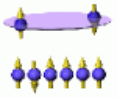


Research Report, AG Adrian (KOMET333-0)



Institute report experimental solid state physics

AG Adrian (KOMET 333-0)

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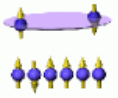
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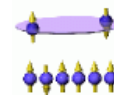
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Magnetism of the heavy fermion compound UNi₂Al₃

M. Jourdan, A. Zakharov, and H. Adrian

Institute of Physics, University of Mainz

A. Hiess¹, T. Charlton², N. Bernhoeft³, D. Mannix⁴

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²*Rutherford Appelton Laboratory, ISIS facility, Chilton, Didcot, Oxfordshire OX11 0QX, UK*

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Funding: DFG, Jo404/2–1, , XMaS is an EPSRC–funded project

The heavy fermion superconductors UPd₂Al₃ (T_{sc} = 2K) and UNi₂Al₃ (T_{sc}=1K) both exhibit the coexistence of superconductivity and magnetic order at low temperatures. However, they display important differences key to the understanding of the interplay between magnetism and superconductivity, an area of active debate in condensed matter physics. A different unconventional superconducting pairing mechanism may be realized in this compound and the magnetic properties of these samples are crucial to an understanding of the origin of superconductivity.

Resonant magnetic x–ray scattering (XMaS UK CGR, ESRF Grenoble) was employed to investigate the magnetic state of epitaxial a* oriented thin films of the heavy fermion superconductor UNi₂Al₃. The observed incommensurate propagation vector as well as the Neel temperature correspond to those of bulk samples. The 120nm film shows magnetic order with a correlation length > 80nm parallel to the growth axis. Out of the three possible magnetic domains the one with the moment direction perpendicular to the film surface is not realized.

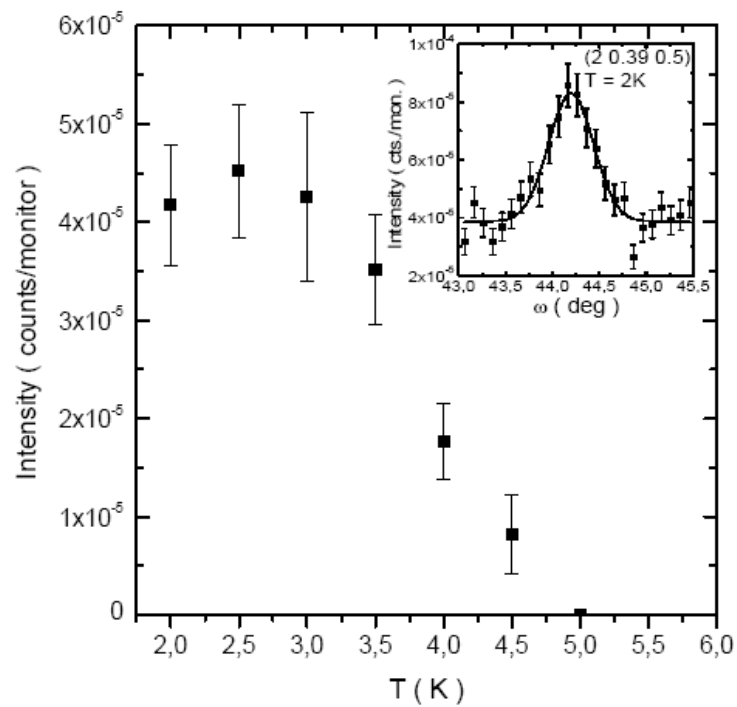
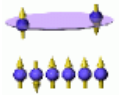
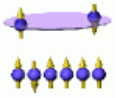


Fig. 1. Temperature dependence of the integrated scattering intensity of ω -scans (see inset) of the magnetic Bragg-peak $Q_m=(2, 0.39, \frac{1}{2})$.

Publications:

Magnetic order in thin films of the heavy fermion superconductor UNi₂Al₃
 M. Jourdan, A. Zakharov, A. Hiess, T. Charlton, N. Bernhoeft, and D. Mannix,
 submitted to Eur. Phys. Journ. B

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Optical conductivity of the heavy fermion compound UPd_2Al_3

M. Jourdan, A. Zakharov, and H. Adrian
Institute of Physics, University of Mainz

M. Scheffler, M. Dressel
1. Physikalisches Institut, Universität Stuttgart, D–70550 Stuttgart, Germany

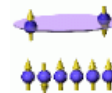
In this project thin film samples from Mainz are used for investigation performed at the University of Stuttgart. Additional information is found on the [Homepage of Prof.Dressels group, Uni Stuttgart](#).

The electrical conduction of metals is governed by mobile electrons, more specifically by how freely they can move throughout the material. This movement is hampered by scattering with other electrons as well as with impurities or with thermal excitations (phonons). Experimentally one does not observe the scattering processes of single electrons, but the overall response of all mobile charge carriers within a sample. This ensemble dynamics can be described by relaxation rates: how fast does the system approach equilibrium after an external perturbation? Here we study the heavy–fermion compound UPd_2Al_3 , a metal with strong interaction among the electrons, and show that the precise shape of its frequency–dependent microwave conductivity accurately follows the prediction for a single relaxation rate (the so–called Drude response) although more complex behaviour might be expected. Furthermore the relaxation rate is extremely low, just a few GHz, several orders of magnitude below those of conventional metals (typically around 10 THz) and at least one order of magnitude lower than previously estimated for comparable metals. These observations are directly related to the high effective mass of the charge carriers in this material and reveal the dynamics of interacting electrons.

Publications:

Extremely slow Drude relaxation of correlated electrons
M. Scheffler, M. Dressel, M. Jourdan, and H. Adrian,
accepted for publication, Nature (2005)

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Unconventional superconductivity and magnetism of the heavy fermion compound UNi_2Al_3

M. Jourdan, A. Zakharov, M. Foerster and H. Adrian

Institute of Physics, University of Mainz

Funding: DFG, Jo404/2–1

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.

Epitaxial thin films of the heavy fermion superconductor UNi_2Al_3 (100) were prepared by molecular beam epitaxy (MBE). The elementary components U, Ni and Al are deposited from electron beam evaporators onto heated single crystalline YAIO_3 (112) substrates.

Resonant magnetic x–ray scattering experiments showed that the magnetic properties of the thin films are very similar to bulk samples. Thus the thin films samples are suitable for the investigation of intrinsic properties of UNi_2Al_3 . By photolithographic patterning of these thin films well defined geometries for the investigation of transport anisotropies are obtained. Directional dependent measurements of the resistivity $R(T)$ give evidence for multiband superconductivity and strongly anisotropic coupling of the itinerant charge carriers to the magnetic order. The temperature dependence of the upper critical field provides an indication of a superconducting spin singlet state in UNi_2Al_3 .

