Institute report experimental solid state physics

AG Adrian (KOMET 333−0)

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Research projects

KOMET 330

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- The nature of heavy quasiparticles in magnetically ordered heavy fermions
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- Superconductivity of $SrTiO_3$
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- Mercury based high−T_c− superconducting films
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- Transmission Electron Microscopy on Epitaxial Layers of Sr_2FeMoO_6 on $SrTiO_3$
- Neutron diffraction measurements on A_2FeReO_6 (A = Ca, Sr, Ba)

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Highly ordered Fe and Nb stripe arrays on facetted Al_2O_3 $(10\bar{1}0)$

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Institute of Physics, University of Mainz

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H. Dosch
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Funding: BMBF within the center for Multifunctional Materials and Miniaturized Devices

We developed a process whereby highly−ordered arrays of epitaxial thin film nano− and mesostripes can be grown using molecular beam epitaxy (MBE) techniques on M−plane sapphire Al_2O_3 $(10\bar{1}0)$ substrates. The planar sapphire substrate surface is unstable and spontaneously forms $(\bar{1}011)$−$(10\bar{1}2)$ nanofacets upon annealing at high temperature. By employing this nanofacetted sapphire as a substrate for MBE growth at controlled shallow incident angles, highly perfect nano−and mesostripes can be produced by means of geometrical shadowing in conjunction with partial de−wetting of the epilayer on the facets. Advantages over other stripe fabrication strategies include epitaxial quality, tunable width and the ability to grow superconducting and rare earth nanowires using well−established MBE techniques. The process is demonstrated by the growth of regular arrays of 100 nm wide Nb nanostripes. Additionally, we have determined the epitaxy of Nb (111) on the Al_2O_3 $(\bar{1}011)$ facet. The applicability of the periodic defect structure of Nb layers with uniform thickness on the facetted surface is exemplarily demonstrated for the study of the vortex dynamics of type−II superconductors.

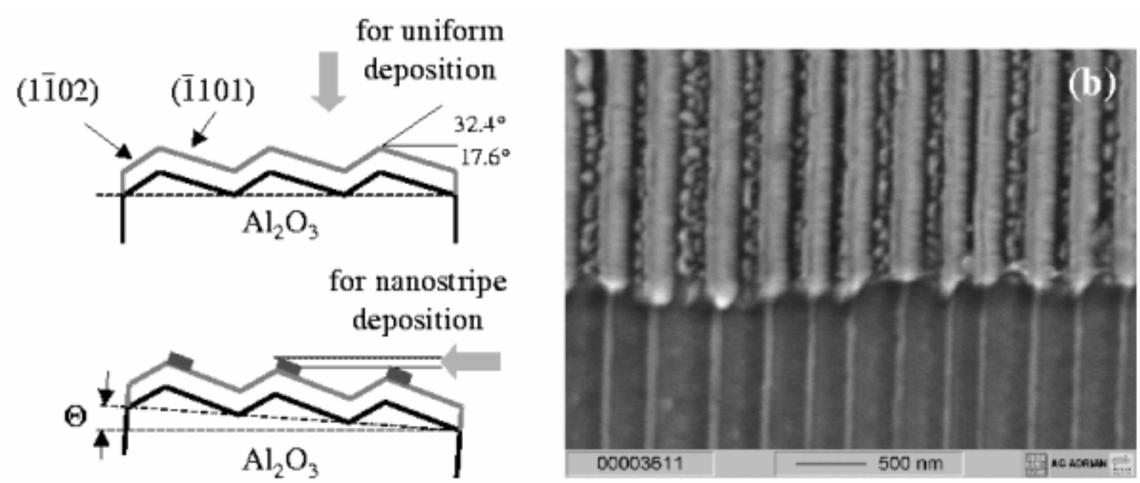

Figure: Scanning electron microscopy images of facetted alumina surface after deposition of 40 nm Nb at elevated temperature under glancing incidence. Nb stripes as formed by de−wetting after ion−beam etching part of the Nb surface to re−expose the facetted alumina.

Publications:

Highly ordered Fe and Nb stripe arrays on facetted α*−*Al_2O_3 *(10−10)*
M. Huth, K. A. Ritley, J. Oster, H. Dosch, H. Adrian,
Adv. Funct. Mater. 12 (2002) 333.

Research projects Publications Diploma theses PhD theses

The nature of heavy quasiparticles in magnetically ordered heavy fermions

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Prof. M. Dressel
Physikalisches Institut, Universität Stuttgart

Funding: MWFZ, Kompetenzzentrum elektronische Eigenschaften

In common metals the intinerant electrons show a constant electical conducitivity for frequencies up to the scattering rate Γ. This is well described by the so−called *Drude* model. While at room temperature heavy fermion materials also follow this behavior, many body effects cause strong deviations at low temperatures.

The optical conductivity of the heavy fermions UPd_2Al_3 and UPt_3 has been measured in the energy range from 0.04 to 5 meV at temperatures 2 K < T < 300 K. In both compounds a well pronounced pseudogap of less than one meV develops in the optical response at low T; we relate this to the antiferromagnetic ordering. From the energy dependence of the effective mass and scattering rate we derive the energies essential for the heavy quasiparticles. The enhancement of the mass mainly occurs below the energy which is related to magnetic correlations between the local magnetic moments and the itinerant electrons. This implies that the magnetic order in these compounds is the pre−requisite to the formation of the heavy quasiparticles and eventually of superconductivity.

Nature of Heavy Quasiparticles in Magnetically Ordered Heavy Fermions UPd_2Al_3 and UPt_3
M. Dressel, N. Kasper, K. Pethukov, B. Gorshunov, G. Grüner, M. Huth, H. Adrian,
Phys. Rev. Lett. 88 (2002) 186404.

Correlation gap in the heavy−fermion antiferromagnet UPd_2Al_3
M. Dressel, N. Kasper, K. Pethukov, D. N. Peligrad, B. Gorshunov, M. Jourdan, M. Huth, H. Adrian,
Phys. Rev. B 66 (2002) 035110.

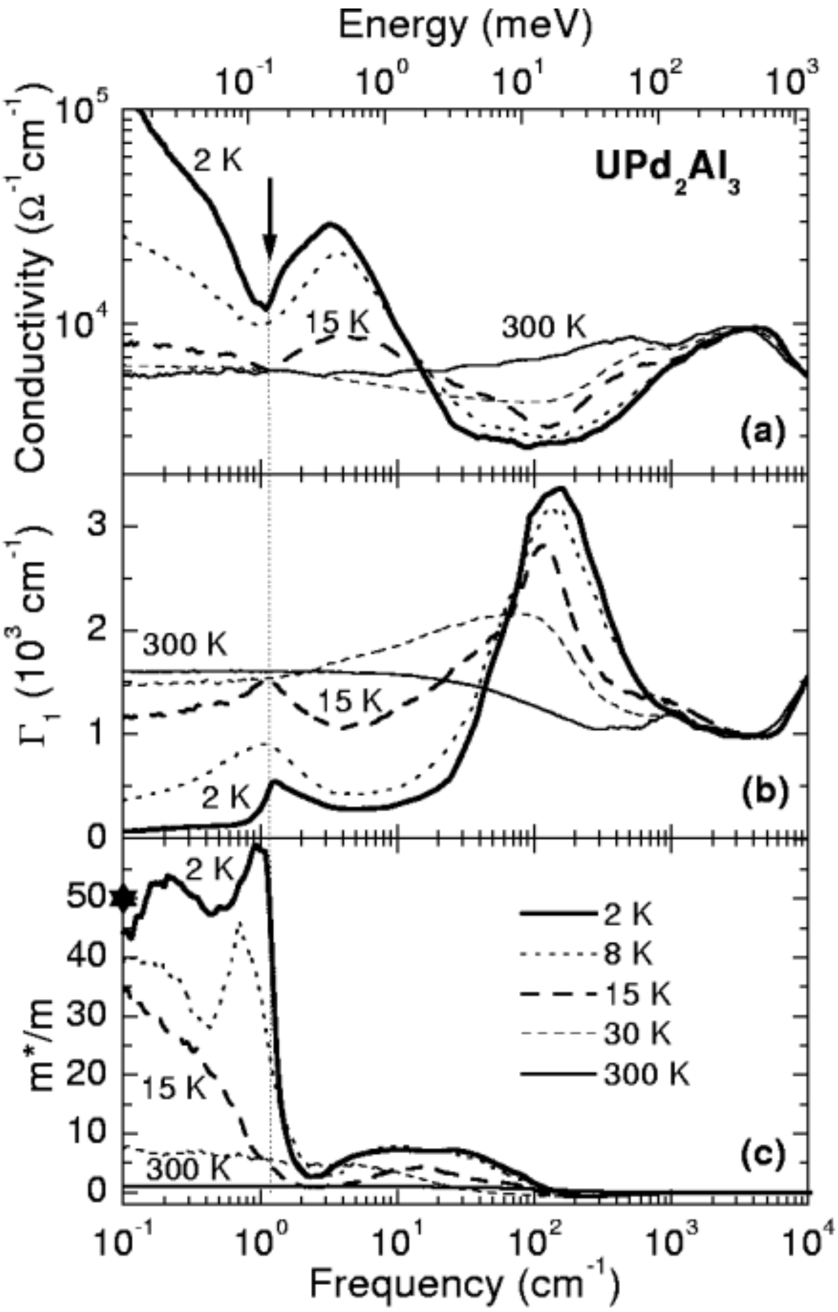

Figure: Frequency dependence of (a) the optical conductivity, (b) the scattering rate, and (c) the effective mass of UPd_2Al_3 for different temperatures. The point on the left axis corresponds to the effective mass derived by thermodynamic measurements. The arrow marks the correlation gap.

