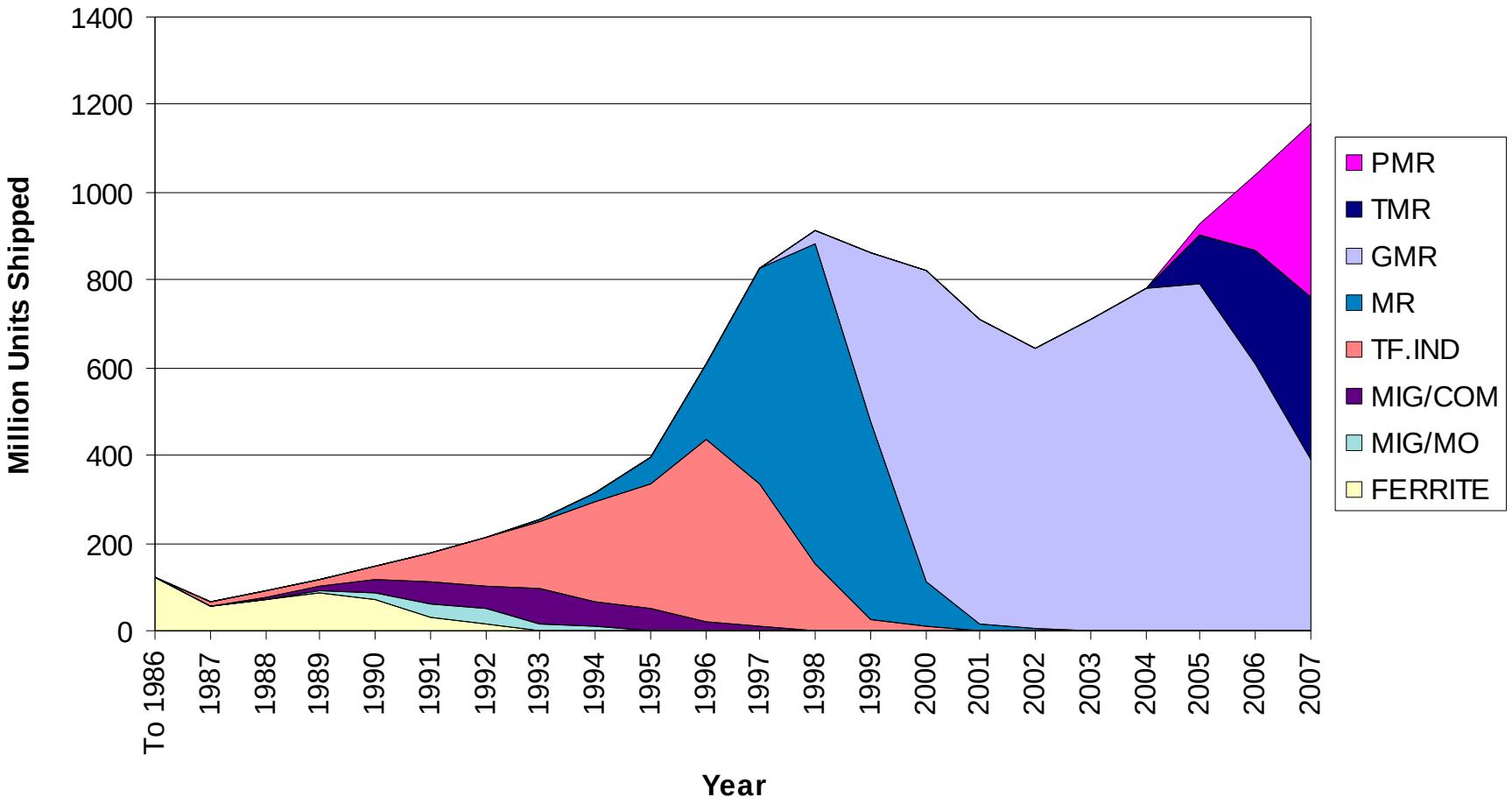


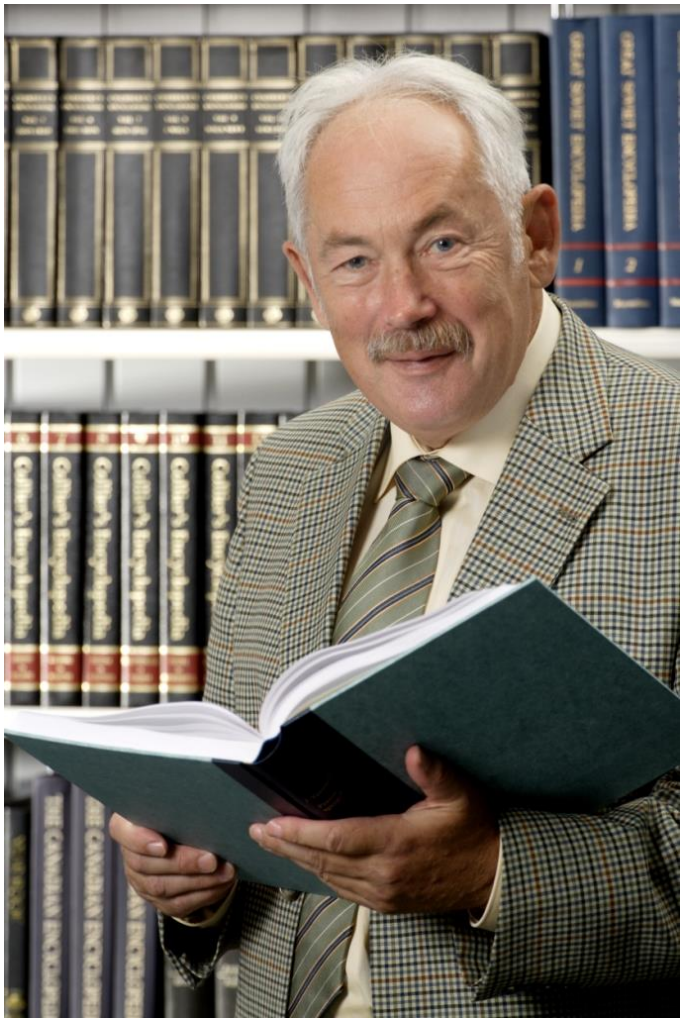
Julliere	1975
Maekawa and Gäfvert	1982
Moodera et al.	1995
Miyazaki and Tesuka	1995

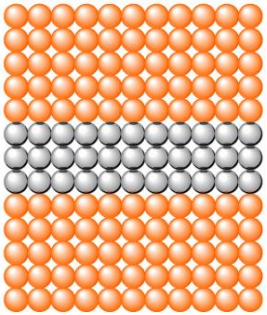

Areal Density (gigabits/in²)
