选题

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张志东

磁性材料与磁学研究部

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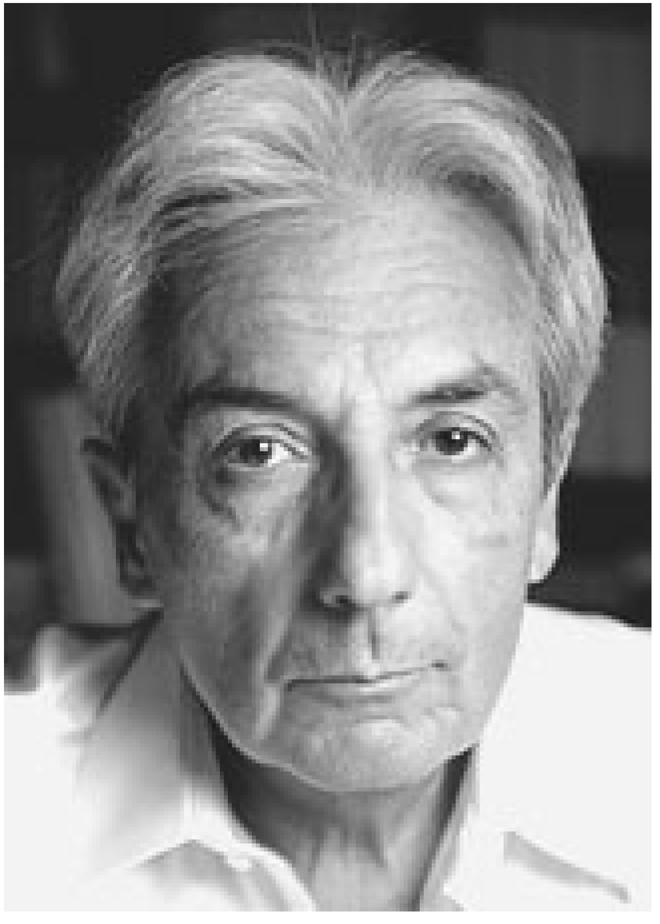
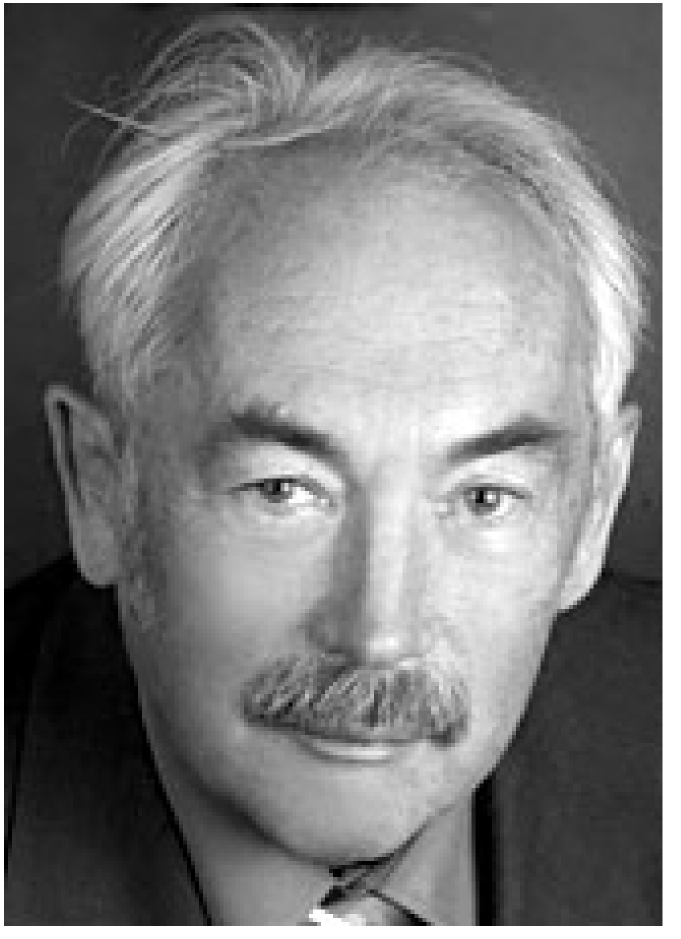
- 如何选题
- 如何选好题
- 如何选高水平的题


ALFR· NOBEL
MDCCC XXXIII
MDCCC XCVI

for the discovery of Giant Magnetoresistance



Albert Fert (1938-)
Université Paris-Sud;
Unité Mixte de Physique
CNRS/THALES
Orsay, France



Peter Grünberg (1939-)
Forschungszentrum Jülich
Jülich, Germany

多层膜中的巨磁电阻效应

1986年德国科学家Grunberg小组在Fe/Cr/Fe三层膜中观察到两个铁磁性层之间通过铬非磁性层产生交换耦合。

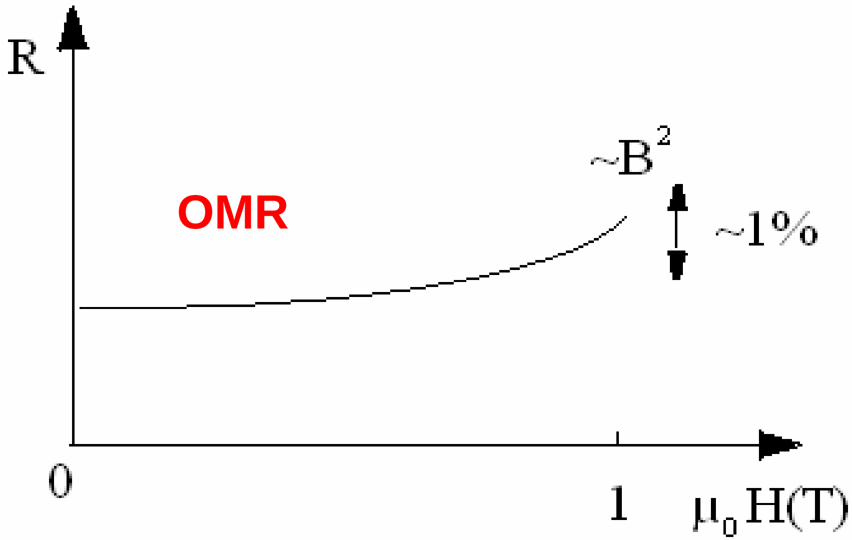
1988年法国科学家Fert小组和Grunberg小组分别在[Fe/Cr]周期性膜/多层膜中，观察 到当施加外磁场时，其电阻下降，变化率高达50％。因此称之为巨磁电阻效应(giant magnetoresistance, GMR)。

1995年，人们以绝缘层Al2O3代替导体Cr，观察到很大的隧道磁电阻(TMR)现象。

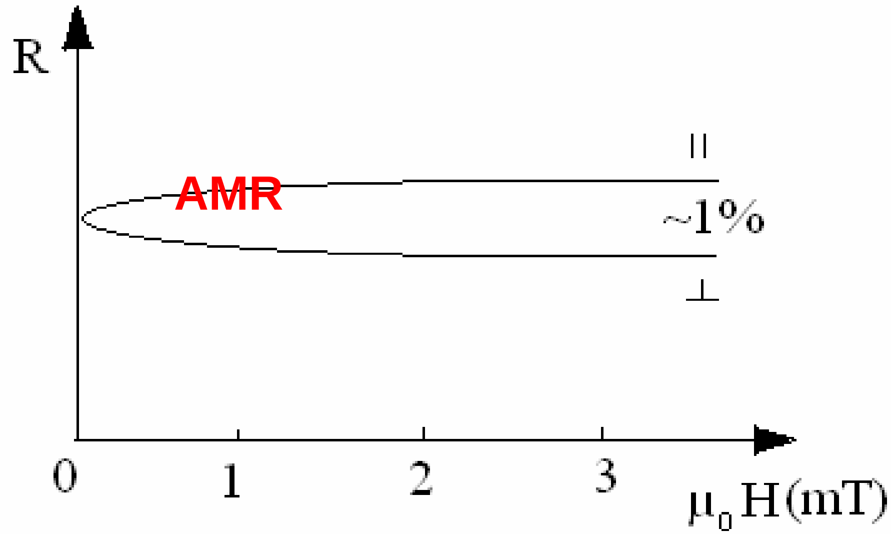
巨磁电阻的应用

- 基于GMR和TMR的发现，产生一个新的学科分支——磁电子学。 科技人员坚持不懈地努力，将上述创新性发现在信息技术(IT)实现产业化。

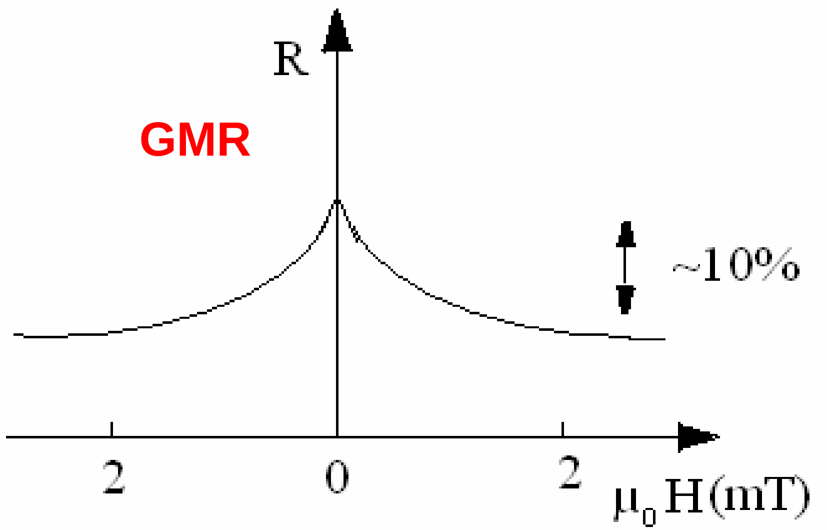
- 1999年以GMR多层膜为磁头的硬盘驱动器进入市场，其存储密度达到11Gbits/in^2，而1990年仅为0.1Gbits/in^2，10年中提高了100倍。现在已经接近100Gbits/in^2 。



Ordinary Magnetoresistance (a)



Anisotropic Mangetoresistance (b)