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Thin films of the heavy fermion superconductor UNi_2Al_3

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Institute of Physics, University of Mainz

Funding: MWFZ, Kompetenzzentrum elektronische Eigenschaften

Any weak attractive electron−electron interaction in metals can cause the formation of Cooper pairs, which then condense into a superconducting ground state. In conventional superconductors this interaction is mediated by lattice vibrations (phonons). However, for heavy fermion superconductors unconventional pairing based on magnetic excitations is favoured. Recently such a interaction could be identified for the first time: In the compound UPd_2Al_3 by means of tunneling spectroscopy on thin film junctions [Jou99, Tha 02] and inelastic neutron diffraction on single crystals [Sat01].

In a new research project we plan to investigate the superconducting order parameter of the isostructural heavy fermion superconductor UNi_2Al_3. Therefore we attempt the preparation of epitaxial superconducting thin films of this compound. The elementary component U, Ni and Al are deposited from electron beam evaporators onto heated single crystalline substrate (Molecular Beam Epitaxy − MBE). First results on non epitaxial Al_2O_3 (a−plane) substrates show (100)−oriented growth of UNi_2Al_3. This orientation is different from the preferential growth direction (001) of the isostructural compound UPd_2Al_3.

Due to impurity phases (e. g. UAl_2) the UNi_2Al_3 thin films on Al_2O_3 are not superconducting. To improve the crystallographic quality of the UNi_2Al_3 thin films it is necessary to find a epitaxial substrate which is suitable for the preferred (001)−growth. The preparation of thin films on various substrates with different growth parameters is in progress.

[1] M. Jourdan, M. Huth and H. Adrian, Nature, 398, 47 (1999)
[2] N. K. Sato et al., Nature, 410, 340 (2001)
[3] P. Thalmeier, M. Jourdan, M. Huth, Physik Journal, 6, 51 (2002)

Publications:

Unkonventionelle Supraleitung
P. Thalmeier, M. Jourdan, M. Huth,
Physik Journal, 6, 51 (2002).

Research projects Publications Diploma theses PhD theses

Superconductivity of $SrTiO_{3-\delta}$

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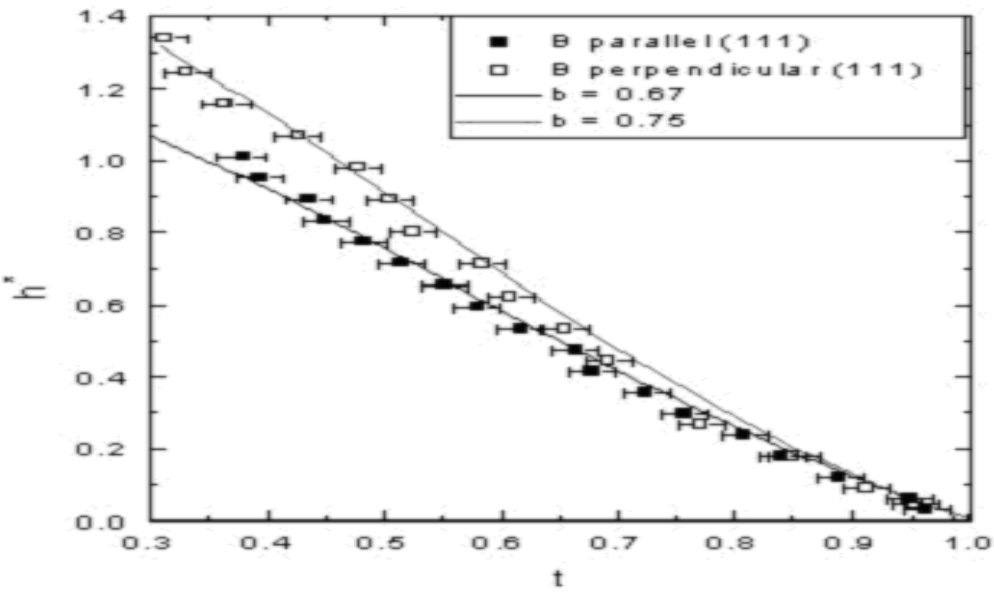
Funding: Forschungsfond der Universität Mainz

Doped $SrTiO_3$ is regarded as a candidate material for bipolaronic superconductivity [Mic90]. The basic idea is that two polarons form a local pair called bipolaron. These bipolarons are charged bosons which can condense into a superfluid−like state. The possibility of bipolaronic superconductivity was extensively discussed for high temperature superconductors, but presumably cannot be applied to these materials [Cha98]. However, in doped $SrTiO_3$ due to its huge dielectric polarizability (ε approx. 300) and low carrier density (approx. 1020 cm^{-3}) the possibility of polaron formation is obvious.

Alternatively, due to the specific band structure and reduced interband scattering, so called two band superconductivity with conventional pairing is possible in $SrTiO_3$. This expression describes the formation of distinct superconducting order parameters on the two sheets of the Fermi surface. Recently two band superconductivity attracted considerable interest because it was proposed to be realized in the new superconductor MgB2 [Gui01]. Superconducting $SrTiO_{3-\delta}$ was obtained by annealing single crystalline $SrTiO_3$ samples in ultra high vacuum. An analysis of the $V(I)$ characteristics revealed very small critical currents I_c which can be traced back to a unavoidable doping inhomogeneity. $R(T)$ curves were measured for a range of magnetic fields B at I close to I_c thereby probing only the sample regions with highest doping level. The resulting curves $B_{c2}(T)$ show upward curvature, both at small and strong doping. These results were discussed in the context of bipolaronic and conventional superconductivity with Fermi surface anisotropy. We conclude that the special superconducting properties of $SrTiO_{3-\delta}$ can be related to its Fermi surface.

[Mic90] R. Micnas, J. Ranninger, and S. Robaszkiewicz, Rev. Mod. Phys. 62, 113 (1990)
[Cha98] B. K. Chakraverty, J. Ranninger, and D. Feinberg, Phys. Rev. Lett. 81, 433 (1998)
[Gui01] F. Giubileo et al., Phys. Rev. Lett. 87, 177008 (2001).



Comparison between the normalized temperature dependence of the upper critical field $h^*(t)$ and fits based on the linearized Gor'kov gap equation with different anisotropy parameter b.

Publications:

Possibility of unconventional superconductivity of $SrTiO_{3-\delta}$
M. Jourdan and H. Adrian
accepted for publication in Physica C (2002)

Superconductivity in $SrTiO_{3-\delta}$
M. Jourdan, N. Blümer, and H. Adrian
submitted to Europ. Phys. Journ. B, cond−mat/0212649

Research projects Publications Diploma theses PhD theses

Guided vortex motion in Nb−films on facetted substrate surfaces

O. Soroka, M. Huth, J. Oster, H. Adrian
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V.A. Shklovskij
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Funding: NATO Advanced Study, MWFZ, Kompetenzzentrum elektronische Eigenschaften

In the presence of parallel pinning planes the pinning force in superconductor is anisotropic: it is much stronger in the transverse direction with respect to the pinning plane than in the parallel direction. Such an anisotropy of the pinning force can cause a guiding effect on the vortices, so called guided vortex motion, when the vortices tend to move along the pinning plane even if the external force acting on them is not aligned parallel to this plane.

Guided vortex motion results in appearance of "new" components of the galvanomagnetic response of a superconductor: the odd longitudinal and even transversal (Hall) voltage, with respect magnetic field reversal. These two components are absent in the isotropic superconductor.

The measurements were performed on thin niobium films deposited on a facetted Al_2O_3 substrate. When Al_2O_3 is annealed in air at high temperatures facets form on the substrate surface. Nb−films grown on this substrates using molecular beam epitaxy techniques replicate the facetted substrate surface as shown on the Fig. 1.

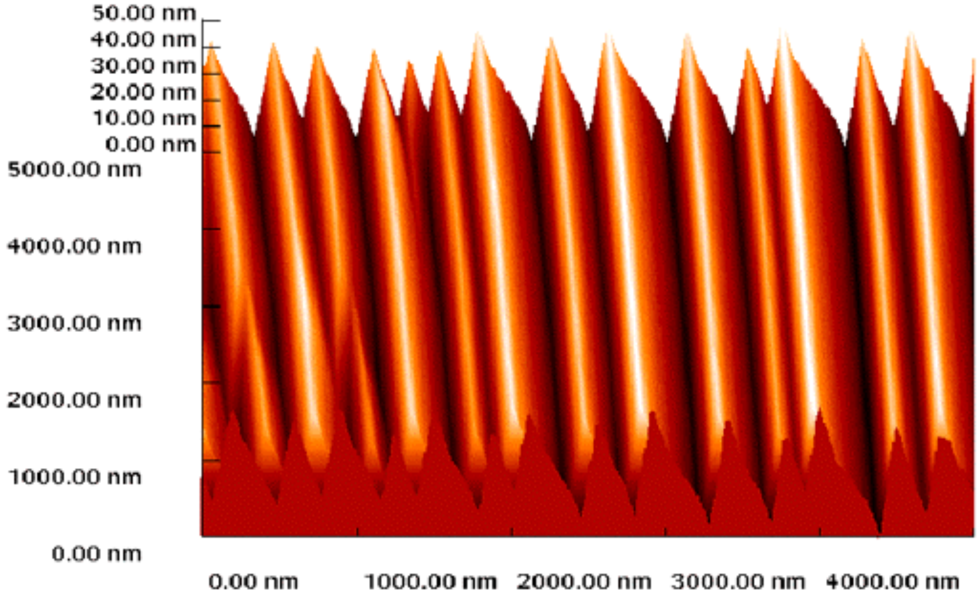

Fig. 1. Typical AFM picture of the surface of Nb film grown on the facetted Al_2O_3 substrate.