The primary objective of this ongoing project is the direct investigation of the superconducting order parameter and coupling mechanism of UNi_2Al_3 . The optimization of the barrier properties of planar UNi_2Al_3 – AlO_x –Pb,In,Ag junctions is in progress.

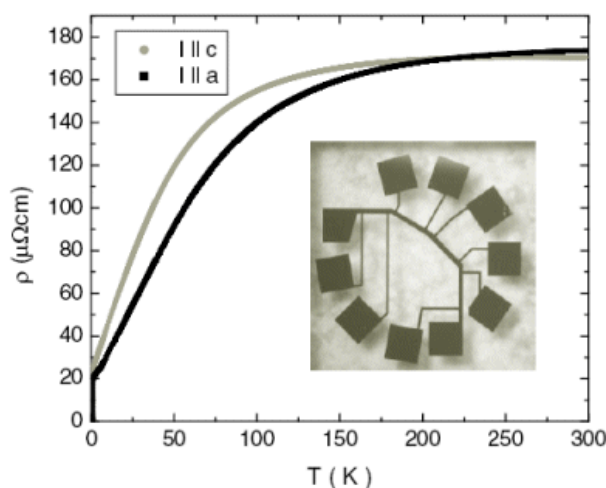


FIG. 2. Specific resistivity $\rho(T)$ of an UNi_2Al_3 thin film for different current directions (black squares: $I \parallel a$; gray dots: $I \parallel c$). Inset: Photograph of a patterned UNi_2Al_3 film ($4 \times 4 \text{ mm}^2$). For $R(T)$ measurements a current is sent through the central conductor path (width $d = 100 \mu\text{m}$), and the thin strips are voltage probes (4-point dc method).

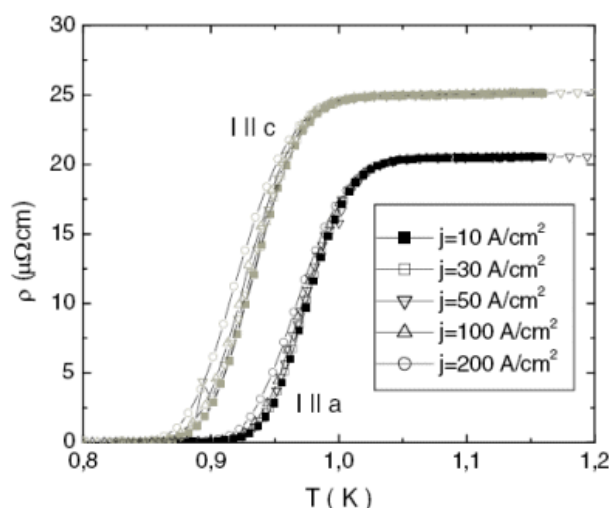
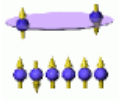


FIG. 3. Superconducting resistive transitions of an UNi_2Al_3 thin film for different current directions (black symbols: $I \parallel a$; gray symbols: $I \parallel c$). Measurements with different current densities are shown to demonstrate that the probe current does not influence the T_c values (for $j \approx 10 \text{ A/cm}^2$).



For details please see M. Jourdan et. al. Phys. Rev. Lett. 93, 097001 (2004).

Publications:

Transport anisotropy and $B_{c2}(\Theta, T)$ of UNi_2Al_3 thin films

A. Zakharov, M. Jourdan, M. Foerster and H. Adrian,
Physica B 359, 1108 (2005)

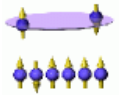
Preparation of superconducting thin films of UNi_2Al_3

M. Jourdan, A. Zakharov, H. Schneider and H. Adrian,
PhysicaB 359, 1153 (2005)

Evidence for multiband superconductivity in the heavy fermion compound UNi_2Al_3

M. Jourdan, A. Zakharov, M. Foerster and H. Adrian,
Phys. Rev. Lett. 93, 097001 (2004)

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Thin films of Heusler compounds with high spin polarization

H. Schneider, S. Falk, A. Conca, M. Jourdan, A. Raih, V. Beaumont, F. Casper, G. Jakob, H. Adrian
Institute of Physics, University of Mainz

Funding: DFG Project Ja821/2–1, MWFZ Mainz

Materials with high spin polarisation are of utmost importance both for spin electronics as for basic research. Thin film films are needed in order to realize applications. They also allow the measurement of physical properties which are hardly accessible in the bulk material. In case of an epitaxial growth on a single crystalline substrate it is possible to determine the magnetic moments and the magnetocrystalline anisotropies as function of film thickness.

In this project we realised thin films of the Heusler compound $\text{Co}_2\text{Cr}_{1-x}\text{Fe}_x\text{Al}$ and related materials. We used pulsed laser deposition and cathode sputtering for film deposition. The degree of atomic order on the 4 different positions in the unit cell is essential for the spin polarization of the material. We succeeded to grow films epitaxial on a-plane Al_2O_3 substrates. An in-situ covering of the surface with a protective layer is essential in order to prevent selective Cr oxidation. Films grown at high temperatures ($T > 600^\circ\text{C}$) on Al_2O_3 are fully epitaxial with the (110) and (110) planes of the film parallel to the (11-20) and (0001) planes of the substrate, respectively. These epitaxial films possess a higher surface roughness than films grown at room temperature. The films show nearly rectangular hysteresis loops with coercive fields of the order of 10 mT. Magneto-optical Kerr measurements show an in-plane anisotropy of the magnetization with the easy axis in (001) direction. Hall measurements show a strong anomalous Hall effect and a weak normal Hall voltage signalling the existence of a compensated Fermi surface.

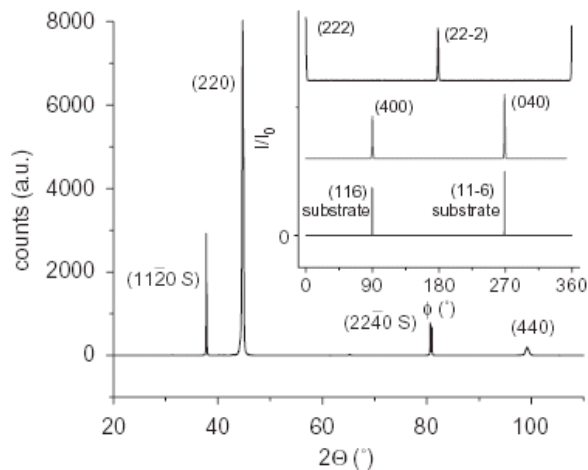


Fig.1: Diffraction pattern of a (110) oriented Heusler film. The inset shows Φ -scans of substrate and film peaks.