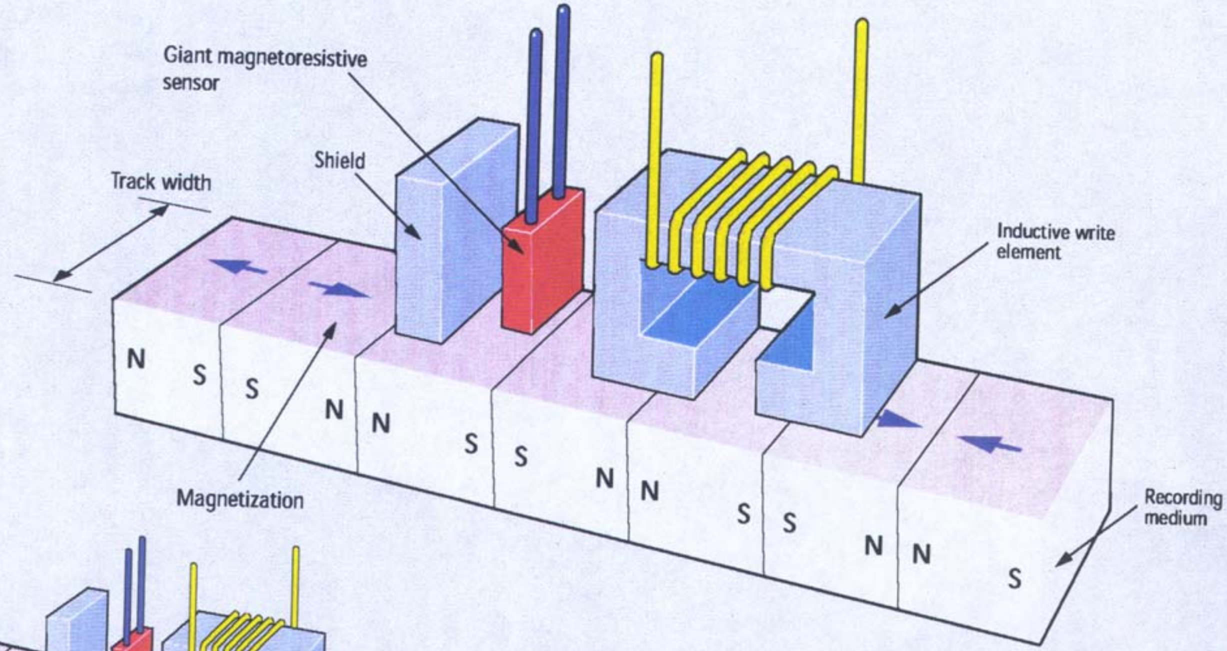


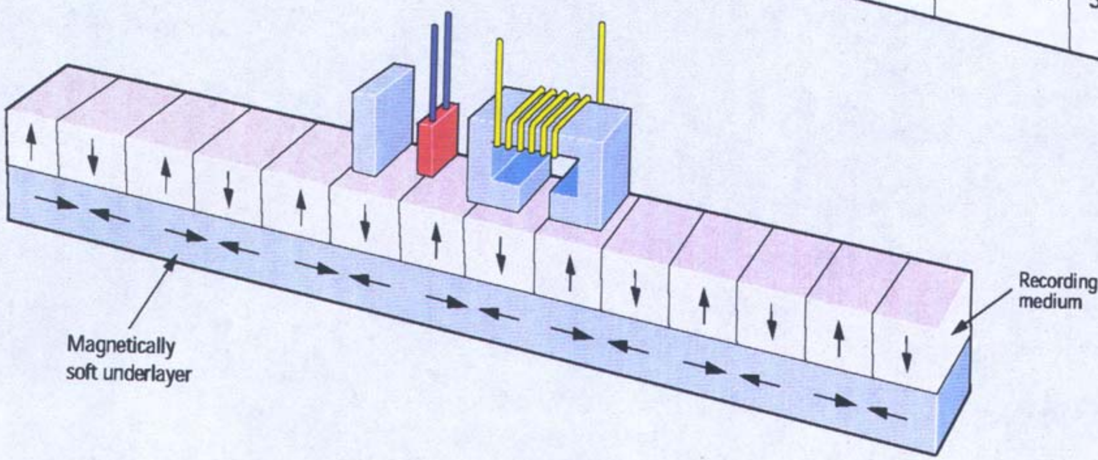
Giant Magnetoresistance (c)

➢ 磁电阻的应用：

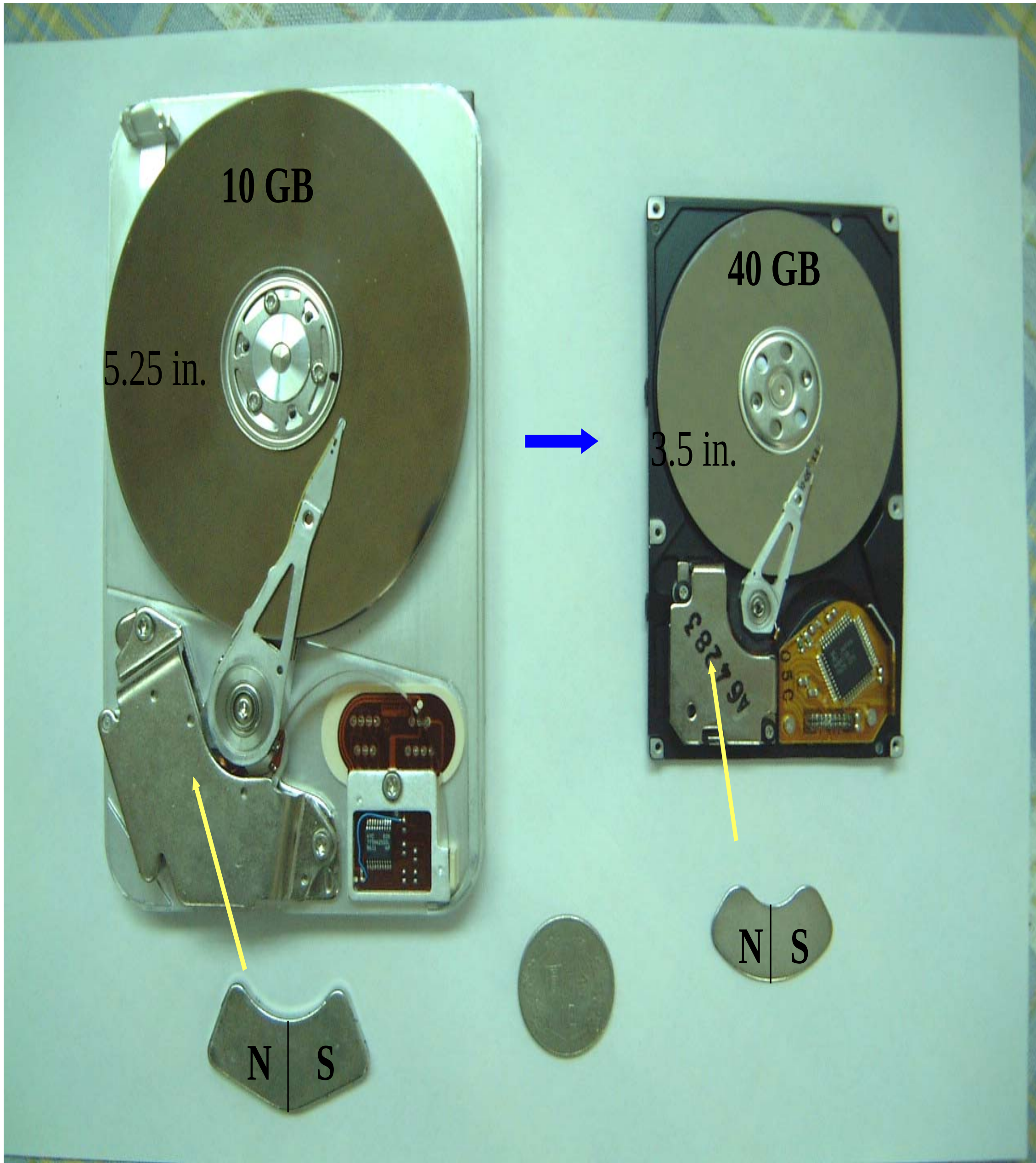
[1] In conventional magnetic disk recording [top], if the area of each horizontally stored bit is too small, thermal effects cause the grains of material to lose magnetization quickly.

Fujitsu found that adding an underlayer to reinforce the magnetization of the bits allows the bit domains to be narrower [bottom]. Also, still greater bit densities are possible if the material is magnetized vertically [bottom, again]. Eventually, Fujitsu thinks, this could boost density eight times to 50 Gb/cm².





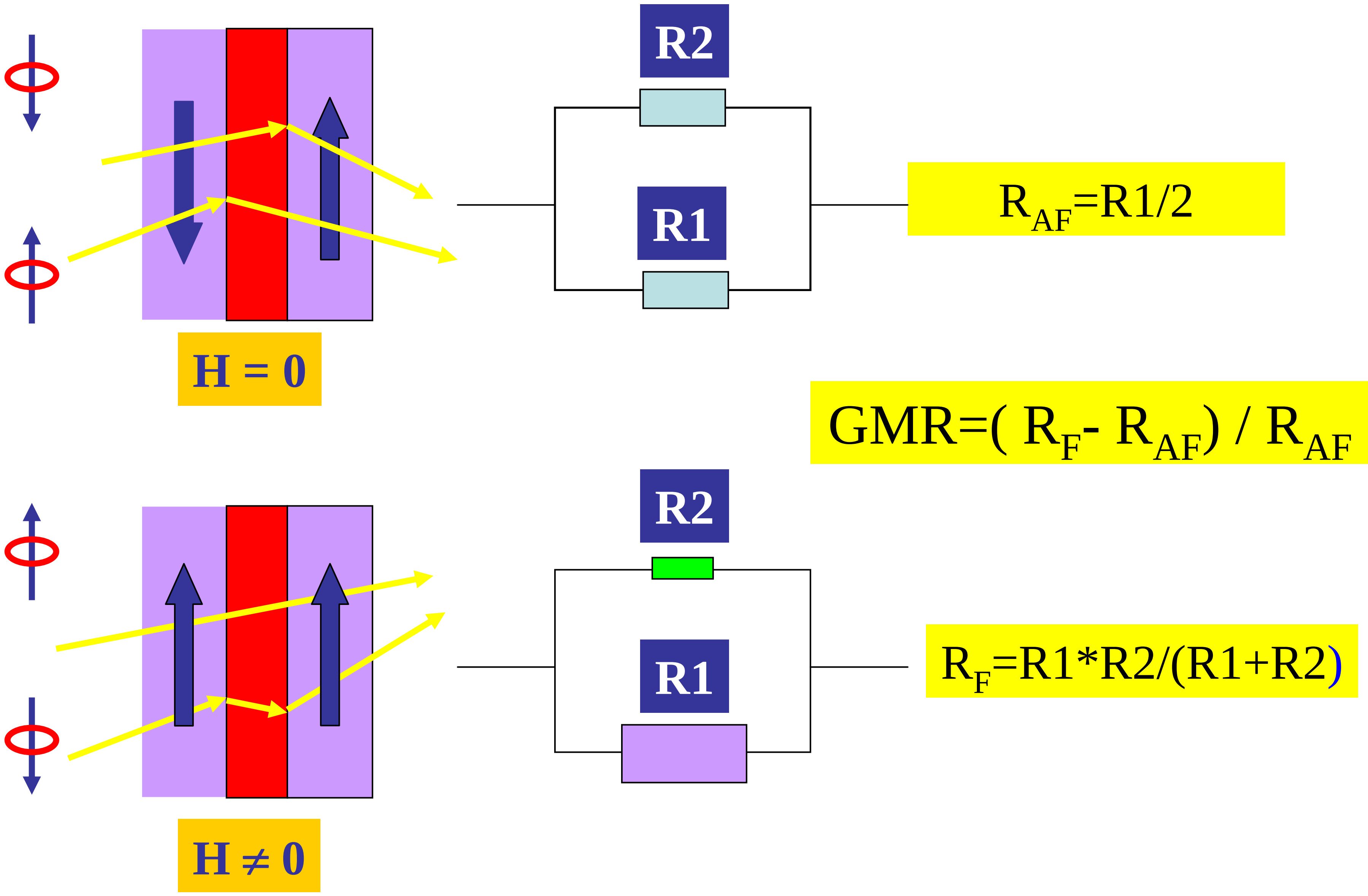
➢ 磁电阻的应用：



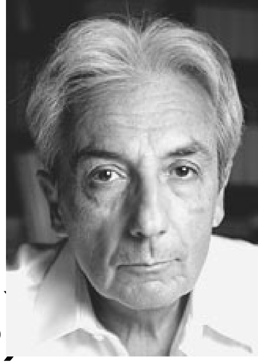
GMR现象的物理机制

- 在Fe/Cr/Fe系统中，相邻铁层间存在着耦合，它随铬层厚度的增加而呈正负交替的振荡衰 减形式。使得相邻铁层磁矩从彼此反平行取向到平行取向交替变化。外磁场也可使多层膜中铁 磁层的反平行磁化状态发生变化。当通以电流时，这种磁化状态的变化就以电阻变化的形式反 映出来。

多层膜GMR效应产生的机制
（双流体模型）

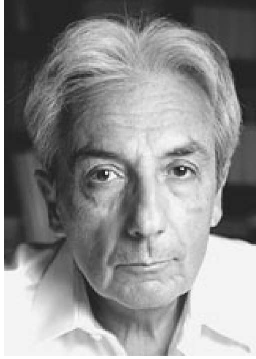


Albert Fert



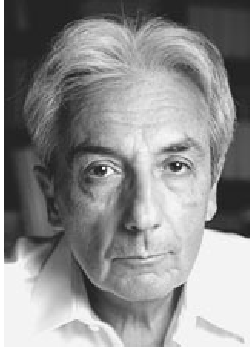
- **Education**
  1957-1962 - Ecole Normale Supérieure (Paris)（巴黎高等师范学院）: Maîtrise de Mathématiques, Maîtrise de Physique.
- 1963 - Université de Paris : Thèse de 3ème cycle, Title: " NMR of hydrogen absorbed by palladium ", Supervisor : P. Averbuch, Preparation at Institut d'Electronique Fondamentale (Orsay) and Laboratoire de Spectrométrie Physique (Grenoble).
- 1970 – Université Paris-Sud（巴黎第十一大学）: Doctorat es Sciences Physiques, Title: " Transport properties of nickel et iron ", Supervisor : I. A. Campbell, Preparation at Laboratoire de Physique des Solides (Orsay).