The facet ridges act as pinning planes. Micro−bridges were patterned by photolithography and ion−beam etching, having different orientation to the facet ridges. The temperature, current, and field dependencies of the sample magnetoresistivities was measured for two mutually opposite directions of the magnetic field **H**, perpendicular to the sample plane, i. e. parallel to the pinning planes. Odd and even components of the magnetoresistivities were calculated.

The results show clear evidence for the guided vortex motion in the Nb films on facetted Al_2O_3. We have observed appearance of the even components in the transversal and the odd components in longitudinal magnetoresistivities of the samples with different transport current orientation and (see Fig. 2)

a) b)

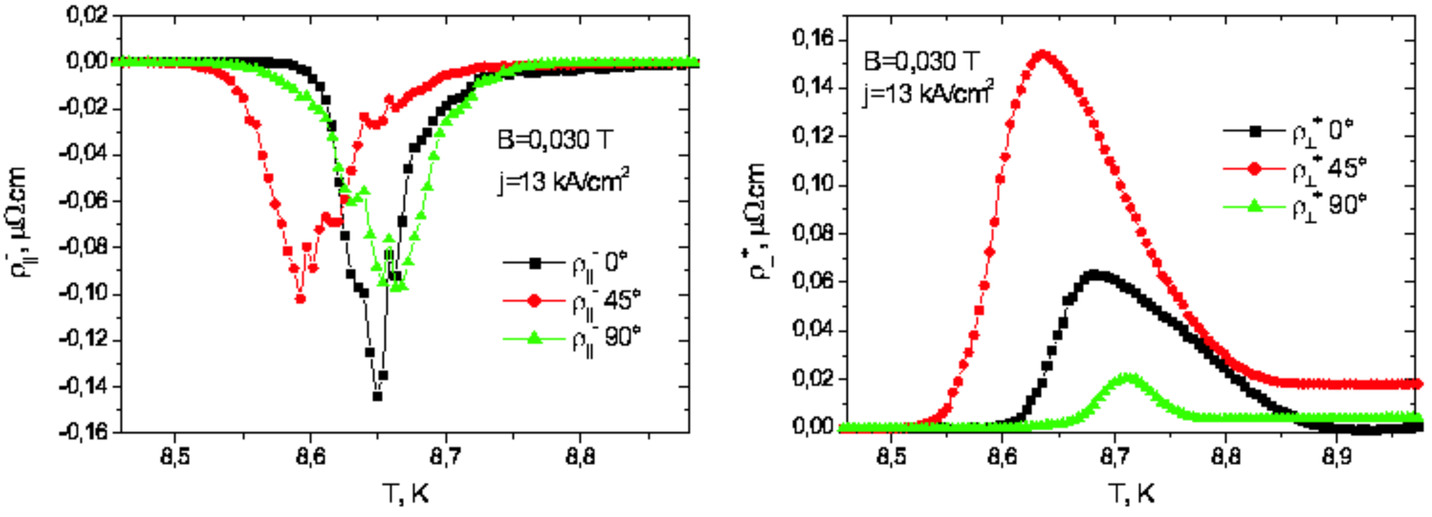

Fig. 2. Temperature dependences of the odd longitudinal (a) and the even transversal (b) magnetoresistivity for the samples with different transport current orientation as indicated.

Nevertheless, clear discrepancies with regard to the theoretical predictions are observed. In particular it is not clear what cause the almost identical behavior of the odd longitudinal component of the magnetoresistivity of the samples.

It should be noted that the this system is a good object for studying guided vortex motion. Parameters such as the facet period and film thickness can be easily varied when the films are being prepared. Also we intend to extend our study to the limit of strong anisotropic pinning by means of decorating the facet ridges with pair breaking materials prior to the Nb film deposition.

Publications:

Guided vortex motion in Nb films on facetted substrate surfaces
O. Soroka, M. Huth, V.A. Shklovskij, J. Oster, H. Adrian
accepted for publication in Physica C (2002)

Mercury based high−T_c− superconducting films

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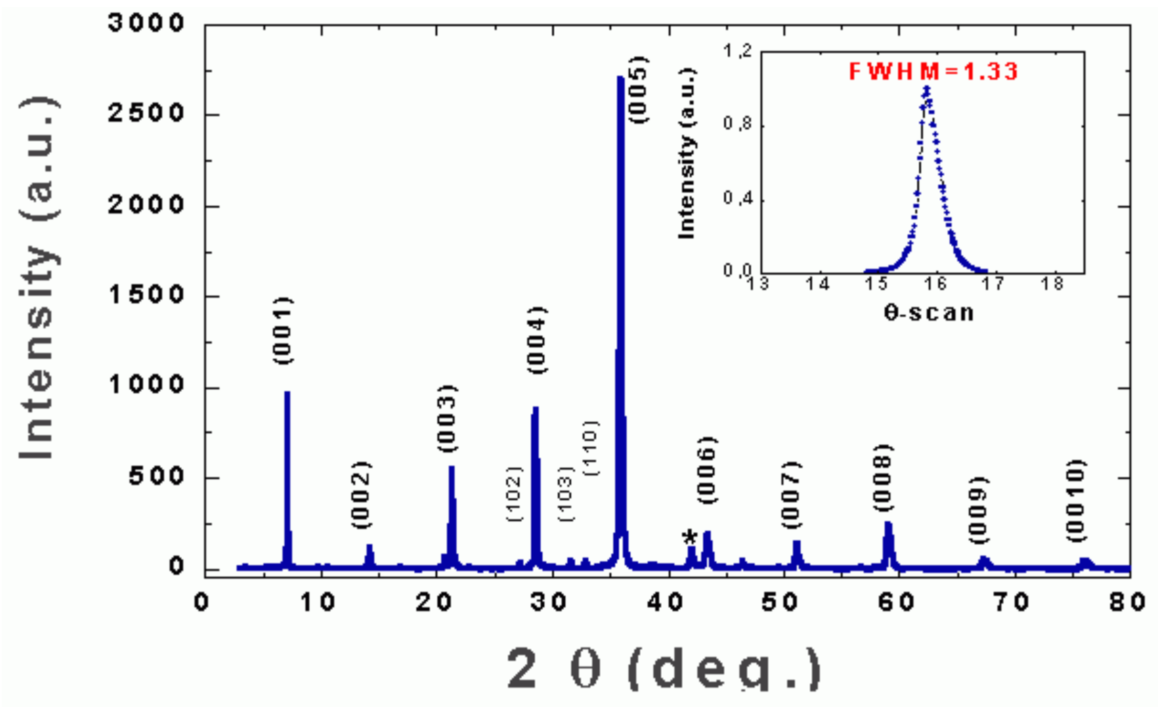
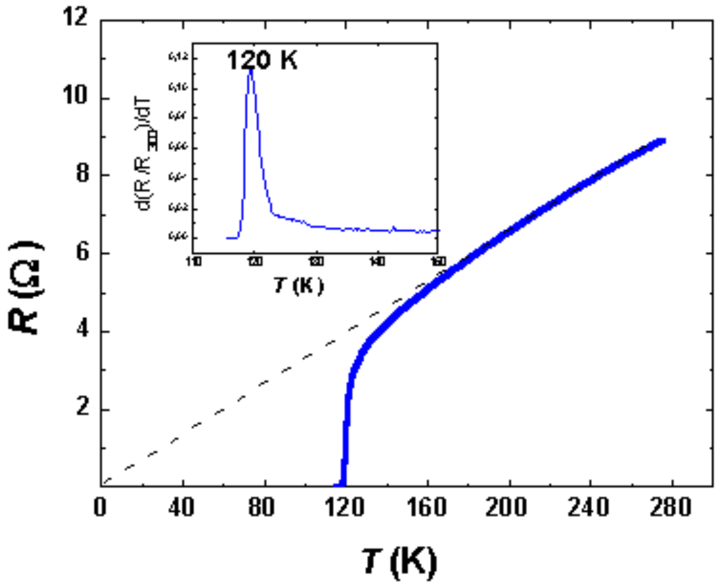
Institute of Physics, University of Mainz

Funding: Government of Egypt, MWFZ, Kompetenzzentrum elektronische Eigenschaften

The discovery of superconductivity in the mercury based $HgBa_2Ca_{n-1}Cu_nO_{2n+2+\delta}$ cuprates has attracted considerable interest due to their record high superconducting transition temperatures (slightly above 130 K and 160 K under presssure). These high critical temperatures suggest the possibility of superconducting applications at 77 K and even a few kelvins above. However, the highly volatile nature and toxicity of Hg, combined with the complexity of processing, has retarded the development of thin film technology, though Hg−1212 films have been successfully used for SQUIDs. At present there are only about one dozen research groups in the world involved in the development of Hg−based films. The main goal of our group is the preparation of "Superconducting Quantum Interference Devices" from mercury based High−T_c− superconductors. The first important step in this work is to achieve a technology for reproducible high quality thin film preparation by understanding film growth mechanism, phase formation and the influence of different synthesis routes with cationic substitutions. We succeeded to prepare the textured $(Hg_{0.9}Re_{0.1})Ba_2CaCu_2O_{6+\delta}$ (HgRe−1212) thin films by pulsed laser deposition (PLD) and post−annealing. The films exhibit sharp superconducting transitions at T_c= 120 K with transition ΔT_c= 2 K (As shown in the figure). On these epitaxial superconducting films of HgRe−1212 we determined the magnetic field anisotropy of thermally activated flux−motion, the irreversibility line, and the critical current densities.