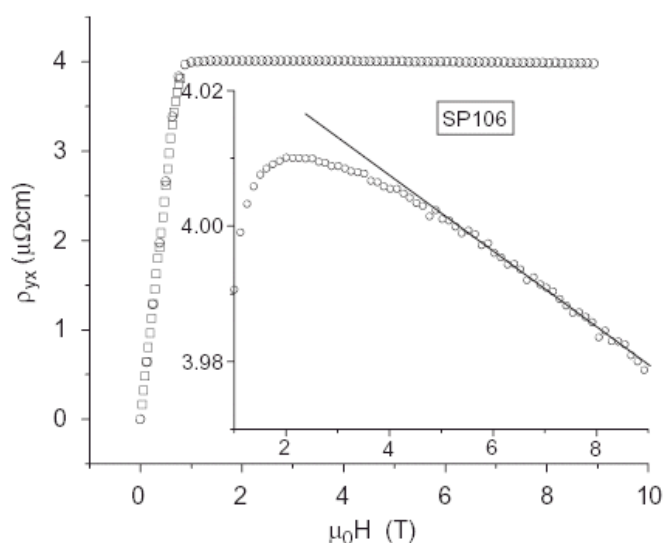
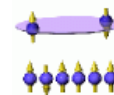


Fig.2: Hall resistivity vs. magnetic field measured at 65 K. The small value of the Hall coefficient is not compatible with a Fermi surface dominated by a single band.

Publications:

Element specific magnetic moments from core-absorption magnetic circular dichroism of the doped Heusler alloy $\text{Co}_2\text{Cr}_{0.6}\text{Fe}_{0.4}\text{Al}$

H.J. Elmers, G. Fecher, D. Valdaitsev, S. Nepijko, A. Gloskowskij, G. Jakob, G. Schönhense, S. Wurmehl, T. Block, C. Felser, P.-C. Hsu, W.-L. Tsai, and S. Cramm
Phys. Rev. B **67**, 104412 (2003)

Large Negative Magnetoresistance Effect in a Heusler Compound at Room Temperature

T. Block, C. Felser, G. Jakob, J. Ensling, B. Mühlning, P. Gütllich, and R. J. Cava
J. Solid State Chem. **176**, 646 (2003)

Investigation of a novel material for magnetoelectronics: $\text{Co}_2\text{Cr}_{0.6}\text{Fe}_{0.4}\text{Al}$

C. Felser, B. Heitkamp, F. Kronast, D. Schmitz, S. Cramm, H.A. Dürr, H.-J. Elmers, G.H. Fecher, S. Wurmehl, T. Block, D. Valdaitsev, S.A. Nepijko, A. Gloskovskii, G. Jakob, G. Schönhense, and W. Eberhardt
J. Phys.: Condens. Matter **15**, 7019 (2003)

Enhanced orbital magnetic moments in the Heusler compounds Co_2CrAl ; $\text{Co}_2\text{Cr}_{0.6}\text{Fe}_{0.4}\text{Al}$; Co_2FeAl

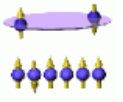
H.J. Elmers, S. Wurmehl, G. Fecher, G. Jakob, C. Felser, and G. Schönhense
J. Magn. Magn. Mater. **272-276**, 758 (2004)

Field dependence of orbital magnetic moments in the Heusler compounds $\text{Co}_2\text{Cr}_{0.6}\text{Fe}_{0.4}\text{Al}$ and Co_2FeAl

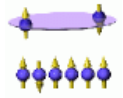
H.J. Elmers, S. Wurmehl, G. Fecher, G. Jakob, C. Felser, and G. Schönhense
Appl. Phys. A **79**, 557 (2004)

Thin epitaxial films of the Heusler compound $\text{Co}_2\text{Cr}_{0.6}\text{Fe}_{0.4}\text{Al}$

G. Jakob, F. Casper, V. Beaumont, S. Falk, H.J. Elmers, C. Felser, and H. Adrian
accepted for publication in J. Mag. Mag. Mat. (2004)



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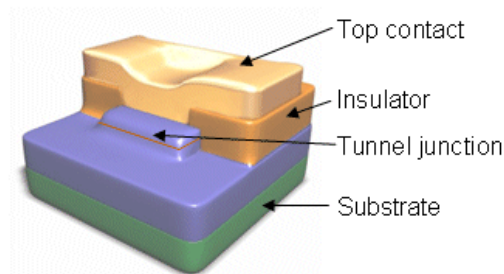
Magnetic sensor elements based on materials with large spin polarization

M. Jourdan, A. Conca, C. Herbort, A. Gerken and H. Adrian
Institute of Physics, University of Mainz

Funding: Stiftung Rheinland–Pfalz für Innovation

Magnetoresistive sensor elements, i. e. devices with a resistivity which depends on the magnetic field, are very important for various applications like Hard Disc read heads, memory cells, position and rotations frequency sensors in automotive industry and mechanical engineering, etc. The size of the magnetoresistivity effect of Spin Valves or Magnetic Tunneling Junctions (MTJs) depends on the spin polarization of the itinerant charge carriers of the ferromagnetic electrodes.

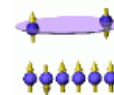
In a new project we started to investigate planar tunneling junctions with Heusler–electrode. The thin films of these materials are prepared by sputter deposition.



Publications:

Magnetic tunnelling junctions with the Heusler compound $\text{Co}_2\text{Cr}_{0.6}\text{Fe}_{0.4}\text{Al}$
A. Conca, S. Falk, G. Jakob, M. Jourdan, and H. Adrian,
Journ. Magn. Mag. Mat. 290, 1127 (2005)

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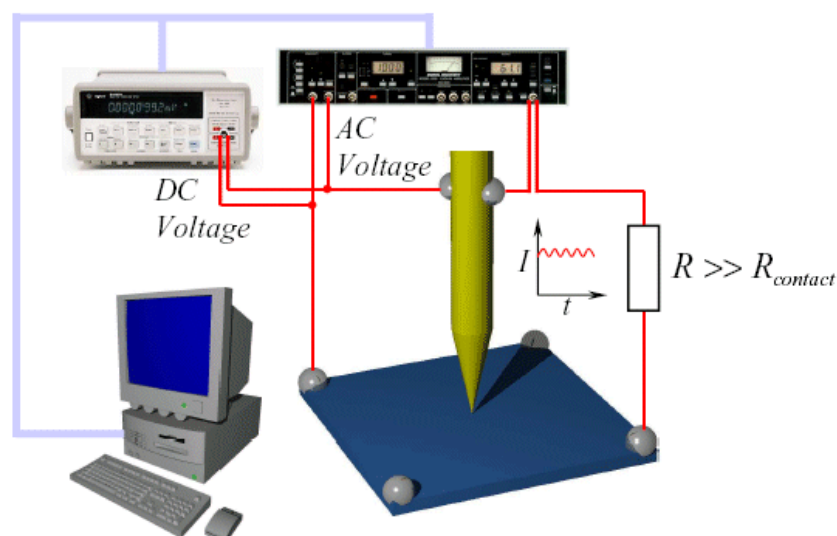
Investigating the spin polarization by Andreev reflection