Albert Fert



- **Main Positions**
  1962-1964 : Assistant at Université de Grenoble
  (1964-1965 : military service)
  1964-1976 : Maitre Assistant at Université Paris-Sud (Orsay)
  1976 to now: Professor of Physics at Université Paris-Sud（巴黎第十一大学物理学教授）.
- **1970-1995: Leader of a research group at Laboratoire de Physique des Solides (Université Paris-Sud, Orsay).**
  1995 to now: Scientific Director at Unité Mixte de Physique CNRS-Thales (Orsay).

Albert Fert

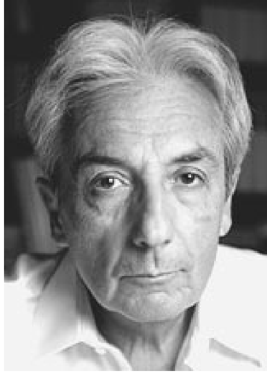


- **Research**
  Experimental (and theoretical) research in condensed matter physics (metals, magnetism, magnetic nanostructures, spin electronics).

- Discovery of Giant Magnetoresistance in 1988. Many contributions to the development of spin electronics.

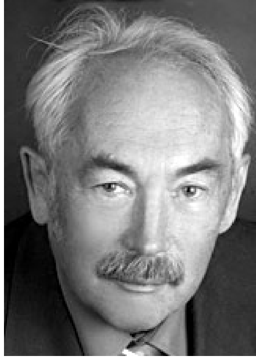
- Publications : about 270 (one of them, with > 3000 citations, is in the " Top Ten " of the ten most cited Physical Review. Letters articles since the creation of PRL in1953)

Albert Fert



- 1994年获美国物理学会颁发的新材料国际奖。
- 1994年: Magnetism Award awarded by International Union for Pure and Applied Physics
- 1997年获欧洲物理协会颁发的Hewlett-Packard欧洲物理学大奖。
- 2003年获法国国家科学研究中心金奖。
- 2007年获Japan Prize
- 2007年获Wolf Prize
- 2007年获得诺贝尔奖。

Peter Grünberg



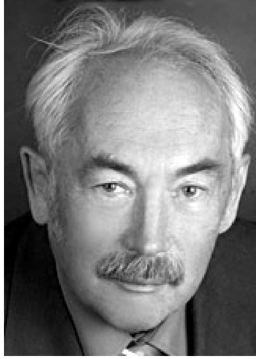
- **Academic Degrees:**

1966 Diploma in Physics, Technische Universität Darmstadt （达姆施塔特工业大学）, Germany

1969 Ph. D in Physics, Technische Universität Darmstadt （达姆施塔特工业大学）, Germany

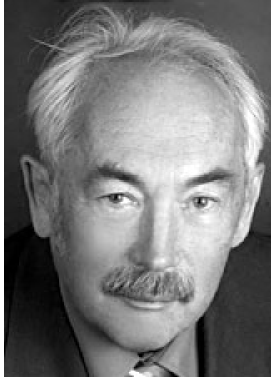
1984 Habilitation, Universität zu Köln, Germany

Peter Grünberg



- **Professional Career:**
- **1969-1972 Postdoctoral fellow at Carleton University，Ottawa Canada**
- **1972 Research scientist，IFF-Forschungszentrum Jülich Germany**（德国于利希研究中心固体问题研究所）
- **1984 Habilitation and lecturer, Universität zu Köln, Germany**
- **1984-1985 Visiting scientist, Argonne National Laboratories, U.S.A.**
- **1998 Visiting professor, IMR, Tohoku University，Sendai, Japan**
- **1988 Visiting professor, JRCAT, Tsukuba Research Center，Japan**

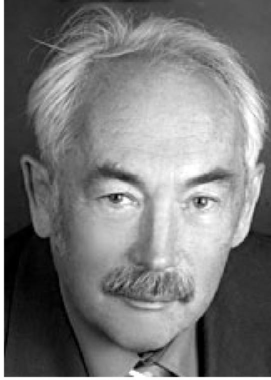
Peter Grünberg



- **Major Publications:**
- **1.G. Binasch, P. Grünberg, F. Saurenbach, and W. Zinn "Enhanced magnetoresistance in layered magnetic structures with antiferromagnetic interlayer exchange", Physical Review B 39, 4828-4830 (1989)**

- **2.P. Grünberg, R. Schreiber, Y. Pang, M.B. Brodsky and H. Sowers "Layered Magnetic Structures: Evidence for Antiferromagnetic Coupling of Fe Layers across Cr Interlayers", Physical Review Letters 57, 2442-2445 (1986)**

Peter Grünberg



- 1994年获美国物理学会颁发的新材料国际奖。
- 1994: Magnetism Award awarded by International Union for Pure and Applied Physics
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- 2007年获Japan Prize
- 2007年获Wolf Prize
- 2007年获诺贝尔奖。

Layered Magnetic Structures: Evidence for Antiferromagnetic Coupling of Fe Layers across Cr Interlayers

P. Grünberg, R. Schreiber, and Y. Pang[a]
Kernforschungsanlage Jülich, 5170 Jülich, West Germany

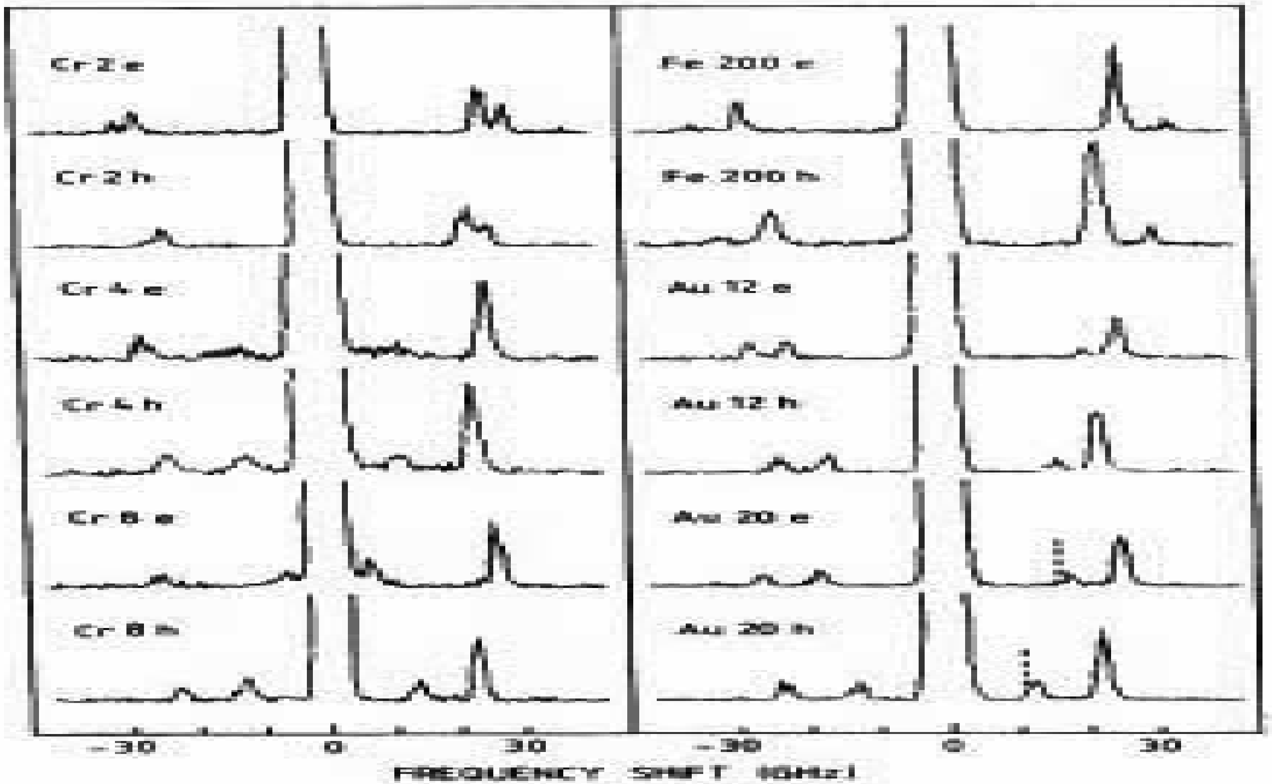

FIG. 1. Light-scattering spectra from spin waves in 200-Å-thick single layers of Fe (upper two traces of left-hand side) and Fe double layers where the interlayer material and thickness is marked on the various traces (e and h indicate direction of external field along easy and hard axis of Fe). From traces Fe 200e and Fe 200h we evaluate $J = 2.0$ T and $B_{ua} = 0.035$ T which yields the position of the exchange mode in the decoupled case marked by dashed lines in traces Au 20e and Au 20h. $B_0 = 0.1$ T in all cases.

Layered Magnetic Structures: Evidence for Antiferromagnetic Coupling of Fe Layers across Cr Interlayers

P. Grünberg, R. Schreiber, and Y. Pang[a]
Kernforschungsanlage Jülich, 5170 Jülich, West Germany

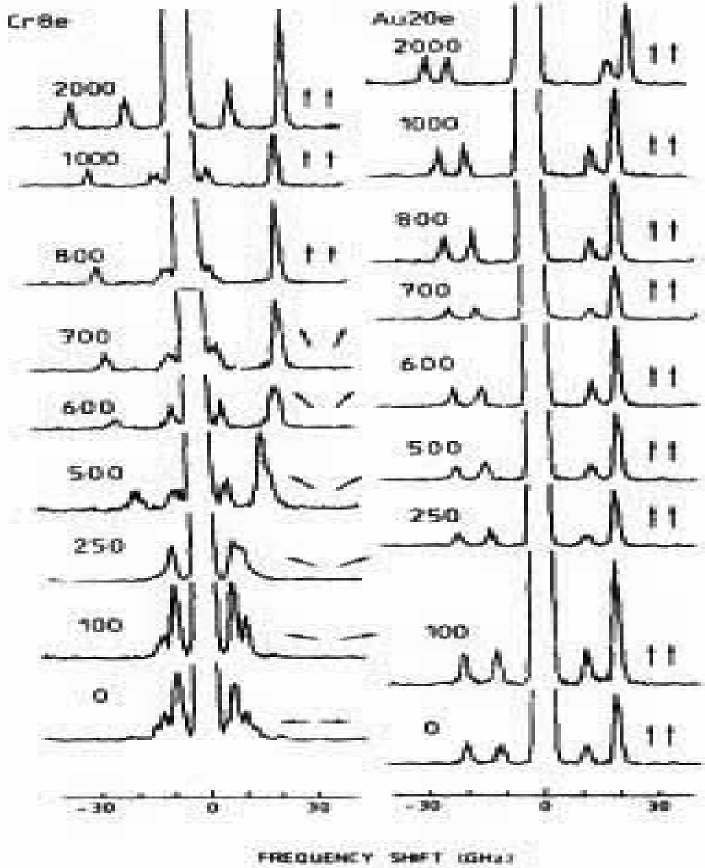

FIG. 2. Spectra from samples Cr 8 and Au 20 with B_0 along the easy axis of Fe. Numbers on the traces mark values of external field in units of 0.1 mT ≙ 1 Oe. The arrows indicate the suggested magnetization directions on the two Fe layers where B_0 is supposed to point up. Observed spin-wave propagation then is along a horizontal line.

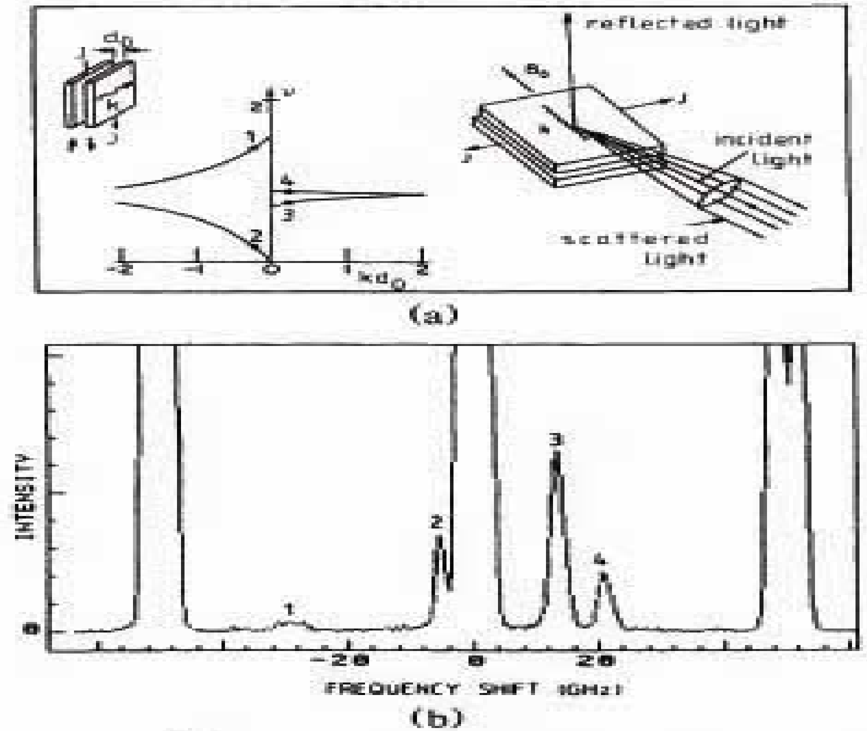

FIG. 3. (a) Dispersion curves of spin waves in antiparallel layers (from Ref. 6) and the employed scattering geometry. (b) The resulting light-scattering spectrum. The numbers indicate the correspondence to the branches in (a). The spectrum proves that the magnetizations J in Cr 8e for small external fields are aligned as proposed in Fig. 2.