XRD pattern for a HgRe1212 thin film. Inset is the rocking curve of the (005) peak.



Temperature dependence of the electrical resistivity for a HgRe−1212 film in zero field with an onset temperature of 120 K. The inset is a relation between the temperature derivative of the resistive transition and temperature.

Publications:

Preparation and characterization of $(Hg_{0.7}Mo_{0.3})Sr_2(Ca_{0.7}Y_{0.3})Cu_2O_x$ and $(Hg_{0.9}Re_{0.1})Ba_2CaCu_2O_y$ superconducting films by laser ablation
Z. L. Xiao, G. Jakob, B. Hensel, H. Adrian, and E. Y. Andrei
Physica C 341−348, 2393 (2000)

Resistivity and irreversibility line of $Hg_{0.9}Re_{0.1}Ba_2CaCu_2O_{6+d}$ HTS thin films
A. Salem, G. Jakob, M. Basset, and H. Adrian
accepted for publication in Physica C (2002)

Vortex glass in heavy ion irradiated films

M. Basset, A. Soroka, G. Jakob, H. Adrian
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G. Wirth
Gesellschaft für Schwerionenforschung, 64291 Darmstadt

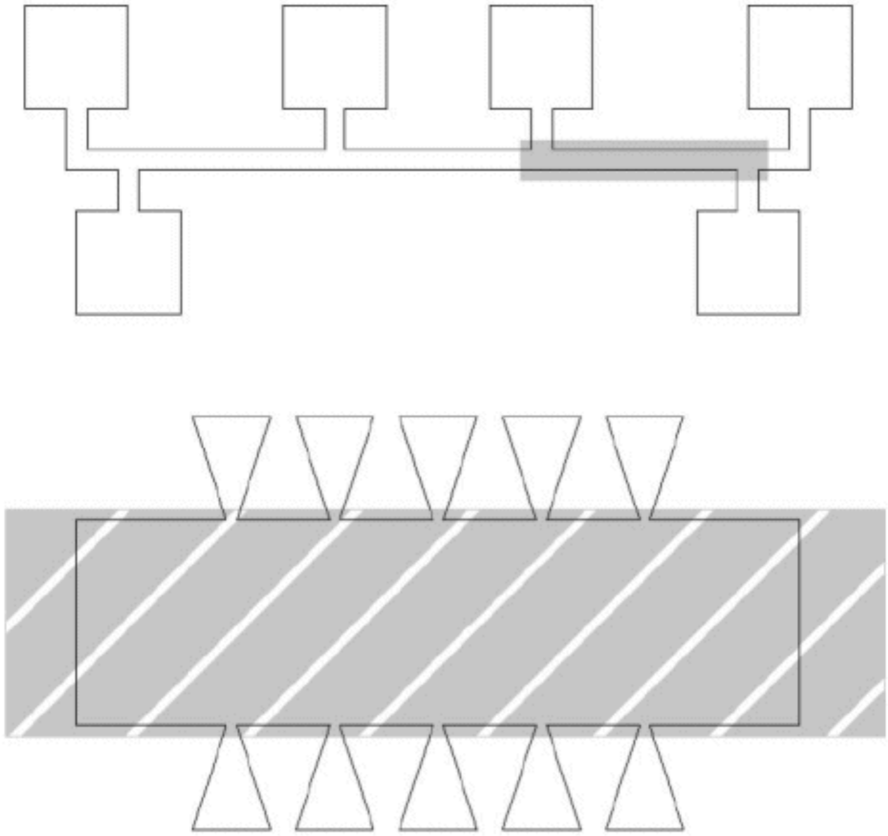
Funding: Deutsche Forschungsgemeinschaft DFG AD87/2, Gesellschaft für Schwerionenforschung

Heavy ion irradiation has proved to be a powerful method to investigate the vortex dynamics of the high temperature superconductors (HTSC). The introduced columnar defects are the most effective pinning centers and as a result of heavy ion irradiation the critical current density is increased. But beside this technological relevance the pinning properties of columnar defects have a strong influence on the dynamics of vortices. Based on the theory of collective pinning and the vortex glass model of Fisher, Fisher and Huse a Bose−glass phase transition is predicted by Nelson and Vinokur for the HTSC compounds in the presence of correlated disorder. The underlying scaling theory is characterized by universal dynamic and static critical exponents z' and ν_s that describe the divergence of the glass correlation length $l_s(T)$ and the relaxation time τ at the characteristic glass temperature T_{BG}. One transport coefficient that is related to this glass transition is the shear viscosity η.

A different realization of correlated defects is found in twin boundaries in $YBa_2Cu_3O_{7-x}$ single crystals. Their influence on the vortex dynamics was extensively studied during the last years in YBCO single crystals with unidirected twin boundaries using electrical transport measurements, ac screening experiments, simulations and analytical methods. For the case that the twin boundaries form an angle θ with the direction of an applied external current, the vortices feel an anisotropic pinning force. This leads to a guided vortex motion that can be detected in measuring the even transverse voltage in the presence of an external magnetic field. In literature, two different mechanisms are proposed to be responsible for the guided motion of vortices in unidirected twins. In the first, vortices will be channeled by the deep pinning potential of the twin boundary and will move in the twin boundary (internal motion), whereas the second mechanism assumes the vortex−vortex interaction to be the dominating mechanism for a guided vortex motion also outside the twin boundary (external motion).

We realized a new experiment on strong and weak pinning channels and discussed its relation to guided vortex motion in twin boundaries. We created channels of different pinning strength in $YBa_2Cu_3O_{7-x}$ thin films using heavy ion irradiation through patterned metal masks consisting of an array of fine stripes. The effects of homogeneous irradiation were analyzed using irradiated and unirradiated reference bridges on the same sample. The transverse voltage on a Hall bar structure showed a strong correspondence to that in $YBa_2Cu_3O_{7-x}$ single crystals with unidirected twin boundaries. However, in our experiment the weak pinning channels had a macroscopic width in contrast to the very narrow channels formed by twin boundaries. This resulted in a nontrivial current density distribution in the samples that was modeled using the longitudinal resistivities. Another difference to the planar twin boundaries was that in our case the columnar defects are linelike pinning centers. Therefore a guided vortex motion can only result from vortex−vortex interaction at the interface of strong and weak pinning regions. If the interaction length becomes large the pinned vortices in the irradiated channels should induce a freezing of free vortices in the unirradiated channels. At this freezing transition a guided vortex motion must vanish. Thus, the arrangement of strong and weak pinning regions represents a Bose−glass contact as introduced theoretically by Marchetti in the definition of a new generation of experiments in order to study the Bose−glass transition in a hydrodynamic context.

We used the heavy ion irradiation as a new tool to investigate the vortex dynamics geometrically confined structures, where the confinement is due to pinning. With the aid of an irradiated and an unirradiated test bridge it was possible to gain input parameters for a numerical simulation of the potential distribution and to analyze the current−voltage characteristics of both the strong and weak pinning parts, respectively. Based on these results, the existence of a Bose−glass contact in the periodically irradiated samples was assumed and the obtained *B−T* phase diagram was interpreted in a hydrodynamic approach near the Bose−glass transition.



Sample with a conventional Hall structure (2mm x 7 mm) and two identical test bridges (200µm x 2000µm). The samples were irradiated with high energy (0.75 GeV Pb and 1.14 GeV U) ions in such a way that columnar defects were arranged in a periodic array of strong (=irradiated) and weak (=unirradiated) pinning regions. Ni masks were used in order to stop the swift ions and to reproduce the irradiation pattern on the thin film structure. Gray regions are irradiated.