1000
100
10
1
0.1
0.01
0.001
Lab demos
On the market
MR
GMR
1980
1990
2000
2010
Year

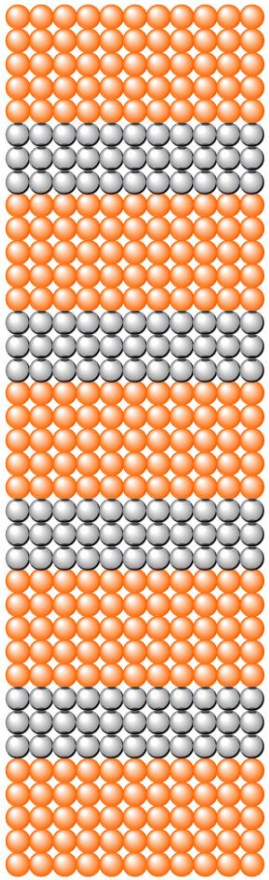


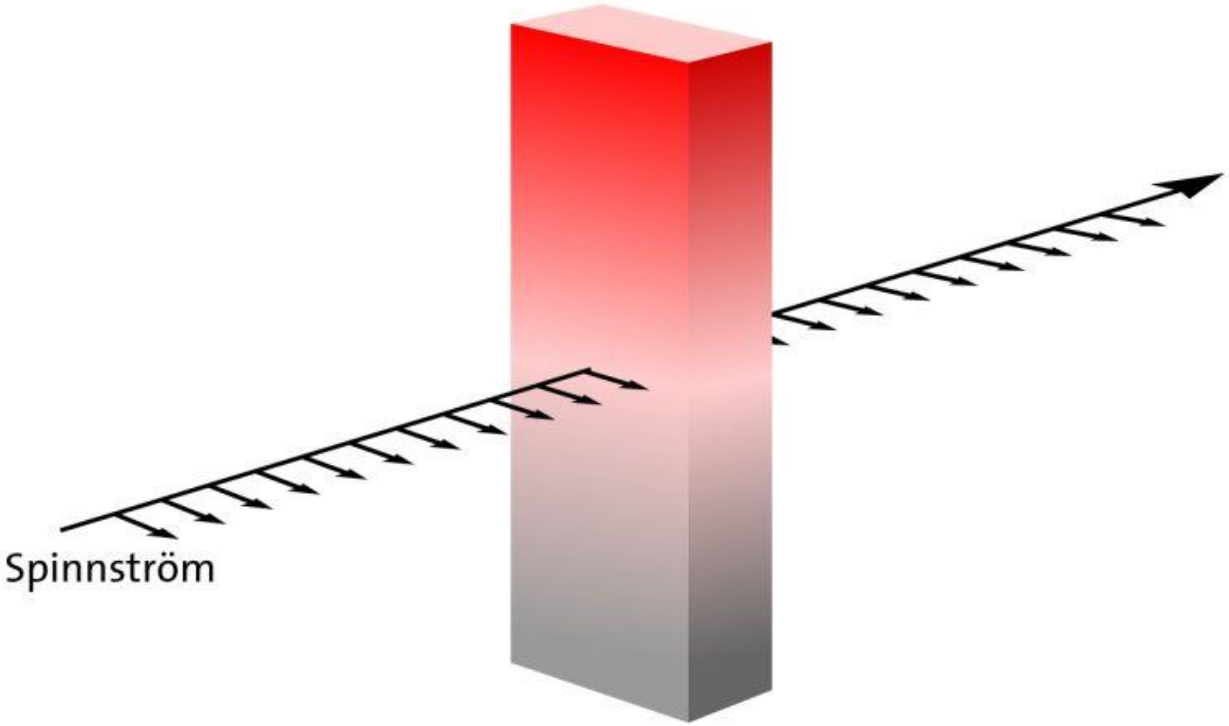
Magnetic Head Shipments vs. Technology (M/year)