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.

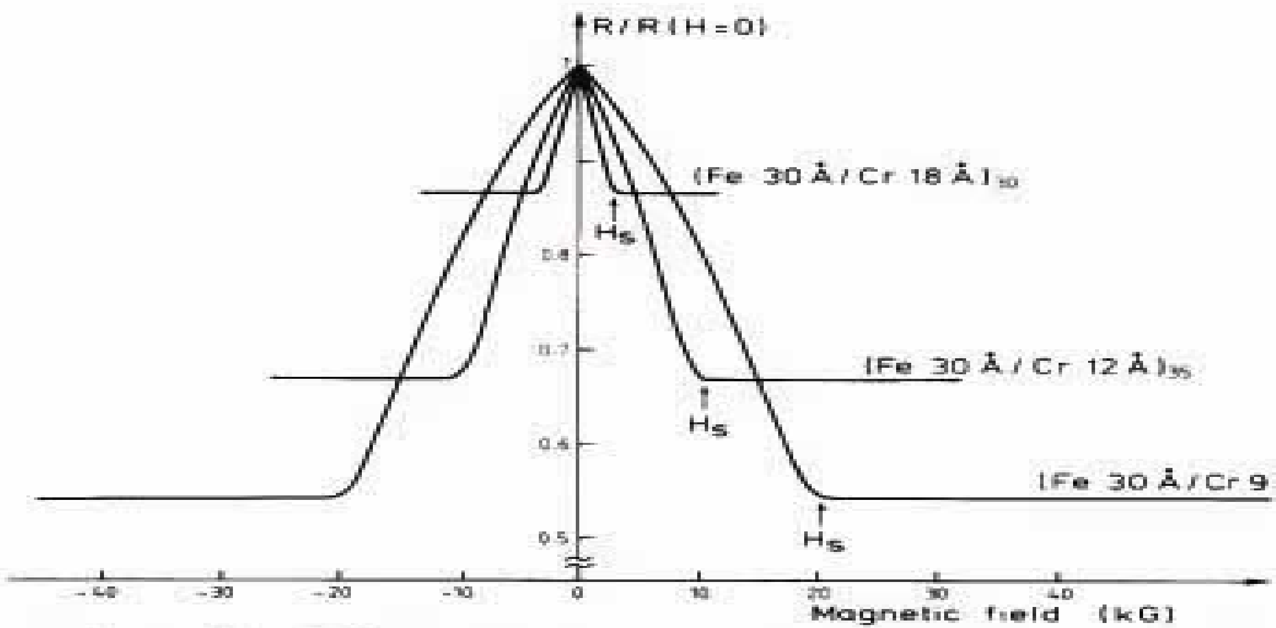

FIG. 3. Magnetoresistance of three Fe/Cr superlattices at 4.2 K. The current and the applied field are along the same [110] axis in the plane of the layers.

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

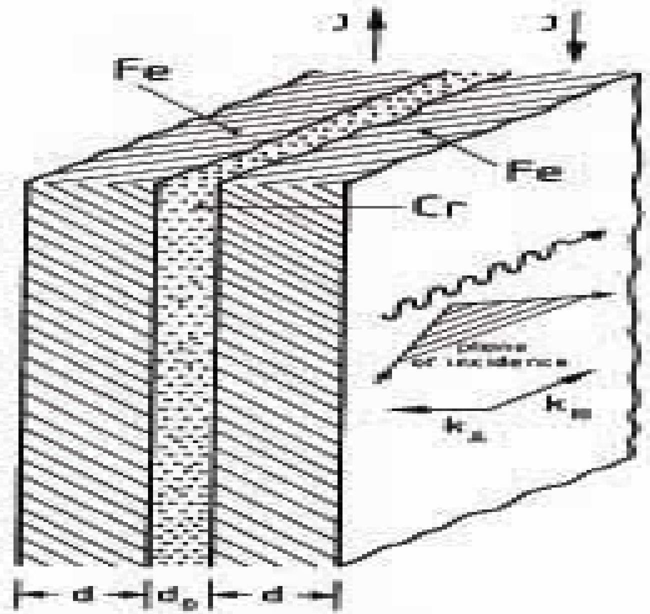

FIG. 1. Ferromagnetic double layer with antiparallel alignment of the magnetizations. Also indicated is the plane of incidence of the laser light for the observation of light scattering from spin waves and hysteresis curves via MOKE.

RAPID COMMUNICATIONS

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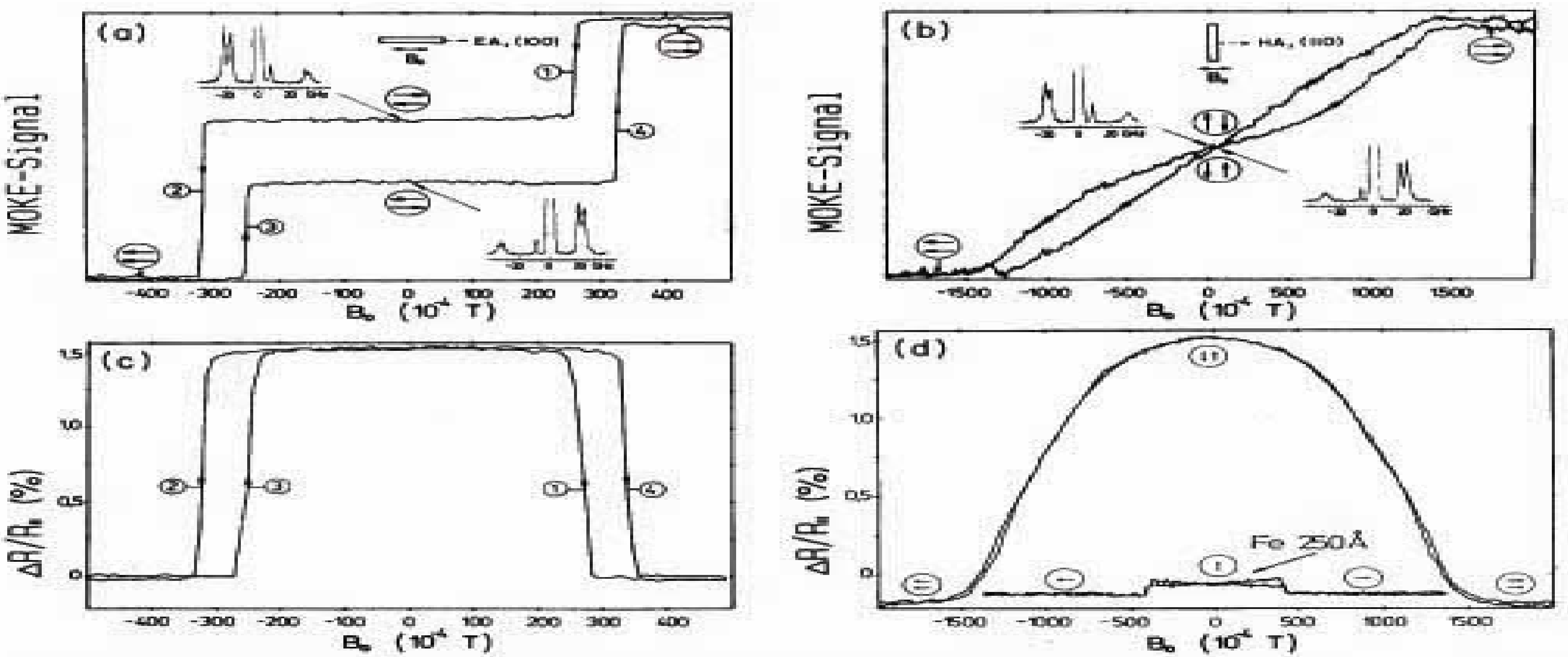

FIG. 2. (a)–(b) MOKE hysteresis curves and (c)–(d) magnetoresistance $\Delta R/R_s = (R - R_s)/R_s$ from Fe double layers with antiferromagnetic coupling. Also, (d) displays the anisotropic MR effect of a 250-Å-thick Fe film.

Grünberg的前期工作-1

- Crystal Field in Dysprosium Garnets（石榴石型铁氧体）P. Grünberg, S. Hüfner, E. Orlich, and J. Schmitt, Phys. Rev. 184, 285 (1969)
- Electronic Raman Spectra: Crystal Field in Terbium Aluminum Garnet and Europium Gallium Garnet D. Boal, P. Grunberg, and J. A. Koningstein, Phys. Rev. B 7, 4757 (1973)
- Phonons in GdS—Raman scattering of an fcc metal（声子）G. Güntherodt, P. Grünberg, E. Anastassakis, M. Cardona, H. Hackfort, and W. Zinn, Phys. Rev. B 16, 3504 (1977)
- Light Scattering from Bulk and Surface Spin Waves in EuO P. Grünberg and F. Metawe, Phys. Rev. Lett. 39, 1561 (1977)

Crystal Field in Dysprosium Garnets*

P. GRÜNBERG, S. HÜFNER†, E. ORLICH, AND J. SCHMITT
Institut für Technische Physik, Technische Hochschule, Darmstadt, Germany
(Received 12 November 1968)

The crystal-field splittings of the ^6H and ^6F multiplets of Dy^{3+} in yttrium gallium garnet and yttrium aluminum garnet have been determined from absorption and emission spectra. In addition, the g factors of some crystal-field levels have been determined from Zeeman-effect measurements. All these experimental data are used to derive a set of crystal-field parameters for the two garnet systems. In these calculations, the full Hamiltonian appropriate for the D_2 symmetry at the rare-earth sites and also the mixing of the different J states by the crystal field were taken into account. The agreement between experimental results and calculations is very satisfactory, and of the same quality as for the case of Yb^{3+}, where far fewer experimental results had to be fitted.

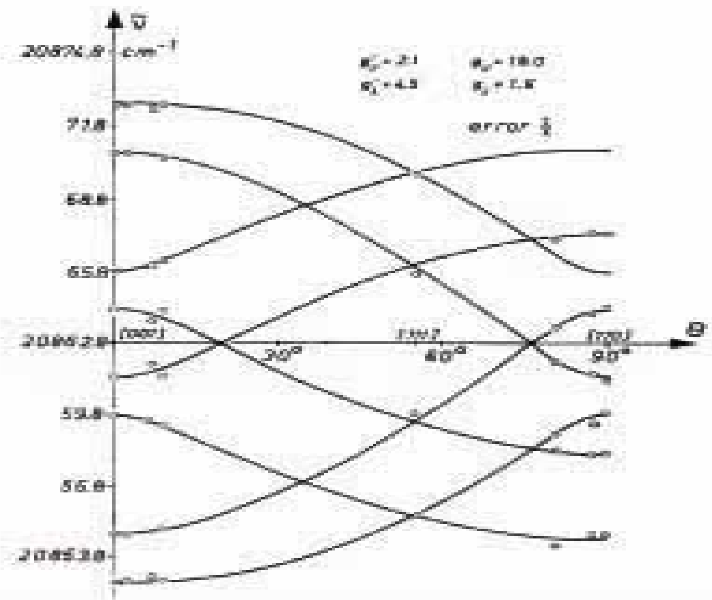

FIG. 1. Angular dependence of the magnetic field splitting of the $\bar{\nu}=20\,860$-cm^{-1} line in Y(D)AG in the (110) plane. The curves have been calculated with the g factors shown in the figure.