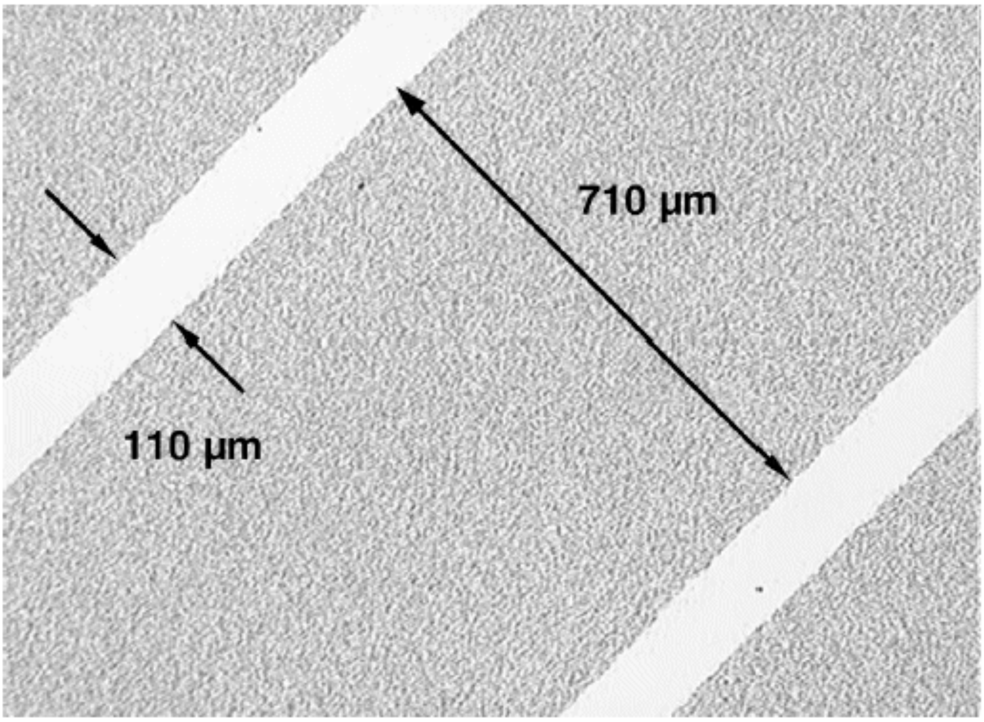
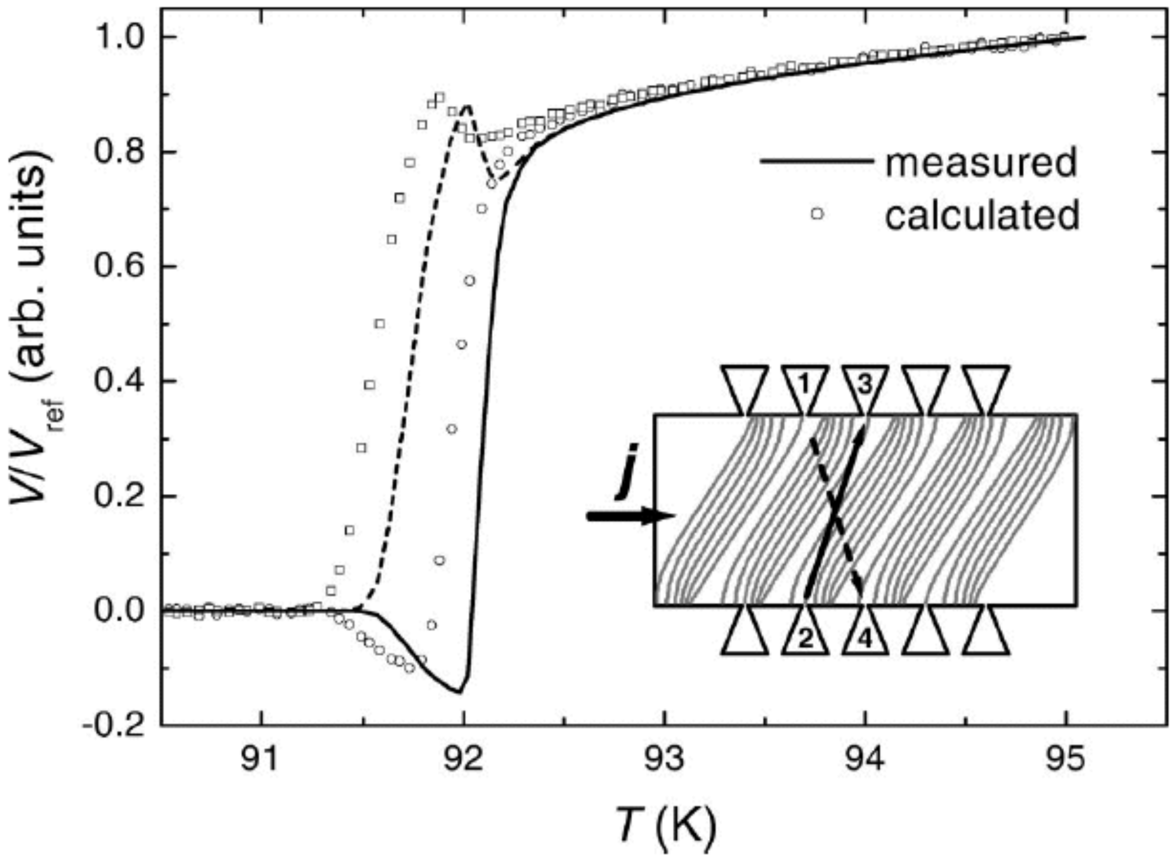


Image of an irradiated glass substrate that was etched in 18% HF for 20 s. For the structure with the 1:7 ratio that is shown here, the channel width is 110µm for the unirradiated and 710µm for the irradiated regions.



Measured and calculated transverse voltages. The inset shows the equipotential lines. The calculation was performed by using independend experimentally determined resistivites as input values for a resistor network and solving Kirchhoffs laws by numerical inversion of a 22401 x 22401 matrix representing a set of independent current loops around each area element.

Publications:

Flux−Flow Instability and Heating Effects in $Bi_2Sr_2CaCu_2O_8$ and $YBa_2Cu_3O_7$ Thin Films
G. Jakob, P. Voss−de Haan, M. Wagner, Z.L. Xiao, and H.Adrian
Physica B 284−288, 897 (2000)

Importance of the crossover−current density for a vortex−glass analysis
P. Voss−de Haan, Gerhard Jakob, and Hermann Adrian
Physica C 341−348, 1387, (2000)

Patterned irradiation of $YBa_2Cu_3O_{7-x}$ thin films
M. Basset, G. Jakob, G. Wirth, and H.Adrian
Phys. Rev. B 64, 0245265 (2001)

Nondiverging vortex pinning barriers at low current densities across the putative elastic vortex−glass−vortex−liquid transition in $YBa_2Cu_3O_{7-d}$ films
L. Miu, M. Basset, G. Jakob, H. Rodriguez, and H.Adrian,
Phys. Rev. B 64, 220502R (2001)

Research projects Publications Diploma theses PhD theses

Perpendicular transport of $YBa_2Cu_3O_7/PrBa_2Cu_3O_7$ superlattices

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Institute of Physics, University of Mainz

Funding: Government of Columbia, MWFZ, BMBF within the center for Multifunctional Materials and Miniaturized Devices

It is known that the superconducing mechanism in high temperature superconductors take place in the CuO_2 planes, because their layered structure result an anisotropic behavior which is reflected in their transport and superconducting properties. Therefore artificial superlattices are an ideal scenario in order to get insight into the interlayer coupling, dimensionality effects etc.

$YBa_2Cu_3O_7/PrBa_2Cu_3O_7$ superlattices have been prepared by high pressure DC sputtering. The quality of the interface, thickness and epitaxy was study by x−ray diffraction. In order to investigate the transport perpendicular to the plane, the samples were patterned using photolitography and ion milling into Mesas between 16x16mm^2 and 30x30mm^2 area and 150nm height.

We have measured the differential conductivity using the lock−in technique on $(YBa_2Cu_3O_7)_4$ $/(PrBa_2Cu_3O_7)_{16}$ superlattices (fig (1)). At low temperature we observe a tunnel characteristic−like curve with maxima at −+46mV. These correspond to a stack of nine junctions i.e. superconducting gap of aprox. 5mV, at high bias voltage appear some peaks which could be related with the periodicity.

Measurement on $(YBa_2Cu_3O_7)_2$ $/(PrBa_2Cu_3O_7)_{16}$ reveals a possible Josephson coupling. Magnetic field dependence of the differential conductivity at zero bias and low temperature exhibit an aprox. 1T periodicity fig (2)

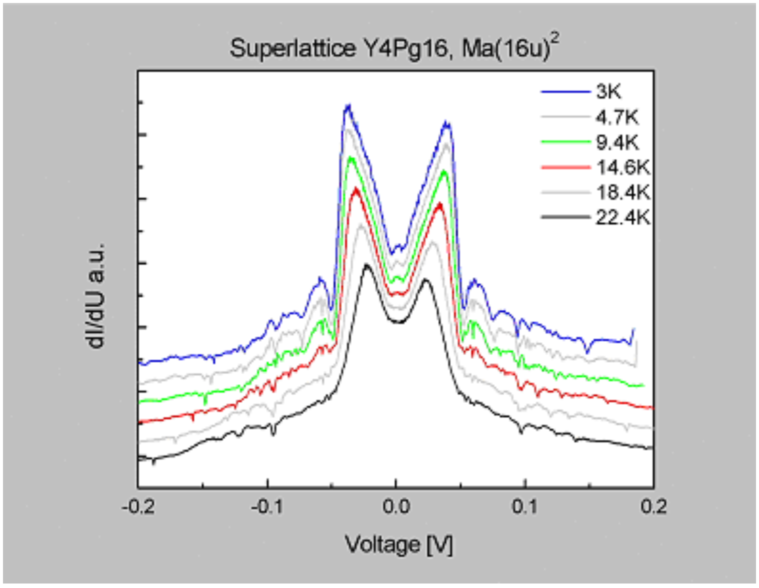

Fig. 1 differential conductance vs bias voltage for a 4:16 superlattice for different temperatures. The 46mV maximum corresponds to a stack of nine junctions