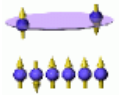
N. Auth, G. Jakob, H. Adrian
Institute of Physics, University of Mainz

Funding: BMBF within the center for Multifunctional Materials and Miniaturized Devices, MWFZ Mainz

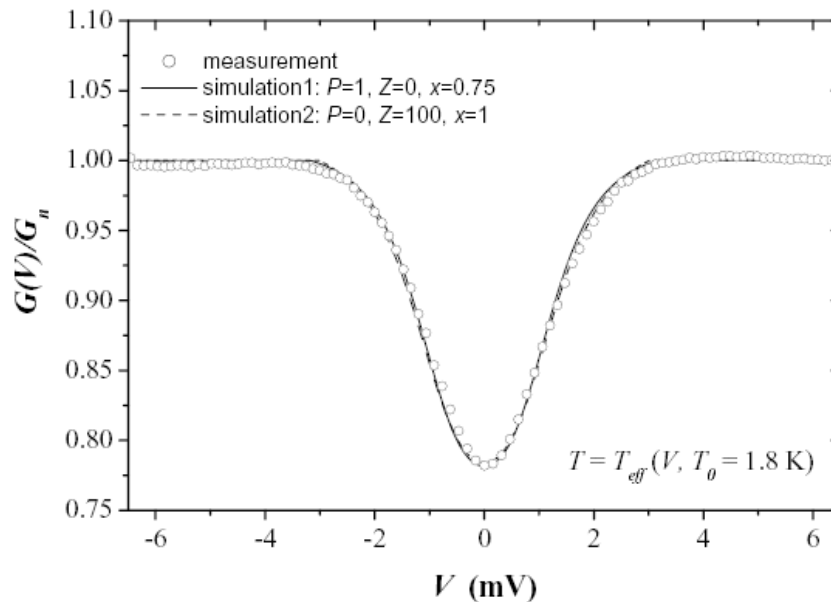
An important task in the investigation of potential half-metallic materials is the experimental validation of a high spin polarisation value. To date a variety of methods have become available, but many still have to give proof of their experimental feasibility. Amongst them the analysis of the Andreev reflection process in point contact junctions (PCAR) has attracted much interest. This effect exploits the coherent charge transport between a normal metal and a superconductor. In this project we investigated the physical limitations of this method and clarified the influence of specific resistivity on the resulting spin polarisation in highly resistive probe materials.

In order to investigate the transport spin polarisation, point contacts between a superconducting tip and a ferromagnetic material were realised. The observed dI/dV anomalies, commonly attributed solely to coherent transport, have been analysed in a generalised framework where a possible contribution of thermal transport is considered. For the first time the implications of this scenario, especially concerning the determination of P , have been critically discussed. It has been shown that for the highly resistive material $\text{Sr}_2\text{FeMoO}_6$ the spectra are most likely dominated by thermal transport. In this case it is impossible to decide whether the observed dI/dV characteristics are caused by a fraction of coherent transport exhibiting the effect of Andreev reflection suppression or just the result of a strongly broadened spectrum dominated by electron tunnelling at the effective barrier Z . This result suggests that the same problem will be encountered for any material in the resistivity range of $500 \mu\Omega\text{cm}$ or above and constitutes the upper limit where the PCAR method can be applied. For $\text{Co}_2\text{Cr}_{0.6}\text{Fe}_{0.4}\text{Al}$, representing materials with a specific resistivity in the range of $100 \mu\Omega\text{cm}$, the dI/dV anomalies can be clearly attributed to coherent transport. Here the ballistic and diffusive model yield comparable descriptions of the data but the different simulations again lead to incompatible values of the transport spin polarisation. To justify the use of one specific approach further studies are needed, especially with respect to mean free path of the charge carriers and the influence of surface effects, but this is not a principle problem as in the case of $\text{Sr}_2\text{FeMoO}_6$.





Point contact Andreev reflection measurement setup. The measurements are current driven with a modulated input from the lock-in amplifier. The AC output voltage of the junction is analysed by the lock-in amplifier and a nano-voltmeter is used to record the DC contribution. This allows to determine the I-V characteristics of the junction and its conductance independently and with highest possible accuracy.

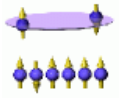


Experimental data of energy resolved differential conductivity at $T=1.8$ K. The lines are fits with the diffusive transport model that has been extended by the introduction of an effective temperature T_{eff} . The critical temperature $T_{\text{eff}} = T_c$ is reached for a voltage of 3.2 mV (3.7 mV) in simulation 1 (simulation 2), i.e. outside the region of nonlinear response.

Publications:

Investigating the spin polarisation of magnetoresistive materials by point contact spectroscopy
N. Auth, G. Jakob, T. Block, and C. Felser
Phys. Rev. B **68**, 024403 (2003)

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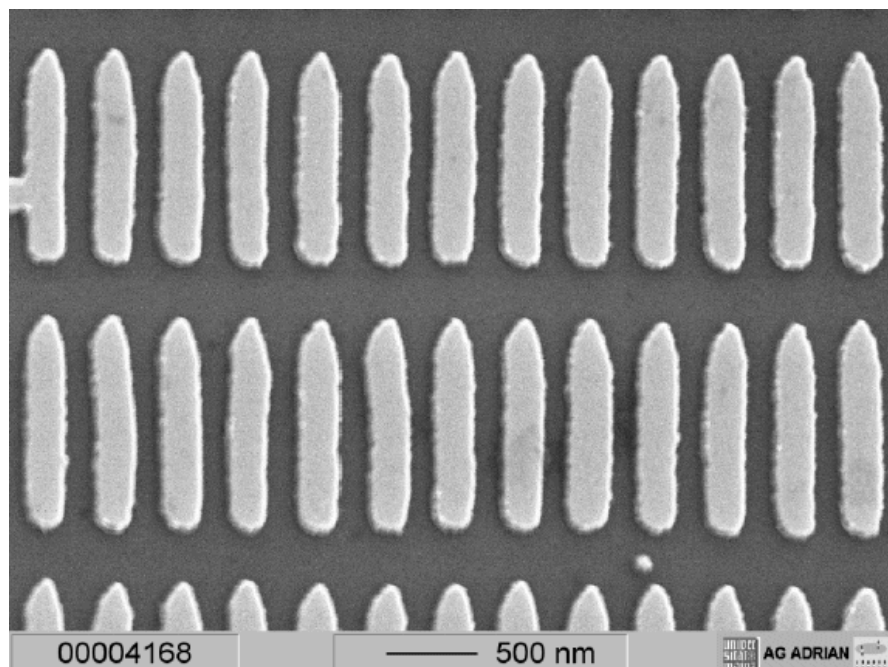
Nanopatterning of thin film structures

N. Auth, M. Gacic, G. Jakob, H.J. Elmers, H. Adrian
Institute of Physics, University of Mainz

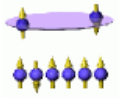
Funding: BMBF within the center for Multifunctional Materials and Miniaturized Devices, MWFZ Mainz

Aiming at the possibility to study new materials in a device-oriented setup of technical relevance, the group's patterning facilities were extended. During the course of this project an electron beam lithography (EBL) and a focussed ion beam (FIB) system specified for achieving sub-micrometer structures were put into operation and fully characterised. The issue of general and system specific resolution limits have been addressed on several examples of patterned magnetic media and the required process chains for nanopatterning have been established.