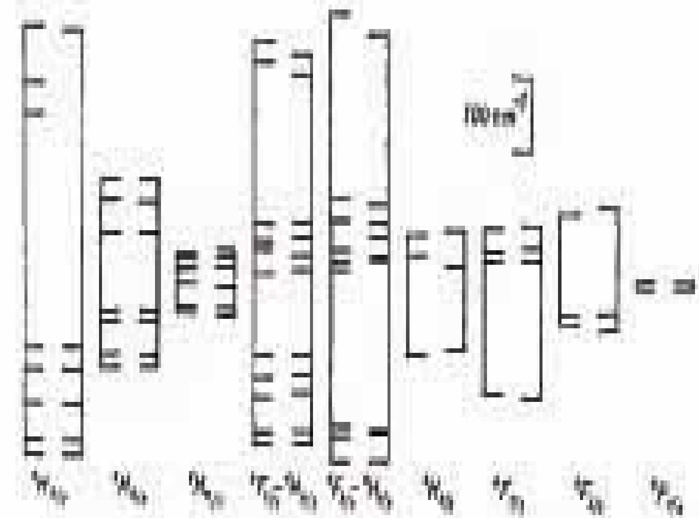

FIG. 5. Comparison of experimental (right-hand) and calculated (left-hand) energy levels in Y(D)GG for the ^6H and ^6F multiplets.

TABLE I. Experimental energy levels of DAG, Y(D)AG, DGG, and Y(D)GG; (a) was obtained from the absorption spectrum, and (f) from the fluorescence spectrum.

Free-ion assignment	DAG(a)	Y(10%Dy)AG(a)	Y(1%Dy)AG(a)	Y(1%Dy)AG(f)	DGG(a)	Y(1%Dy)GG(a)	Y(1%Dy)GG(f)
$^6F_{3/2}$	13379	13368	13366.0		13318.7	13319	
	13372	13360	13358.6		13308.5	13310	
$^6F_{5/2}$	12683	13676	12673.7		12619.8	12622.0	
	12538	12521	12523.0		12475.5	12474.5	
	12507	12497	12493.9		12451.8	12451.4	
$^6F_{7/2}$	11321		11310		11241	11242	
	11279		11265		11210	11211	
	11247		11235		11191	11194	
	11063		11053		11008	11006	
$^6H_{5/2}$	10515	10503			10391		
	10363	10354			10343		
	10257	10252			10225		
$\{^6F_{9/2}, ^6H_{7/2}\}$	9662		9656		9563		
			9380		9333		
	9385		9367		9310		
	9349		9334		9287		
	9329		9315	9316	9264	9262	9260
	9321		9308	9308	9255	9254	9253
	9092		9074	9075	9026	9023	9023
	9057		9040	9041		9021	9021
	9022		9007	9007	8986	8983	8983
$\{^6F_{11/2}, ^6H_{9/2}\}$	8292	8285			8161		
	8223	8218			8134		
	8009	7994			7934		
	7983	7966		7963.8	7918		7911.6
	7958	7943		7941.8	7896		7888.6
	7927	7907		7909.3	7875		7868.1
	7823	7805		7802.1	7751		7747.9
	7780	7763		7760.2	7724		7723.8
	7760	7746		7742.2	7697	7701	7700.0
	7684	7677		7672.8	7646	7647	7648.4
	7651	7642		7640.8	7626	7627	7629.9
$^6H_{11/2}$	6132	6109	6110	6105.8	6042	6035	6034.3
	6113	6104	6104	6101.7	6033	6021	6023.1
	6062	6090		6087.0	6018		6014.1
	6040	6046	6041	6042.8	5997		5984.8
	5965	5956	5952	5953.8	5952	5956	5954.6
	5938	5927	5925	5926.2	5938		5944.6
$^6H_{13/2}$				3950.6			3823.4
				3821.3			3793.5
				3777.1			3751.8
				3720.2			3644.7
				3697.7			3632.3
				3590.4			3582.8
				3564.4			3566.7
$^6H_{15/2}$				741			579.3
							515 [b]
		232[a]		233			149.0
		173[a]		174.7			117.6
	117[a]	98[a]		101.3	72[a]	71[a]	71.1
	70[a]	57[a]		59.4	20.3[a]	21[a]	20.4
	0	0		0	0	0	0

[a] At $T = 77$°K.
[b] Weak and hazy.

- 苦练基本功
- 精益又求精

Grünberg的前期工作-2

- Stokes—anti-Stokes asymmetry in Brillouin scattering from magnons in thin ferromagnetic films (自旋波)R. E. Camley, P. Grünberg, and C. M. Mayr, Phys. Rev. B 26, 2609 (1982)
- Magnetostatic spin-wave modes of a ferromagnetic multilayer P. Grünberg and K. Mika, Phys. Rev. B 27, 2955 (1983)
- Brillouin light scattering study of magnon branch crossover in thin iron films P. Kabos, W. D. Wilber, C. E. Patton, and P. Grünberg, Phys. Rev. B 29, 6396 (1984)
- Dipolar spin-wave modes of a ferromagnetic multilayer with alternating directions of magnetization K. Mika and P. Grünberg, Phys. Rev. B 31, 4465 (1985)

- 淡漠名和利
- 无声胜有声

VOLUME 57, NUMBER 19 PHYSICAL REVIEW LETTERS 10 NOVEMBER 1986

Layered Magnetic Structures: Evidence for Antiferromagnetic Coupling of Fe Layers across Cr Interlayers

P. Grünberg, R. Schreiber, and Y. Pang[a]
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and

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Argonne National Laboratory, Argonne, Illinois 60439
(Received 10 June 1986)

RAPID COMMUNICATIONS

PHYSICAL REVIEW B VOLUME 39, NUMBER 7 1 MARCH 1989

Enhanced magnetoresistance in layered magnetic structures with antiferromagnetic interlayer exchange

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

Fert的前期工作-1

- Two-Current Conduction in Nickel, A. Fert and I. A. Campbell, Phys. Rev. Lett. 21, 1190 (1968)
- Temperature Dependence of the Electrical Resistivity of Dilute Ferromagnetic Alloys, D. L. Mills, A. Fert, and I. A. Campbell, Phys. Rev. B 4, 196 (1971)
- Left-Right Asymmetry in the Scattering of Electrons by Magnetic Impurities, and a Hall Effect, A. Fert and O. Jaoul, Phys. Rev. Lett. 28, 303 (1972)
- Electron Scattering by the Electronic Quadrupole Moment of Rare-Earth Impurities, A. Friederich and A. Fert, Phys. Rev. Lett. 33, 1214 (1974)
- Skew scattering by rare-earth impurities in silver, gold, and aluminum, A. Fert and A. Friederich, Phys. Rev. B 13, 397 (1976)

TWO-CURRENT CONDUCTION IN NICKEL

A. Fert and I. A. Campbell
Physique des Solides,* Faculté des Sciences, Orsay, France
(Received 3 July 1968)

Measurements on the low-temperature electrical resistivity of dilute nickel-based alloys give strong evidence that spin-↑ and spin-↓ electrons carry current in parallel, providing important implications for the interpretation of transport properties of pure as well as alloy ferromagnets.

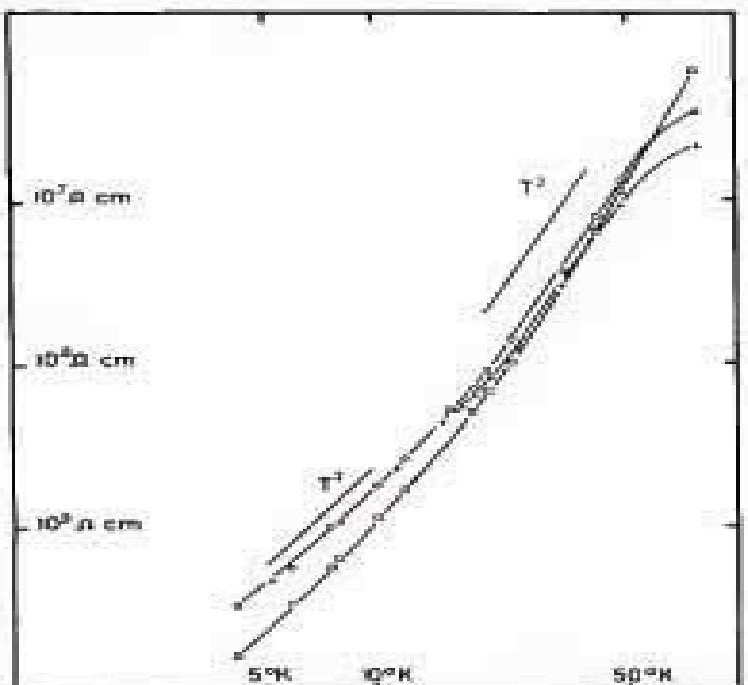


FIG. 1. Low-temperature resistivity variations. Squares: $\rho_i(T)$, ideal resistivity of pure Ni. Circles: deviation $\Delta\rho(T)$ for Ni:Cr with 1400 ppm Cr. Crosses: deviation $\Delta\rho(T)$ for Ni:Cr with 700 ppm Cr.

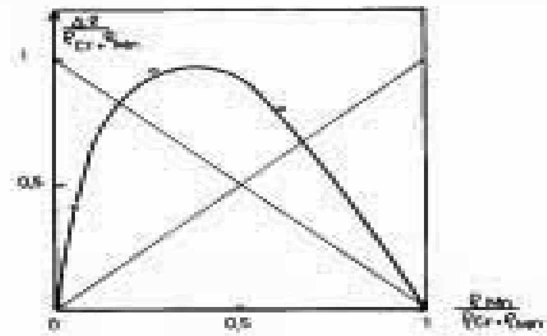
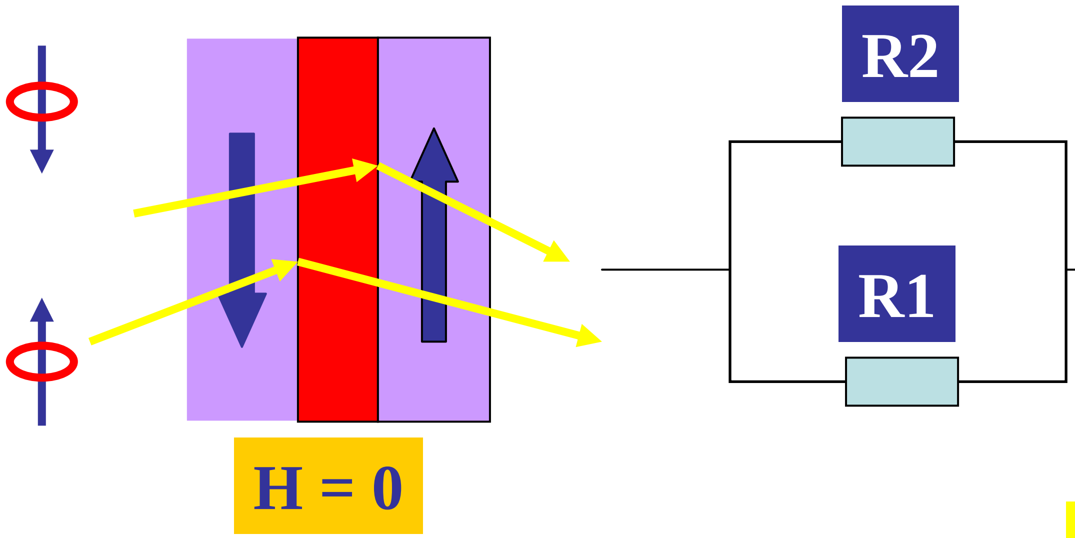


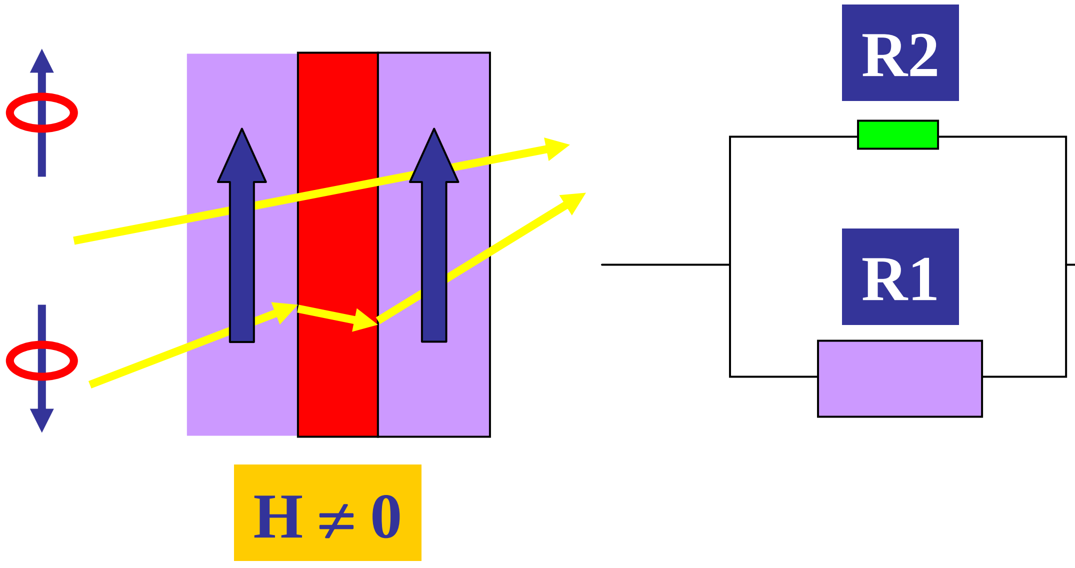
FIG. 2. The deviation $\Delta\rho$ in the residual resistance of Ni containing Cr and Mn impurities as a function of the relative concentrations of Cr and Mn. ρ_{Cr}, ρ_{Mn} are the corresponding residual resistances when Cr or Mn is present alone at the same concentration, $\Delta\rho = \rho - \rho_{Cr} - \rho_{Mn}$.