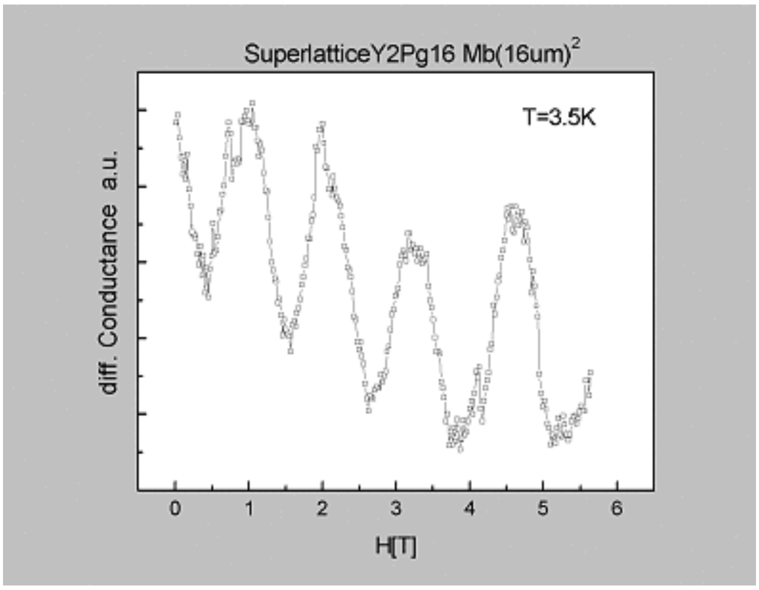

Fig. 2 zero bias differential conductance vs magnetic field for a 2:16 superlattice. A modulation of aprox. 1T was observed.

Publications:

Perpendicular transport properties of $YBa_2Cu_3O_7$/$PrBa_2Cu_3O_7$ superlattices
J.C.Martinez, A.Schattke, G.Jakob, and H.Adrian
Physica B 284−288, 553 (2000)

c−Axis tunneling in $YBa_2Cu_3O_7$/$PrBa_2Cu_3O_7$ superlattices
J.C. Martinez, A. Schattke, M. Jourdan, G. Jakob, and H.Adrian
Phys. Rev. B 61, 9162 (2000)

Research projects   Publications   Diploma theses   PhD theses

Preparation and characterisation of Sr_2FeMoO_6 thin films

N. Auth, D. Reisinger, W. Westerburg, L. Wiehl, G. Jakob
Institute of Physics, University of Mainz

Funding: DFG Project Ja821/1−3, MWFZ Mainz and BMBF Project 03N 6500

In continuation of our previous studies on perovskite manganites we investigated the double−perovskite compound Sr_2FeMoO_6 (SFMO). The high Curie temperature T_c = 420K, the observation of room temperature magnetoresistance in polycrystalline samples and the prediction of 100% spin polarisation[Kob98] render this material attractive as part of field sensors, e.g. in magnetic tunnel junctions.

SFMO thin films were prepared by pulsed laser deposition (PLD) in an oxygen partial pressure of 10^{-1} – 10^{-7} Torr or in argon atmosphere of 10^{-1} Torr from a stoichiometric target on (100) SrTiO3 substrates. During deposition the substrate temperature T_D was constant with values covering the range from 300°C to 950°C. Crystal structure investigations were performed using a two−circle and four−circle diffractometer.

Both, oxygen partial pressure and deposition temperature T_D play a crucial role for phase formation and epitaxy. At 320°C there is a sharp boundary for epitaxial thin film growth. For lower temperatures a yellow insulating phase was observed. From 320°C up to 920°C the samples are single phase, dark and a high degree of *a*,*b* and *c*−axis orientation is achieved. In these samples semiconductorlike behaviour is found. Films prepared above 920°C in 0.1mbar Argon are metallic, while the crystal quality is slightly reduced with an angular spread of 0.23°. The transition from semiconducting to metallic behaviour is connected with the appearance of the (111) reflection signaling ordering of the Fe/Mo sublattice in a rock−salt structure (Fig.1).

The resistivity of metallic films as a function of temperature and magnetic field is presented in Fig.2. Two different regimes with a high magnetoresistance (MR), defined by MR = $[\rho(T,\mu_0 H = 0\text{ T}) - \rho(T,\mu_0 H = 8\text{ T})]/\rho(T,\mu_0 H = 0\text{ T})$ (Fig.2 right axis) can be distinguished. At very low temperatures the MR increases supposedly to grain boundary effects. The peak at 380K in the neighbourhood of the Curie temperature is probably due to the suppression of spin−fluctuations by the external magnetic field.

[Kob98] K.−I. Kobayashi, T. Kimura, H. Sawada, K. Terakura and Y. Tokura, Nature 395, 677 (1998)

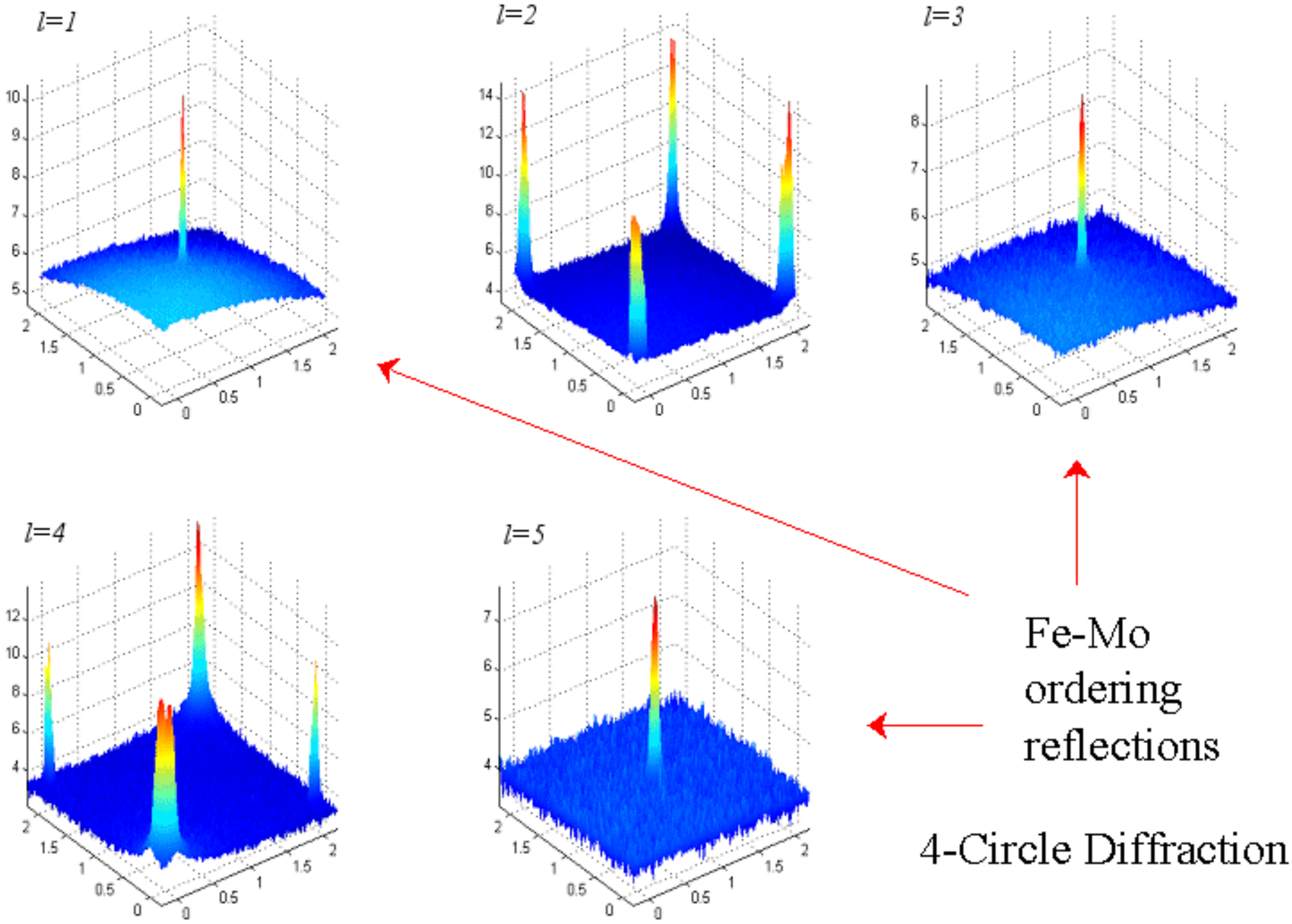

Fig 1: X−ray diffraction of Fe/Mo superstructure peaks (*l* = 1,3,5) compared to simple perovskite positions (*l* = 2,4).