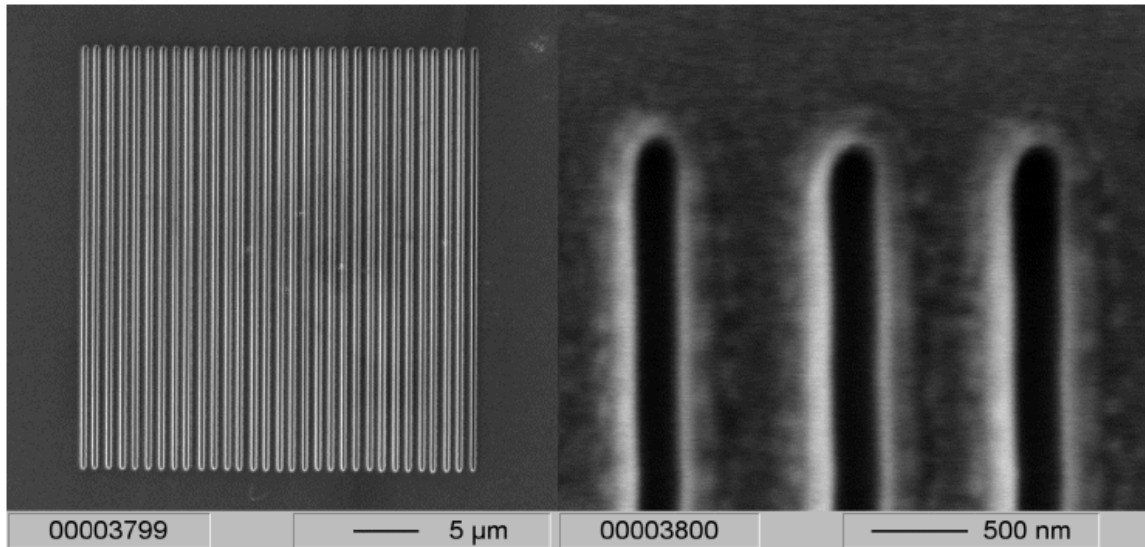
Arrays of identical permalloy lines and circular dots were fabricated on silicon (100) substrates by lift-off. The template resist structures were patterned by electron beam lithography. While the permalloy layer of line arrays was deposited by thermal evaporation, the dots were made by sputtering. For the purpose of lift-off structures the sputtering technique has a grave disadvantage. Due to the necessary argon background pressure of about 0.1mbar the deposited material reaches the substrate with a large spread of incident angles. As a result the typical undercut profile of the PMMA 950k is not sufficient to obtain free standing structures, which are vital for a clean liftoff. Therefore the dots were defined in a double layer resist system consisting of PMMA 950k on top of a copolymer with higher sensitivity. The magnetization curves of the shapes in the figure below depend strongly on the direction of the magnetic field.



Section of an array of permalloy structures for studying the magnetic behaviour depending on variations of size and spacings.

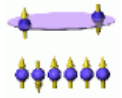


In addition to electron beam lithography a material patterning by focussed ion beam (FIB) system was investigated. As one of a few techniques FIB allows the direct fabrication of nanometre scale structures by ablating material from the exposed areas. Positively charged Gallium ions are extracted from a field emission tip which is covered by the liquid metal. Accelerated to several kilovolts and focussed into a beam with diameter down to a few nanometres the Ga^+ ions can be used to sputter material from the surface of a target.



SEM micrographs of a FIB etched line array at two different magnifications. The 200 nm wide lines have been written in a Fe/Mo film on Si substrate. The structure size is close to the resolution limit.

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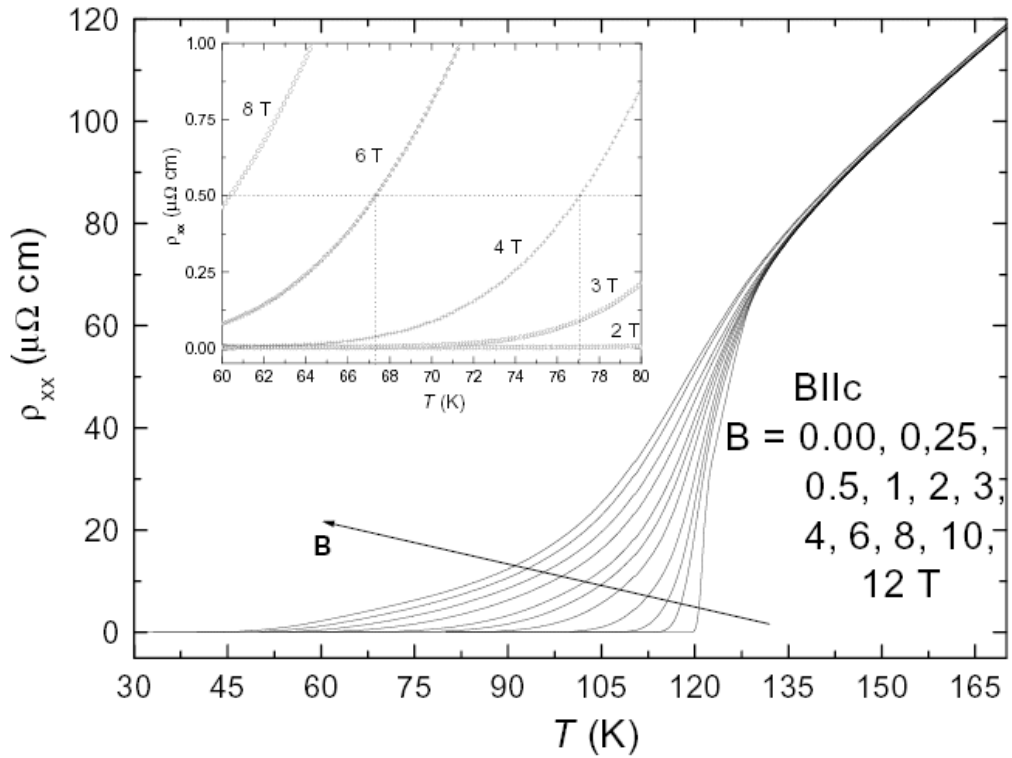
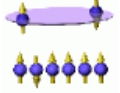
Mercury based high- T_c - superconducting films