多层膜GMR效应产生的机制
(双流体模型)



R_{AF}=R1/2

GMR=(R_F- R_{AF}) / R_{AF}



R_F=R1*R2/(R1+R2)

- **Your Search**
  Author: I. A. Campbell

- **Journals**
  Phys. Rev. B (36)
  Phys. Rev. Lett. (23)
  Phys. Rev. E (2)

- 名师出高徒
- 学术需传承

Fert的前期工作-2

- **Magnetotransport properties of noble metals containing rare-earth impurities. I. Quadrupole scattering by rare-earth impurities in gold , A. Fert, R. Asomoza, D. H. Sanchez, D. Spanjaard, and A. Friederich, Phys. Rev. B 16, 5040 (1977)**
- **Magnetotransport properties of noble metals containing rare-earth impurities. II. Theory , A. Fert and P. M. Levy, Phys. Rev. B 16, 5052 (1977)**
- **Role of Anisotropic Exchange Interactions in Determining the Properties of Spin-Glasses , A. Fert and Peter M. Levy, Phys. Rev. Lett. 44, 1538 (1980)**
- **Anisotropy induced by nonmagnetic impurities in *Cu* Mn spin-glass alloys , Peter M. Levy and A. Fert, Phys. Rev. B 23, 4667 (1981)**

- **Your Search**
  Author: P. M. Levy

- **Journals**
  Phys. Rev. B (67)
  Phys. Rev. Lett. (21)
  Phys. Rev. (6)

- 工作要系统
- 深入需理论

Fert的前期工作-3

- Anisotropy of Spin-Glasses from Torque Measurements , A. Fert and F. Hippert, Phys. Rev. Lett. 49, 1508 (1982)
- Anisotropy in metallic spin glasses arising from gold impurities , Stephen M. Goldberg, P. M. Levy, and A. Fert, Phys. Rev. B 31, 3106 (1985)
- Theory of the Hall effect in heavy-fermion compounds , A. Fert and P. M. Levy, Phys. Rev. B 36, 1907 (1987)
- Hall effect in the heavy-fermion compound CePtSi , A. Hamzic, A. Fert, M. Miljak, and S. Horn, Phys. Rev. B 38, 7141 (1988)
- Rigid spin rotation in amorphous rare-earth alloys , M. J. O'Shea and A. Fert, Phys. Rev. B 37, 9824 (1988)

- 兴趣要广泛
- 功到自然成

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
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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.

诺贝尔奖？

- 诺贝尔奖得主的成功，是因为站在国际的科技前沿和已经群聚的科学共同体的基础之上，而这一点是其飞跃最高峰的本质。

!

!

- 为什么Parkin没得奖
- 为什么中国人没得奖
- 为什么我没得奖

Stuart S.P. Parkin

- ***IBM Fellow and manager, magnetoelectronics***
- **1991年发现改变非磁性层的厚度导致磁性层间出现平行和反平行磁性排列的振荡。**
- **1994年和同事用这个原理设计和制备了硬盘读写磁头的GMR元件。IBM于1997年应用到硬盘产品上。硬盘存储能力从1997年至今有超过30倍的增长 (2.4 to more than 70 gigabits per square inch).**

Oscillations in Exchange Coupling and Magnetoresistance in Metallic Superlattice Structures: Co/Ru, Co/Cr, and Fe/Cr

S. S. P. Parkin, N. More, and K. P. Roche
IBM Almaden Research Center, 650 Harry Road, San Jose, California 95120-6099
(Received 27 November 1989)

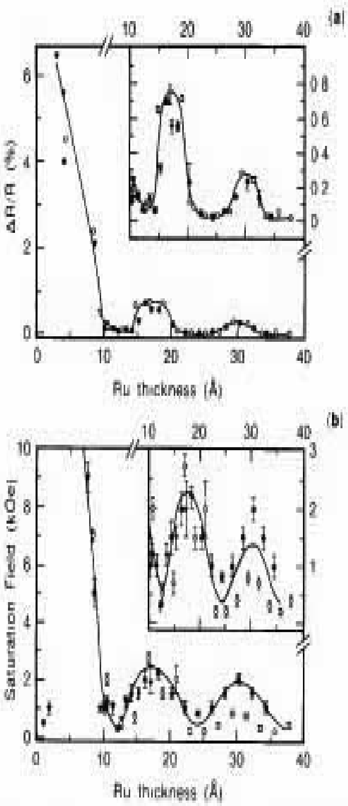

FIG. 3. (a) Transverse saturation magnetoresistance (4.5 K) and (b) saturation field (300 K) vs Ru layer thickness for structures of the form Si(111)/(100 Å) Ru/[20 Å) Co/t_{Ru} Ru]$_{20}$/(50 Å)Ru deposited at temperatures of ●, 40 °C; ○, 125 °C; ×, 200 °C.

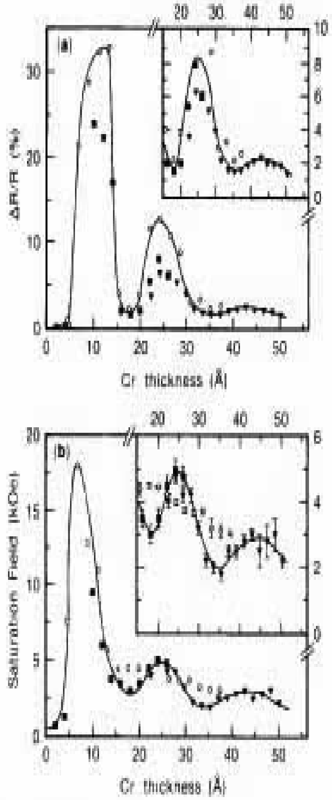

FIG. 4. (a) Transverse saturation magnetoresistance (4.5 K) and (b) saturation field (4.5 K) vs Cr layer thickness for three series of structures of the form Si(111)/(100 Å) Cr/[(20 Å) Fe/t_{Cr} Cr]$_N$/(50 Å) Cr, deposited at temperatures of △,■, 40 °C (N=30); ○,125 °C (N=20).

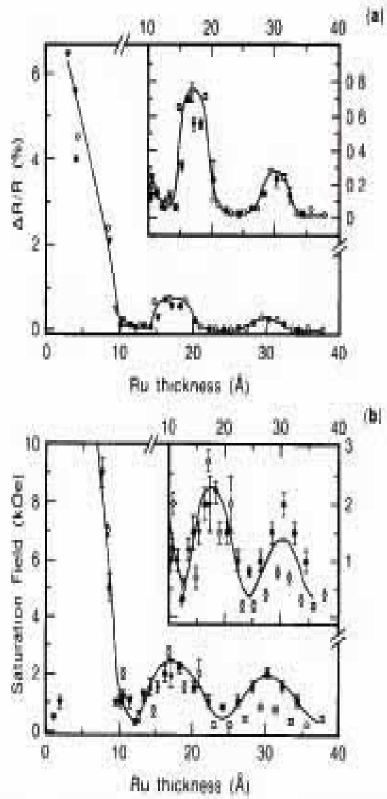

FIG. 3. (a) Transverse saturation magnetoresistance (4.5 K) and (b) saturation field (300 K) vs Ru layer thickness for structures of the form Si(111)/(100 Å) Ru/[20 Å) Co/t_{Ru} Ru]$_{20}$/(50 Å)Ru deposited at temperatures of ●, 40 °C; ○, 125 °C; ×, 200 °C.

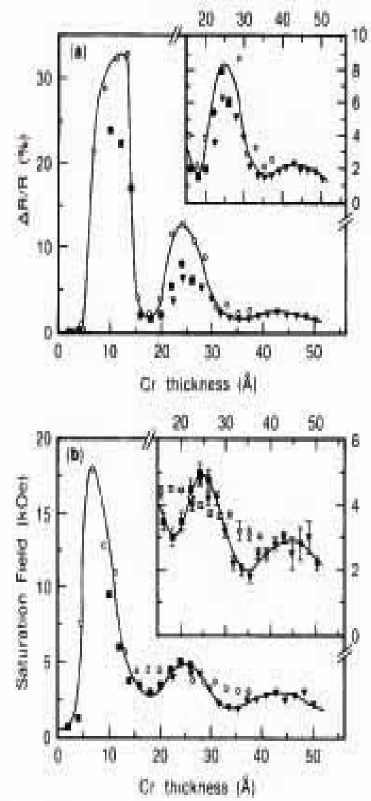

FIG. 4. (a) Transverse saturation magnetoresistance (4.5 K) and (b) saturation field (4.5 K) vs Cr layer thickness for three series of structures of the form Si(111)/(100 Å) Cr/[(20 Å) Fe/t_{Cr} Cr]$_N$/(50 Å) Cr, deposited at temperatures of △,■, 40 °C (N=30); ○,125 °C (N=20).

- 设备要精良
- 观察贵细致

RAPID COMMUNICATIONS

PHYSICAL REVIEW B VOLUME 43, NUMBER 1 1 JANUARY 1991

Giant magnetoresistance in soft ferromagnetic multilayers

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(Received 25 July 1990; revised manuscript received 21 September 1990)

We show that the in-plane magnetoresistance of sandwiches of *uncoupled* ferromagnetic ($Ni_{81}Fe_{19}$, $Ni_{80}Co_{20}$, Ni) layers separated by ultrathin nonmagnetic metallic (Cu, Ag, Au) layers is strongly increased when the magnetizations of the two ferromagnetic layers are aligned antiparallel. Using NiFe layers, we report a relative change of resistance of 5.0% in 10 Oe at room temperature. The comparison between different ferromagnetic materials (alloys or pure elements) leads us to emphasize the role of bulk rather than interfacial spin-dependent scattering in these structures, in contrast to Fe/Cr multilayers.

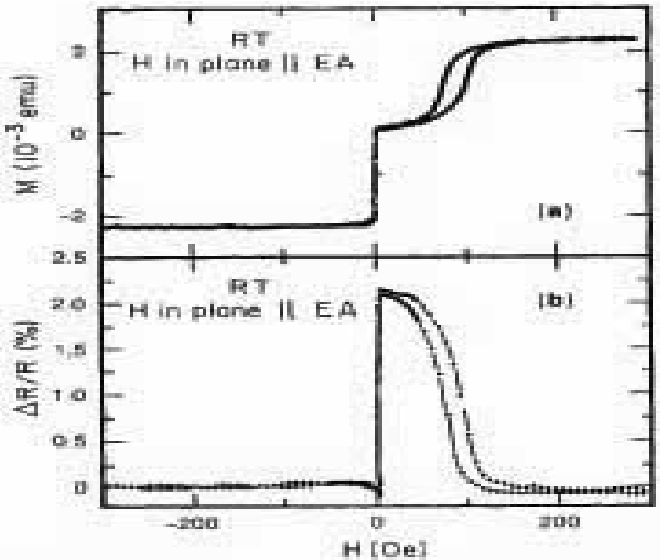

FIG. 1. Magnetization curve (a) and relative change in resistance (b) for Si/(150-Å NiFe)/(26-Å Cu)/(150-Å NiFe)/(100-Å FeMn)/(20-Å Ag). The field is applied parallel to the exchange anisotropy field created by FeMn (EA). The current is flowing perpendicular to this direction.