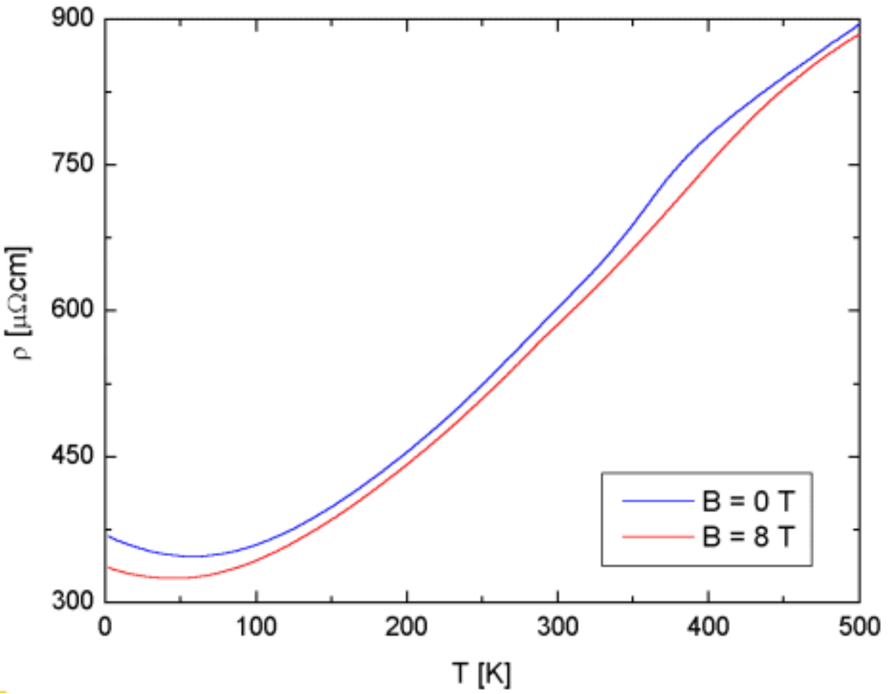

Fig 2: Temperature dependent resistivity in zero and 8 T magnetic field.

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Transport and magnetic properties of $La_{1-x}Ca_xMnO_3$ *films (0.1<x<0.9)*
G.Jakob, F. Martin, S. Friedrich, W. Westerburg, and M. Maier
Physica B 284−288, 1440 (2000)

Charge carrier density collapse in $La_{0.67}Ca_{0.33}MnO_3$ *and* $La_{0.67}Sr_{0.33}MnO_3$ *epitaxial thin films*
W. Westerburg, F. Martin, G. Jakob, P. J. M. van Bentum, and J.A.A.J. Perenboom
Eur. Phys. J. B 14, 509 (2000)

Epitaxy and magnetotransport of Sr_2FeMoO_6 *thin films*
W. Westerburg, D. Reisinger, and G. Jakob
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Hall−effect of epitaxial double perovskite Sr_2FeMoO_6 *thin films*
W. Westerburg, F. Martin, and G. Jakob
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Magnetic and structural properties of the double−perovskite Ca_2FeReO_6
W Westerburg, O. Lang, C. Felser, W Tremel, C. Ritter, and G. Jakob,
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Investigating the spin polarisation of magnetoresistive materials by point contact spectroscopy
N. Auth, G. Jakob, T. Block, and C. Felser
subm. to PRB (2002)

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Transmission Electron Microscopy on Epitaxial Layers of Sr_2FeMoO_6 on $SrTiO_3$

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Funding: BMBF within the center for Multifunctional Materials and Miniaturized Devices, DFG Project Ja821/1−3, MWFZ Mainz

Sr_2FeMoO_6 thin films (SFMO) on $SrTiO_3$ substrate have been prepared by Pulsed Laser Deposition under various pressure and temperature conditions in order to optimize crystal quality and electrical performance. The ordered double−perovskite structure with high magnetic moment was found for films deposited at high substrate temperatures [Wes2000]. Films deposited at lower substrate temperatures (down to 590 K) were semiconducting and showed reduced magnetic moments, but a much better crystal quality with rocking curve widths <0.05°. This unusual observation motivated our investigations of the low temperaure phase.

The ordered double−perovskite SFMO has a tetragonal unit cell with size $2^{1/2}$ x $2^{1/2}$ x 2 as large as the simple perovskite cell. Structural details however are in question up to now and may even depend on preparation. There exist two structure models, one in spacegroup $P4_2/m$ from neutron powder diffraction [Rit00] and the other in I4/mmm from single crystal X−ray diffraction [Tom00]. Moreover additional phases were reported [Dai01].

The magnetic and electric properties of SFMO change considerably with preparation condi−tions and these differences should be correlated to structural details. This covers crystal sym−metry as well as ion−ordering and texture (domain sizes and orientations). These features were investigated with transmission electron microscopy

Electron diffraction photos (Selected Area Diffraction) and high resolution images (HRTEM) from cross−section specimen were made with a TECNAI F30 electron microscope. The diffraction pattern of several different zone axes show a complex super structure, which does not correlate to the double−perovskite. Instead there is a tripling of reflexions in all directions (Fig. 1), not only along the c−axis as was reported recently [Dai01] for polycrystalline magnetoresistive Sr_2FeMoO_6.

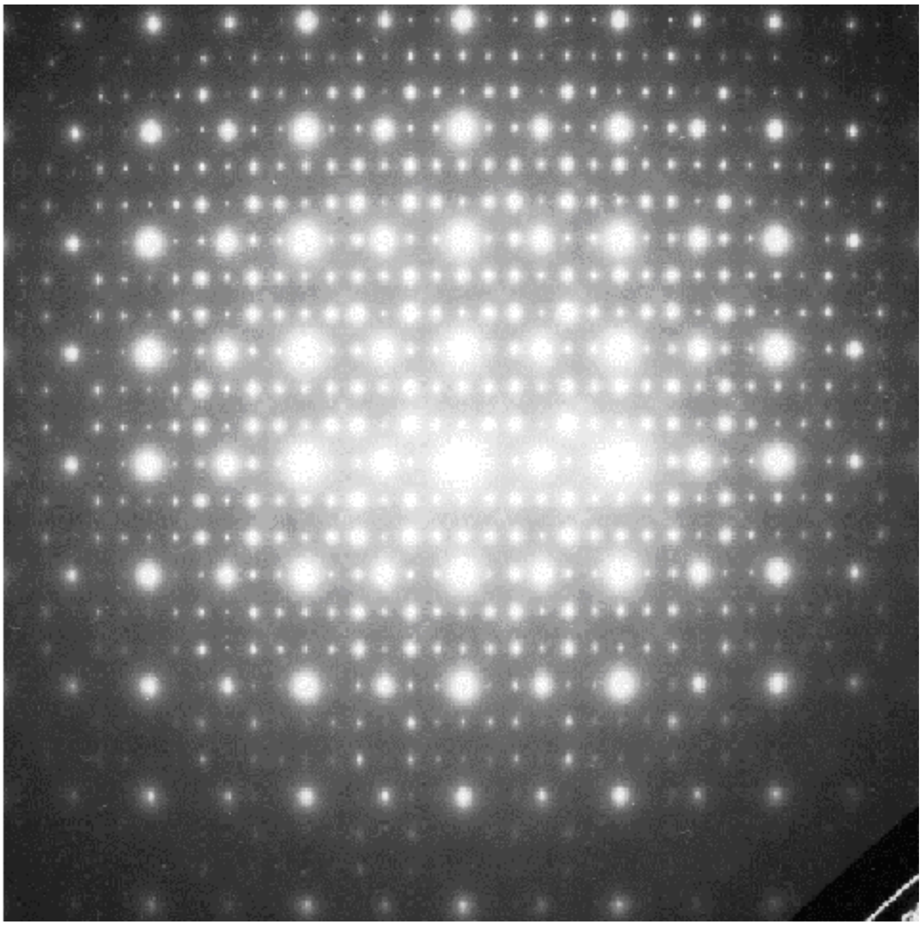

Fig 1: Electron diffraction pattern of [100] zone of Sr_2FeMoO_6.

Electron images show the texture of the films with single crystalline grains of some 10−100 nm size. In high resolution images the relative orientations of these grains was measured and the quality of the SFMO/STO interface could be judged. Near the interface film growth is locally perfect. At larger lateral distances there are distortions because of the lattice mismatch of ca. 1%. These grains are all oriented parallel. However, away in the film there is columnar growth and differently oriented domains appear, which are twins with twin plane (111). The twins partly contribute to the diffraction pattern, but most of the satellite reflexions cannot be explained by twinning and else are from a new super structure [Wie02a,Wie02b].

The HRTEM−pictures show atomic resolution. Distances of bright spots correspond to atomic distances in the crystal structure. Nevertheless we cannot identify the visible spots with certain atom−columns directly, as electron contrast varies considerably with defocus and crystal thickness. Therefore image calculations where performed with the Programm JEMS [Stade]. First results show clearly different image contrast for Fe and Mo at suitable thickness and defocus values. Thus in HRTEM−images Fe−Mo−ordering schould be visible in focus−series of ordered samples.