A. Salem, G. Jakob, and H. Adrian

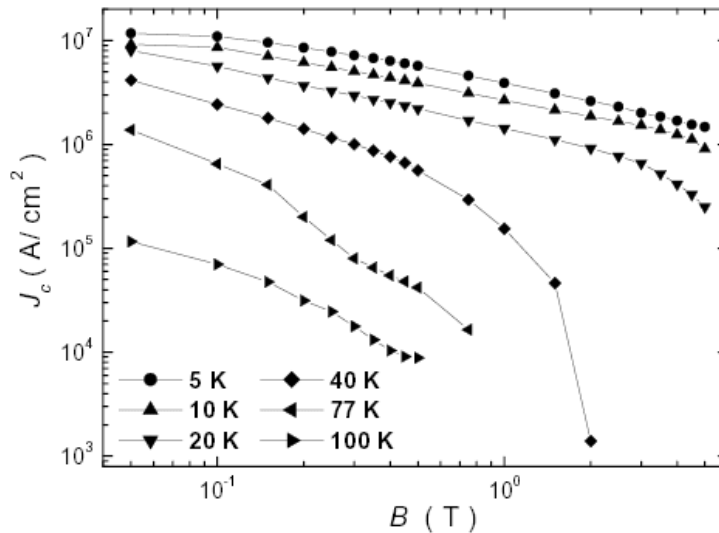
Institute of Physics, University of Mainz

Funding: Government of Egypt, MWFZ, Kompetenzzentrum elektronische Eigenschaften

Mercury superconductors possess excellent superconducting properties, even above 77 K. This project studies the preparation, characterization, and electronic properties of thin films of the high-temperature superconductor $\text{HgBa}_2\text{Ca}_{n-1}\text{Cu}_n\text{O}_{2n+2+\delta}$. The main goal of this project was to achieve a reliable technology for reproducible high quality thin film preparation by understanding the film growth mechanism, the phase formation, and the influence of different synthesis routes with cationic substitutions. Fully textured $(\text{Hg}_{0.9}\text{Re}_{0.1})\text{Ba}_2\text{CaCu}_2\text{O}_{6+\delta}$ HTSC thin films were successfully prepared by pulsed laser deposition (PLD) of a precursor on (100)- oriented SrTiO_3 substrates and then followed by annealing in controlled mercury vapor. The films exhibit sharp superconducting transitions at $T_c = 124$ K with transition width ΔT_c of 2 K. The resistive transitions and the activation energy of thermally activated flux-motion have been investigated in magnetic fields up to 12 T parallel and perpendicular to the c -axis. The irreversibility line for the $(\text{Hg}_{0.9}\text{Re}_{0.1})\text{Ba}_2\text{CaCu}_2\text{O}_{6+\delta}$ thin films has been deduced from the electrical resistance measurements. At different temperatures magnetization loops were measured with a magnetic field applied normal to the film in a SQUID magnetometer and the corresponding critical current densities J_c were calculated. Under variation of the angle Θ between the field direction and the c -axis of the film the anisotropic properties of the vortex state and the depinning field $B_{dp}(\Theta)$ have been studied. The films exhibit a rather low critical field anisotropy of 7.7. The angular dependence $B_{dp}(\Theta)$ close to T_c resembles the functional form expected for an anisotropic vortex flux liquid, which consists of pancake vortices and in-plane vortex segments. This way of determining the anisotropy yields an effective anisotropy of the material relevant for estimations of the useful range in the T - B - μ phase space of the material. The Hall resistivity ρ_{xy} of thin films has been measured in the ab -plane at fields up to 12 T. In the mixed state a power-law behavior is observed, where ρ_{xy} scales as a power-law $\rho_{xy} = \rho_{xy}^{\beta}$, with $\beta = 1.4$. Above 130 K the T^2 dependence of the cotangent of the Hall angle is observed. The total Hall conductivity for these compounds is well described by $\rho_{xy}(B) = C_1/B + C_2B + C_3$.

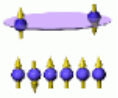


Temperature dependence of the electrical resistivity for a $(\text{Hg}_{0.9}\text{Re}_{0.1})\text{Ba}_2\text{CaCu}_2\text{O}_{6+\delta}$ film in various magnetic fields up to 12 T oriented parallel to the c -axis. In the inset the resistivity axis is magnified for the determination of the irreversibility temperature $T_{\text{irr}}(B)$.



The critical current density J_c as a function of the applied magnetic fields and temperatures for a $(\text{Hg}_{0.9}\text{Re}_{0.1})\text{Ba}_2\text{CaCu}_2\text{O}_{6+\delta}$ thin film. All lines are guides for the eye.

Publications:



Resistivity and irreversibility line of $Hg_{0.9}Re_{0.1}Ba_2CaCu_2O_{6+\delta}$ HTS thin films

A. Salem, G. Jakob, M. Basset, and H. Adrian
Physica C **388–389**, 747 (2003))

Preparation, scaling behavior of activation energy, and flux–flow anisotropy of $(Hg_{0.9}Re_{0.1})Ba_2CaCu_2O_{6+\delta}$ HTS thin films

A. Salem, G. Jakob, and H. Adrian
Physica C **402**, 354, (2004)

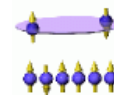
Superconductivity in high–quality $(Hg_{0.9}Re_{0.1})Ba_2CaCu_2O_{6+\delta}$ HTS thin films

A. Salem, G. Jakob, and H. Adrian
Phys. Stat. Sol. (c) **1**, 1961, (2004)

Normal and mixed state Hall effect in $Hg_{0.9}Re_{0.1}Ba_2CaCu_2O_{6+\delta}$ fully textured HTS's thin films

A. Salem, G. Jakob and H. Adrian
Physica C **415**, 62 (2004)

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Perpendicular transport of $\text{YBa}_2\text{Cu}_3\text{O}_7/\text{PrBa}_2\text{Cu}_3\text{O}_7$ superlattices

H. Rodriguez and H. Adrian

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 superconducting 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.

$\text{YBa}_2\text{Cu}_3\text{O}_7/\text{PrBa}_2\text{Cu}_3\text{O}_7$ 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 photolithography and ion milling into Mesas between $16 \times 16 \text{mm}^2$ and $30 \times 30 \text{mm}^2$ area and 150nm height.