- 设计要巧妙
- 应用明目标

Oscillatory Magnetic Exchange Coupling through Thin Copper Layers

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(Received 24 September 1990)

Confirming theoretical predictions more than 25 years old, we show that Co slabs are indirectly exchanged coupled via thin Cu layers with a coupling that alternates back and forth between antiferromagnetic and ferromagnetic. Four oscillations are observed with a period of ≈10 Å. Moreover, the antiferromagnetically coupled Co/Cu superlattices exhibit extraordinarily large saturation magnetoresistances at 300 K of more than 65%.

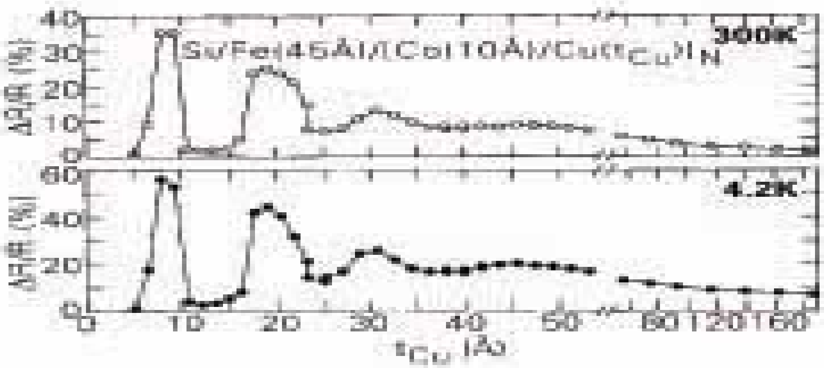

FIG. 3. Dependence of saturation transverse magnetoresistance on Cu spacer layer thickness for a family of related superlattice structures of the form Si/Fe(45 Å)/[Co(10 Å)/Cu(t_{Cu})]$_N$. An additional Cu layer was deposited on each film structure such that the uppermost Cu layer was ≈55 Å thick. The number of bilayers in the superlattice, N, is 16 for t_{Cu} below 55 Å (●,○) and 8 for t_{Cu} above 55 Å (■,□). Values of $\Delta R/R$ are highly reproducible, within ≈ ±5% of $\Delta R/R$, as evidenced by multiple sample points at t_{Cu}=25, 38, 40, and 42 Å.

Systematic Variation of the Strength and Oscillation Period of Indirect Magnetic Exchange Coupling through the 3*d*, 4*d*, and 5*d* Transition Metals

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(Received 26 April 1991)

TABLE I. Periodic table of A_1 (Å), the spacer-layer thickness corresponding to the position of the first peak in antiferromagnetic exchange-coupling strength as the spacer-layer thickness is increased; J_1 (erg/cm^2), the magnitude of the antiferromagnetic exchange-coupling strength at this first peak; ΔA_1 (Å), the approximate range of spacer-layer thickness of the first antiferromagnetic region; and P (Å), the oscillation period. The most stable crystal structure of the various elements is included for reference, as well as values of the Wigner-Seitz radii [r_{WS} (Å)]. Note that no dependence of the coupling strength on crystal structure nor any correlation with electron density ($\propto r_{WS}^{-3}$) is found. An asterisk indicates that, as discussed in the text for the elements Nb, Ta, and W, only one AF-coupled spacer-layer thickness region was observed, so it was not possible to directly determine P.

Element	Structure	A_1	ΔA_1	J_1	P	r_{WS}
Ti	hcp	No Coupling				2.89
V	bcc	9	3	0.1	9	2.62
Cr	bcc	7	7	.24	18	2.50
Mn	complex cubic					2.24
Fe	bcc	Ferro-Magnet				2.48
Co	hcp	Ferro-Magnet				2.50
Ni	fcc	Ferro-Magnet				2.49
Cu	fcc	8	3	0.3	10	2.56
Zr	hcp	No Coupling				3.17
Nb	bcc	9.5	2.5	.02	*	2.86
Mo	bcc	5.2	3	.12	11	2.72
Tc	hcp					2.71
Ru	hcp	3	3	5	11	2.65
Rh	fcc	7.9	3	1.6	9	2.69
Pd	fcc	No Coupling				2.76
Ag	fcc	No Coupling				2.89
Hf	hcp	No Coupling				3.13
Ta	bcc	7	2	.01	*	2.86
W	bcc	5.5	3	.03	*	2.74
Re	hcp	4.2	3.5	.41	10	2.74
Os	hcp					2.68
Ir	fcc	4	3	.185	9	2.71
Pt	fcc	No Coupling				2.77
Au	fcc	No Coupling				2.88

fcc; bcc; hcp; complex cubic

Element	
A_1 (Å)	ΔA_1 (Å)
J_1	P (Å)
r_{WS} (Å)	

- 耐心加创新
- 系统寻规律

Origin of Enhanced Magnetoresistance of Magnetic Multilayers: Spin-Dependent Scattering from Magnetic Interface States

S. S. P. Parkin
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(Received 16 June 1992)

The origin of giant magnetoresistance exhibited by ferromagnetic/nonmagnetic multilayered structures is examined by inserting thin layers of a second ferromagnetic material at the interfaces in ferromagnetic/nonmagnetic/ferromagnetic sandwiches. It is generally observed, for many different combinations of metals, that the magnetoresistance depends exponentially on the thickness of the interface layer, with a characteristic length, ξ. ξ is extremely short and is typically just ≈ 1.5 to 3 Å at room temperature. At lower temperatures ξ becomes even shorter. The giant magnetoresistance effect is thus clearly shown to be determined by the character of the ferromagnetic/nonmagnetic interfaces.

Stuart S.P. Parkin

- 1991年获Materials Research Society's Inaugural Outstanding Young Investigator Award and the Charles Vernon Boys Prize of Institute of Physics (U.K.).
- 1994年获美国物理学会颁发的新材料国际奖。
- 1997年获欧洲物理协会颁发的Hewlett-Packard欧洲物理学大奖。
- 1999年获 American Institute of Physics (AIP) Prize for Industrial Application of Physics.
- a Fellow of the American Physical Society, one of IBM's Master Inventors and an IBM Fellow -- IBM's highest technical honor, Fellow of the Royal Society (London).

- 跟踪缺原创
- 功亏差一篑

中国没有高水平研究工作的原因!

历史	半封建半殖民地落后挨打战乱频繁的近代史。
政治	受制于政治信仰或宗派式政治无独立思想空间
经济	经济基础落后导致科学设备、技术条件等落后
政策	国家科技政策的不断变化导致思想的混淆
传统	没有从事自然科学研究的传统
传承	由于文化大革命的导致学术传承被打断
精神	缺少献身精神、创新精神、独立思考的精神
团队	没有形成自发而纯粹的协作团队

我如何选题的!

- 研究部的总体发展方向
- 个人的研究兴趣

研究部的发展史

孙校开　研究员

庄育智　研究员
中国科学院院士

F.R. de Boer教授

研究部的总体发展方向

稀土永磁材料

磁性与磁性材料

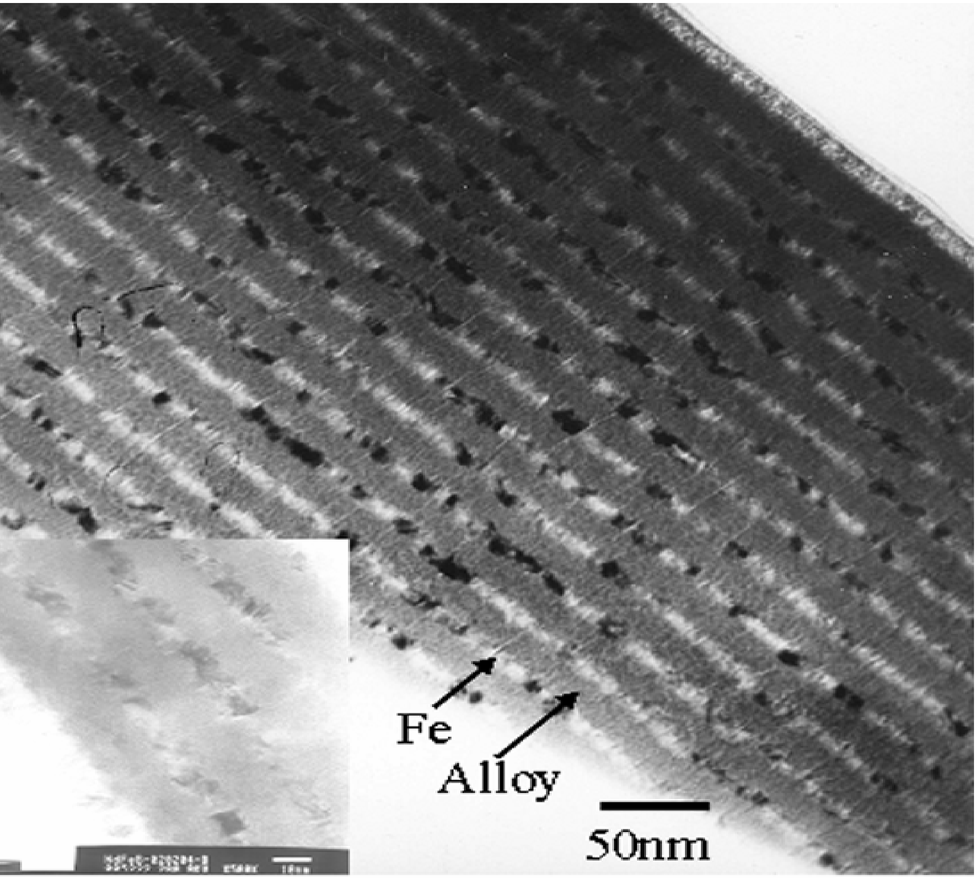
材料物理及功能材料

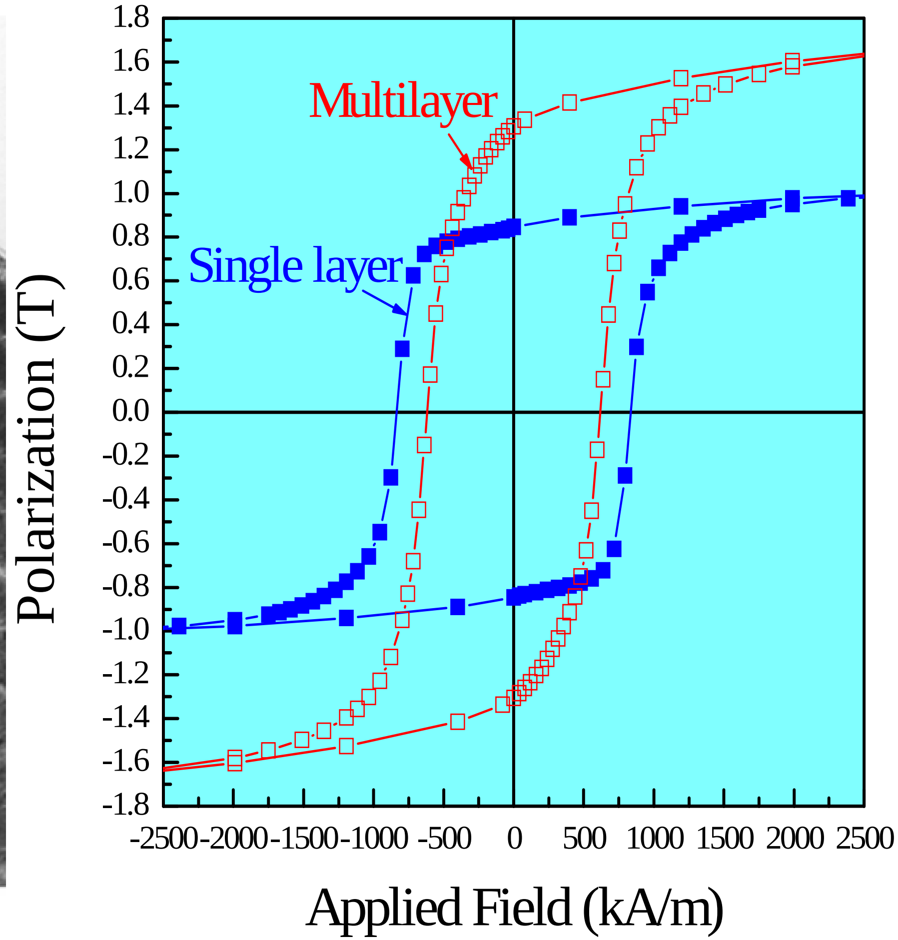
稀土永磁材料
磁致伸缩材料
巨磁电阻材料
磁性纳米胶囊
薄膜磁性材料
超导材料
铁电材料
半导体材料
光学材料

稀土永磁材料

- 稀土过渡金属化合物
- 稀土亚稳相
- 纳米复合稀土永磁
- 稀土永磁薄膜材料

高磁性能纳米复合磁性薄膜的制备





各 向 同 性 多 层 膜 磁 能 积 达 到 2 5 . 6 M G O e .