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[Stade] JEMS: P. Stadelmann, I2M−EPFL, CH−1015 Lausanne, Switzerland

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Neutron diffraction measurements on A_2FeReO_6 (A = Ca, Sr, Ba)

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Funding: DFG Project Ja821/1−3, MWFZ Mainz, Institut Laue Langevin

We investigated A_2FeReO_6 (A = Ca, Sr, Ba) double perovskites where half metallic behavior is possible due to a strong Hunds rule coupling and a double exchange like interaction between Fe and Re atoms. The samples were synthesized by sintering stoichiometric mixtures of the corresponding oxides and metals in evacuated quartz tubes. In the series Ca_2FeReO_6, Sr_2FeReO_6, Ba_2FeReO_6 the Curie temperatures decrease from T_C = 540 K, 400K to 340 K. Increasing A−site cation radii lead to tolerance factors of 0.89, 0.94, and 0.99, respectively. We found the Ca−compound to order ferrimagnetically and to crystallize with a monoclinic distortion due to the small tolerance factor of the perovskite structure [1]. Therefore we expected Ba_2FeReO_6 to be cubic, whereas Sr_2FeReO_6 is likely to show a tetragonal distortion. To investigate the crystal and spin structure of the Ba− and Sr−compounds neutron diffraction experiments were carried out.

While Ba_2FeReO_6 stays cubic over the whole temperature range we examined (below and above T_C), the Sr−compound could be fitted best with the $P4_2/m$ space group (Fig.1). The oxygen octahedra show an alternating rotation around the c−axis ($a^0a^0c^-$ in Glazers notation) (Fig.2). The rotation angle is 6.2° at 1.5K and becomes smaller with rising temperature, but it does not completely vanish up to about 520K (1.3°) which is much higher than T_C. In the refinement of the magnetism a ferrimagnetic alignment of the Fe, Re ions is found. Like in the Ca compound the Fe and Re ions carry magnetic moments which are smaller than expected from formal valence considerations. Due to the similarity of the scattering lengths of Fe and Re additional x−ray measurements were performed to verify Fe, Re stoichiometry and positional order.

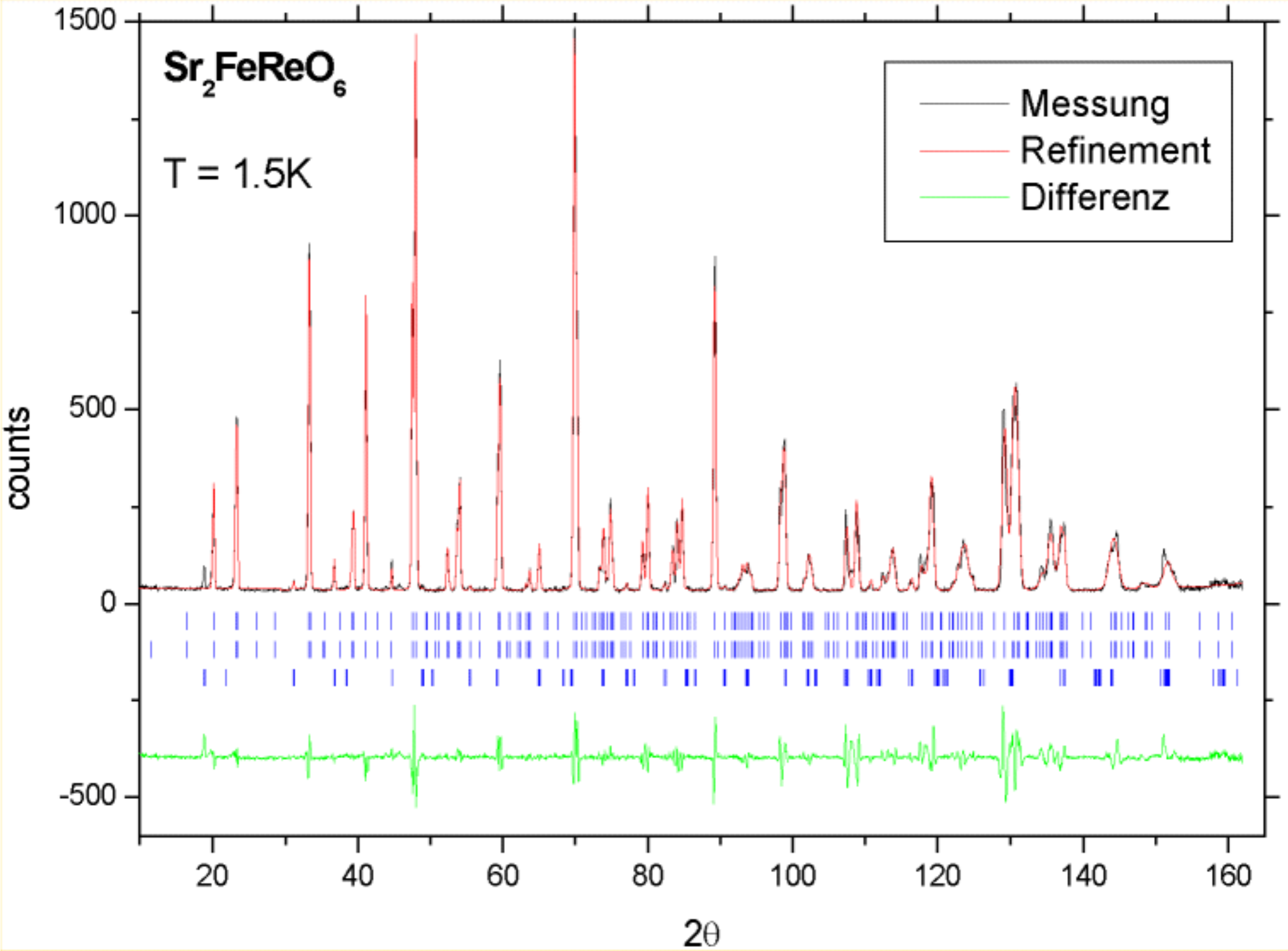

Fig 1: Example of a neutron diffraction pattern (black) and its refinement with Fullprof (red).

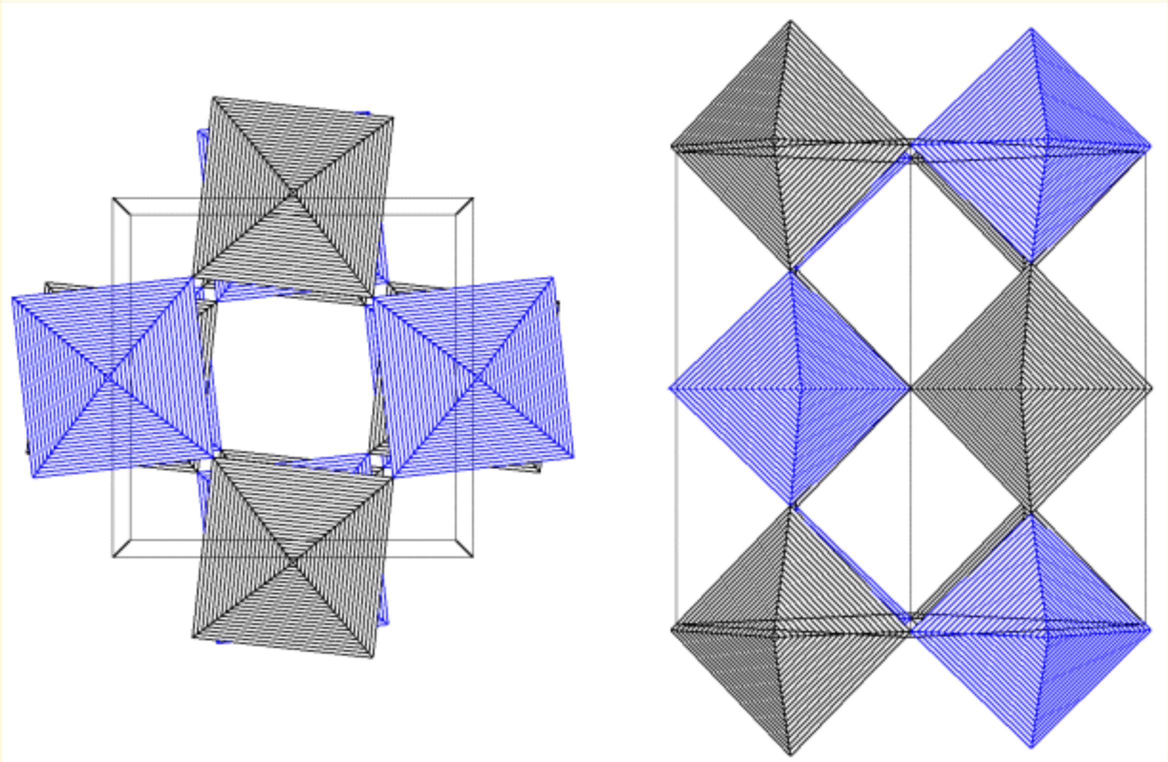

Fig 2: Schematic drawing of rotation and stretching/compressing of oxygen octahedra around Fe/Re centres in the double perovskite structure (along (001)− and (110)−direction). The distorsions have been exaggerated to emphasise the special features.

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[1] *Magnetic and structural properties of the double−perovskite* Ca_2FeReO_6
W. Westerburg, O. Lang, C. Felser, W. Tremel, C. Ritter, and G. Jakob,
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M. Jourdan, N. Blümer, and H. Adrian
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N.V. Kasper, P. Wochner, G. Carbone, A. Vigliante, D. Mannix, G. Jakob
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Investigating the spin polarisation of magnetoresistive materials by point contact spectroscopy

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Patrick Haibach, (Juni 2000)

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Quenched Disorder and Magnetism in $TiFe_2$ Laves Phase Thin Films
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