We have measured the differential conductivity using the lock–in technique on $(\text{YBa}_2\text{Cu}_3\text{O}_7)_4/(\text{PrBa}_2\text{Cu}_3\text{O}_7)_{16}$ superlattices (fig (1)). At low temperature we observe a tunnel characteristic–like curve with maxima at $\pm 46 \text{mV}$. 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 $(\text{YBa}_2\text{Cu}_3\text{O}_7)_2/(\text{PrBa}_2\text{Cu}_3\text{O}_7)_{16}$ 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)

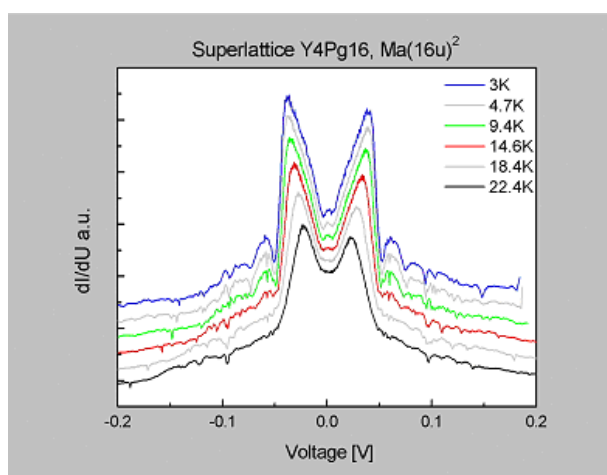


Fig. 1 differential conductance vs bias voltage for a 4:16 superlattice for different temperatures. The 46mV maximum corresponds to a stack of nine junctions

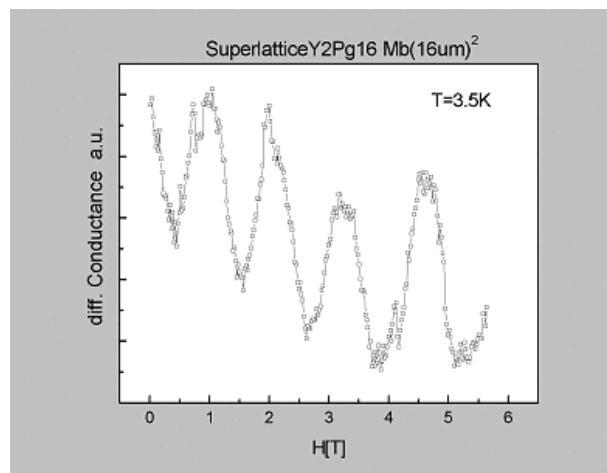
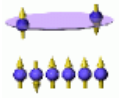


Fig. 2 zero bias differential conductance vs magnetic field for a 2:16 superlattice. A modulation of approx. 1T was observed.

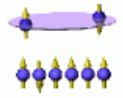
In cooperation with the University of Hamburg Raman scattering was used as an additional probe for the electronic structure in superlattices. This allowed us to identify the proximity effect of the superconducting order parameter into the antiferromagnetic barrier as signified, e.g., by the sharpening of the two-magnon excitation. This proximity effect as well as gap feature and phonon anomalies reveals the delicate interplay between superconducting and antiferromagnetic order parameters.

Publications:

Antiferromagnetic and superconducting proximity effects in $YBa_2Cu_3O_7/PrBa_2Cu_3O_7$ superlattices

D. Budelmann, J. Holmlund, J. Andreasson, H. Rodriguez, J. Bäckström, L. Börjesson, H. Adrian, U. Merkt, and M. Rübhausen
 Phys. Rev. B **67**, 140507R (2003)

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Preparation and characterisation of Sr₂FeMoO₆ thin films

N. Auth, D. Sanchez*, G. Jakob, H. Adrian
Institute of Physics, University of Mainz

Funding: DFG Project Ja821/1–3, MWFZ Mainz and *Institut Ciencia de Materiales, Madrid

In continuation of our previous studies on perovskite manganites we investigated the double-perovskite compound Sr₂FeMoO₆ (SFMO). The high Curie temperature $T_c = 420\text{K}$, the observation of room temperature magnetoresistance in polycrystalline samples and the prediction of 100% spin polarisation 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.

A careful study, involving samples on different types of substrates, allowed us to get a close insight into the complex mechanisms of charge transport and magnetoresistance in this material. The temperature dependence of resistivity in films with high epitaxial quality and well ordered cation sublattice can be reproduced by small-polaron transport. Deviations, which occur for temperatures below 50 K, are attributed to the small but non-zero structural disorder. However, it was shown that quantum corrections due to Coulomb interaction and dephasing cannot play an important role here.

In a detailed analysis of the field dependent magnetoresistance intra- and intergrain contributions have been identified in the low temperature regime. We arrive at the conclusion that grain boundaries are effectively contributing to the LFMR in this system but their influence is outweighed by disorder induced LFMR in the epitaxial samples.

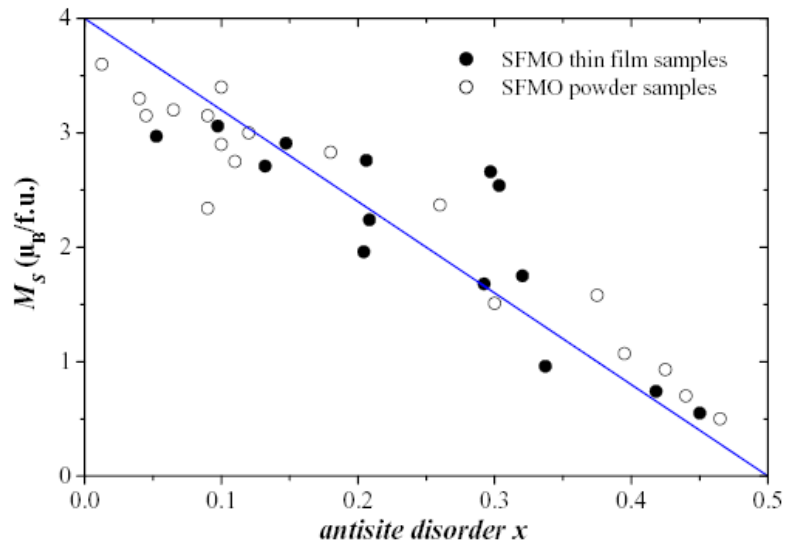
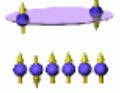


Fig 1: Fe/Mo antisite disorder determines the saturation magnetization.