最新结果：33.9MGOe。

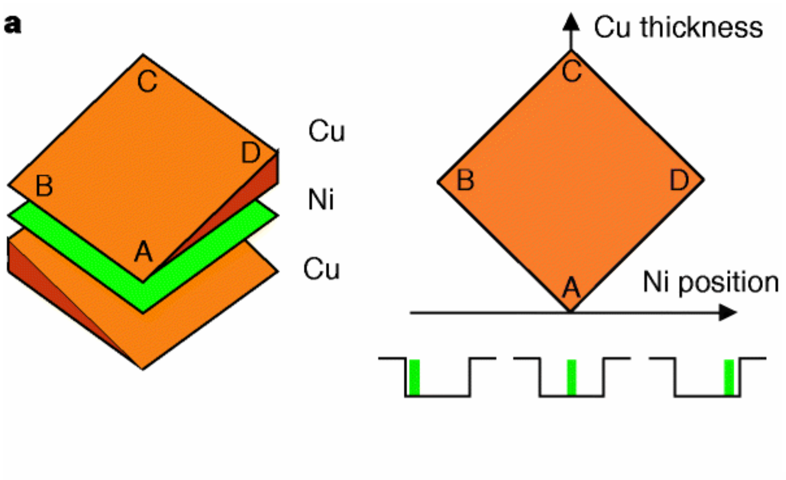
Advanced Materials 14(2002)1832

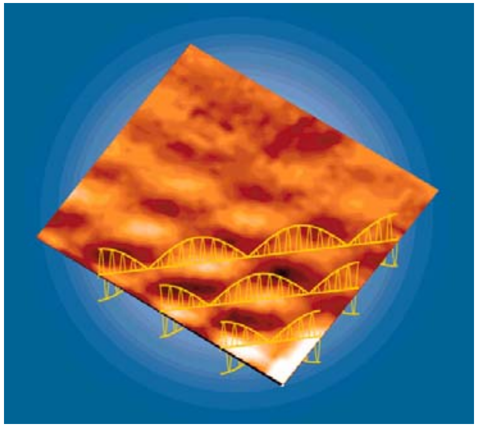
- 小米加步枪
- 跟踪又模仿

磁性与磁性材料

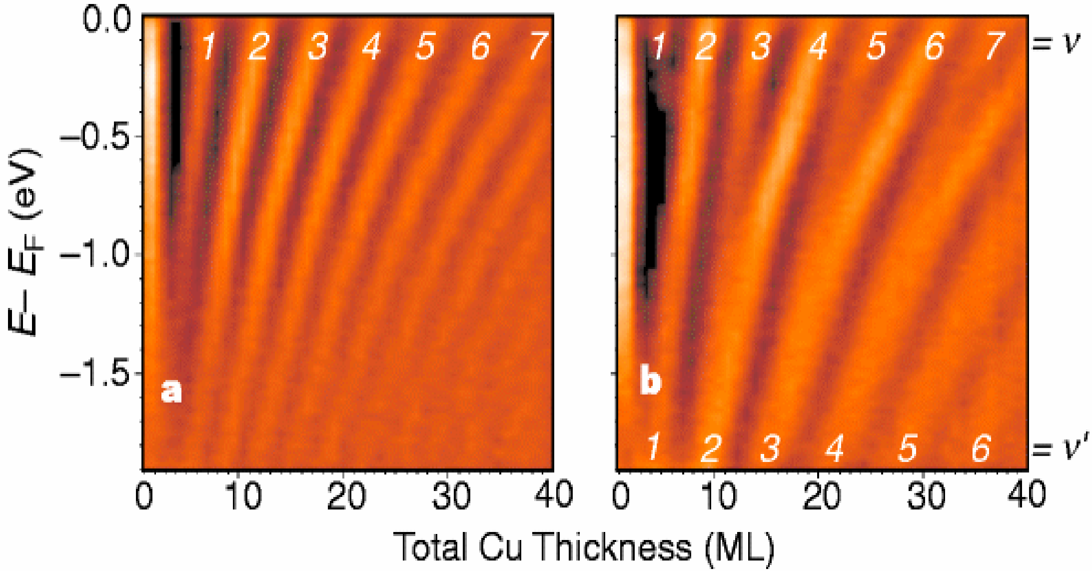
- 磁致伸缩材料
- 巨磁电阻材料
- 磁性纳米胶囊
- 薄膜磁性材料
- 磁制冷材料

磁性薄膜材料的对称性





Cu/Ni/Cu/Co薄膜双量子阱
结构和电子态密度
Nature 398 (1999)132



研究金属量子阱的对称性、电子的波函数宇称对电子能态、磁性交换耦合的影响。

Cu/Co和Cu/Ni/Cu/Co磁性薄膜的电子能谱的比较

- 教学互相长
- 国际勤合作

材料物理及功能材料

- 超导材料
- 铁电材料
- 半导体材料
- 光学材料
- 复合材料

- 飞机加大炮
- 视野要拓宽

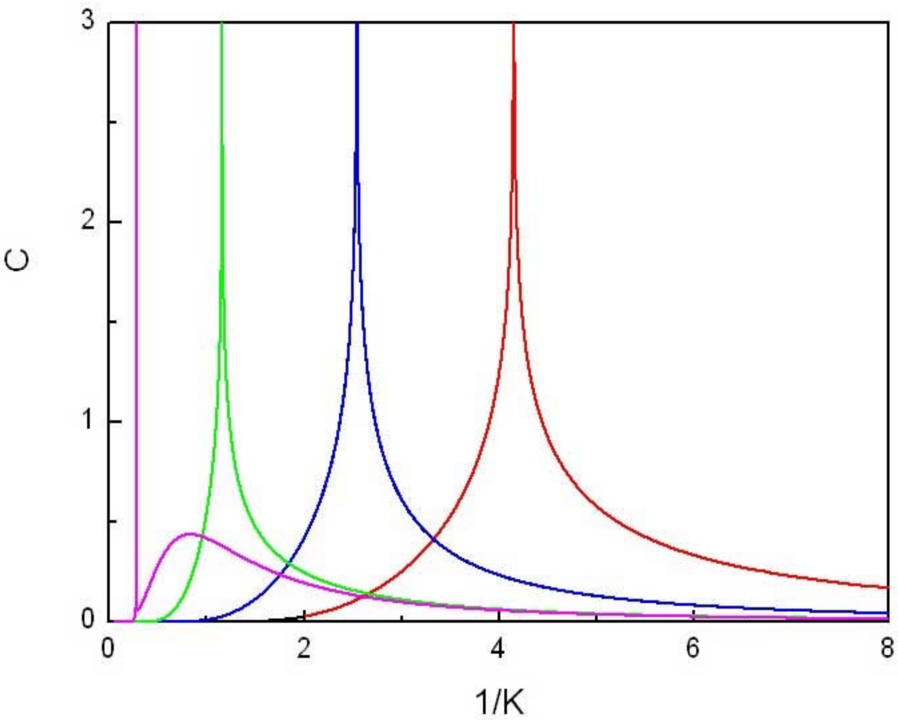
我如何选题的!

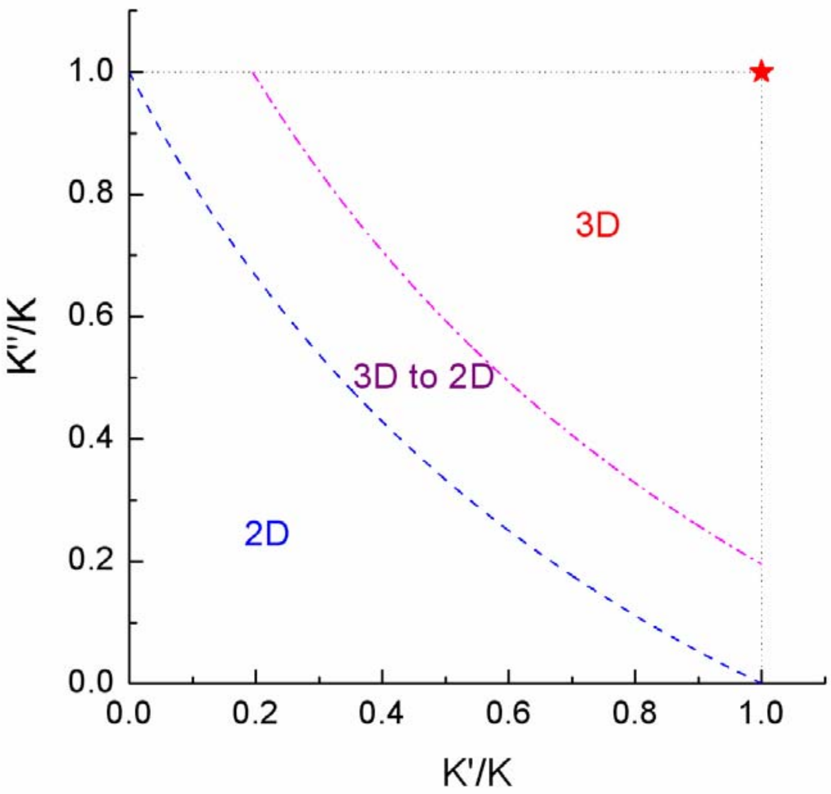
- 研究部的总体发展方向
- 个人的研究兴趣

凝聚态物理及统计物理

- 分子场理论
- 自旋波理论
- 量子阱效应
- 非线性理论
- 伊辛模型

三维伊辛(Ising)模型精确解的猜想





从三维到二维、一维比热的变化　　　临界指数的过渡

Phil. Mag. 87 (2007) 5309.

- 兴趣加好奇
- 其乐又融融

■ ■ ■ ■ ■ ■

诺贝尔奖……

- 诺贝尔奖只是对已经成名的大家的一种物质和精神奖励，然而它却从来不会告诉我们应该怎么去做才能获得相应的成功；迷恋这些附加的荣誉，和科学追求真理的终极相去太远。

无题破有题……

科学研究的境界

- 最高境界是为科学事业献身或达到忘我。
- 第二层次是从科学研究中得到乐趣。
- 第三层次是以科学为谋生的手段。
- 第四层次是以科学牟取名利。

王国维的治学三境界

- 古今之成大事业、大学问者，必经过三种之境界。“昨夜西风凋碧树，独上高楼，望尽天涯路。”此第一境也。“衣带渐宽终不悔，为伊消得人憔悴。”此第二境也。“众里寻他千百度，回头蓦见那人正在灯火阑珊处。”此第三境也。

晏殊《蝶恋花》

- 槛菊愁烟兰泣露。罗幕轻寒，燕子双飞去。明月不谙离恨苦。斜光到晓穿朱户。昨夜西风凋碧树。独上高楼，望尽天涯路。欲寄彩笺兼尺素。山长水阔知何处。

- 做学问成大事业者，首先要有执着的追求，登高望远，瞰察路径，明确目标与方向，了解事物的概貌。

柳永《蝶恋花》

- 伫倚危楼风细细，望极春愁，黯黯生天际。草色烟光残照里，无言谁会凭阑意。拟把疏狂图一醉，对酒当歌，强乐还无味。衣带渐宽终不悔，为伊消得人憔悴。

- 对事业和理想要执着追求，忘我奋斗，为了达到成功的彼岸，一切都要在所不惜。所谓书山有路勤为径，学海无涯苦作舟；宝剑锋从磨砺出，梅花香自苦寒来。

辛弃疾《青玉案•元夕》

- 东风夜放花千树，更吹落星如雨。宝马雕车香满路，凤箫声动，玉壶光转，一夜鱼龙舞。蛾儿雪柳黄金缕，笑语盈盈暗香去。众里寻他千百度，蓦然回首，那人却在，灯火阑珊处。

- 经过多次周折、多年磨练后，逐渐成熟起来，能明察秋毫，豁然领悟，达致最后的成功。所谓踏破铁鞋无觅处，得来全不费功夫。厚积薄发、功到自然成。

夸夫

追日


精卫填海


愚公移山

谢
谢……