Spinnström

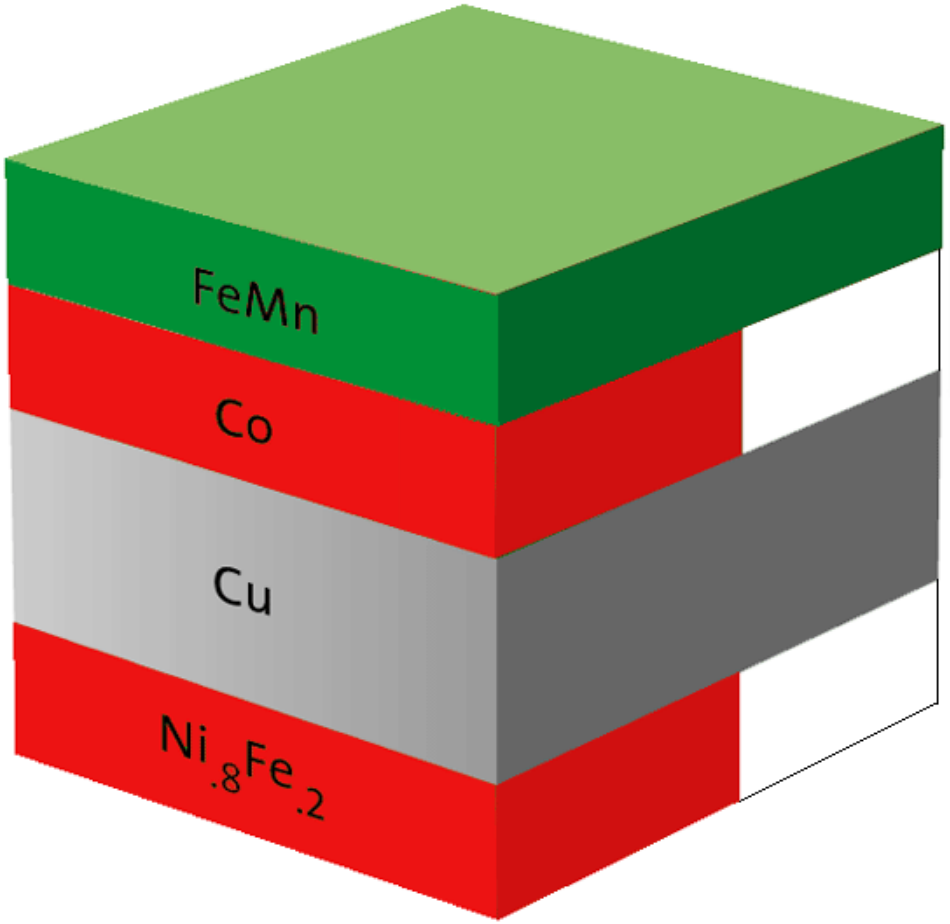
Spin valve

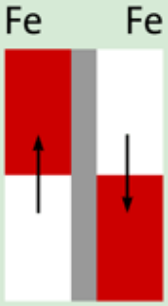
Pinning antiferromagnet

Pinned ferromagnet

Nonmagnetic spacer

Free ferromagnet





Ferromagnet (electron spin, magnetic moment)