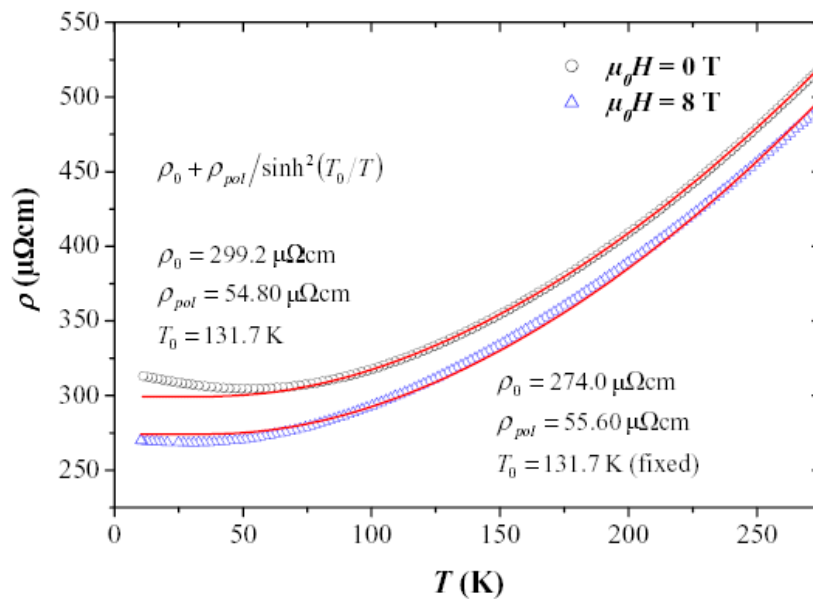
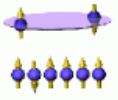


Fig 2: Analysis of the temperature dependence of the electrical resistivity with a model of small-polaron transport.

Publications:

Crystal structure and magnetism of the double perovskites $A_2\text{FeReO}_6$ ($A=\text{Ca}, \text{Sr}, \text{Ba}$)
 N. Auth, G. Jakob, W. Westerburg, C. Ritter, I. Bonn, C. Felser, W. Tremel
 J. Magn. Magn. Mater. 272–276, e607 (2004)



Structural, magnetic and transport properties of high quality epitaxial Sr_2FeMoO_6 thin films prepared by pulsed laser deposition

D. Sánchez, N. Auth, G. Jakob and M. García-Hernández
J. Appl. Phys. **96**, 2736 (2004)

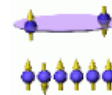
Picosecond energy relaxation in $La_{0.67}Ca_{0.33}MnO_3$

V. Dorosinets, P. Richter, E. Mohler, H.G. Roskos, and G. Jakob
accepted for publication in Physica B (2004)

Pulsed laser deposition of Sr_2FeMoO_6 thin films

D. Sánchez, N. Auth, G. Jakob, J.L. Martínez and M. García-Hernández
accepted for publication in J. Mag. Mat. (2004)

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Publications (2003–2004) of the AG Adrian, KOMET 333–0

Resistivity and irreversibility line of $Hg_{0.9}Re_{0.1}Ba_2CaCu_2O_{6+\delta}$ HTS thin films

A. Salem, G. Jakob, M. Basset, and H. Adrian
 Physica C **388–389**, 747 (2003))

Element specific magnetic moments from core–absorption magnetic circular dichroism of the doped Heusler alloy $Co_2Cr_{0.6}Fe_{0.4}Al$

H.J. Elmers, G. Fecher, D. Valdaitsev, S. Nepijko, A. Gloskowskij, G. Jakob, G. Schönhense, S. Wurmehl, T. Block, C. Felser, P.–C. Hsu, W.–L. Tsai, and S. Cramm
 Phys. Rev. B **67**, 104412 (2003)

Investigating the spin polarisation of magnetoresistive materials by point contact spectroscopy

N. Auth, G. Jakob, T. Block, and C. Felser
 Phys. Rev. B **68**, 024403 (2003)

Antiferromagnetic and superconducting proximity effects in $YBa_2Cu_3O_7/PrBa_2Cu_3O_7$ superlattices

D. Budelmann, J. Holmlund, J. Andreasson, H. Rodriguez, J. Bäckström, L. Börjesson, H. Adrian, U. Merkt, and M. Rübhausen
 Phys. Rev. B **67**, 140507R (2003)

Guided vortex motion in Nb films on faceted substrate surfaces

O. Soroka, M. Huth, V.A. Shklovskij, J. Oster, H. Adrian
 Physica C **388–389**, 733 (2003)

Large Negative Magnetoresistance Effect in a Heusler Compound at Room Temperature

T. Block, C. Felser, G. Jakob, J. Ensling, B. Mühling, P. Gütlich, and R. J. Cava
 J. Solid State Chem. **176**, 646 (2003)

Investigation of a novel material for magnetoelectronics: $Co_2Cr_{0.6}Fe_{0.4}Al$

C. Felser, B. Heitkamp, F. Kronast, D. Schmitz, S. Cramm, H.A. Dürr, H.–J. Elmers, G.H. Fecher, S. Wurmehl, T. Block, D. Valdaitsev, S.A. Nepijko, A. Gloskovskii, G. Jakob, G. Schönhense, and W. Eberhardt
 J. Phys.: Condens. Matter **15**, 7019 (2003)

Shift of the surface barrier part of the irreversibility line due to columnar defects in $Bi_2Sr_2CaCu_2O_8$ thin films

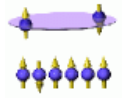
Yu. Talanov, H. Adrian, M. Basset, G. Jakob, and G. Wirth
 Physica C **402**, 114 (2004)

Enhanced orbital magnetic moments in the Heusler compounds Co_2CrAl ; $Co_2Cr_{0.6}Fe_{0.4}Al$; Co_2FeAl

H.J. Elmers, S. Wurmehl, G. Fecher, G. Jakob, C. Felser, and G. Schönhense
 J. Magn. Magn. Mater. **272–276**, 758 (2004)

Crystal structure and magnetism of the double perovskites A_2FeReO_6 ($A=Ca, Sr, Ba$)

N. Auth, G. Jakob, W. Westerburg, C. Ritter, I. Bonn, C. Felser, W. Tremel
 J. Magn. Magn. Mater. **272–276**, e607 (2004)



Preparation, scaling behavior of activation energy, and flux–flow anisotropy of (Hg_{0.9}Re_{0.1})Ba₂CaCu₂O_{6+δ} HTS thin films

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A. Salem, G. Jakob, and H. Adrian
Phys. Stat. Sol. (c) **1**, 1961, (2004)

Structural, magnetic and transport properties of high quality epitaxial Sr₂FeMoO₆ thin films prepared by pulsed laser deposition

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J. Appl. Phys. **96**, 2736 (2004)

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A. Salem, G. Jakob and H. Adrian
Physica C **415**, 62 (2004)

Field dependence of orbital magnetic moments in the Heusler compounds Co₂Cr_{0.6}Fe_{0.4}Al and Co₂FeAl

H.J. Elmers, S. Wurmehl, G. Fecher, G. Jakob, C. Felser, and G. Schönhense
Appl. Phys. A **79**, 557 (2004)

Picosecond energy relaxation in La_{0.67}Ca_{0.33}MnO₃

V. Dorosinets, P. Richter, E. Mohler, H.G. Roskos, and G. Jakob
accepted for publication in Physica B (2004)

Thin epitaxial films of the Heusler compound Co₂Cr_{0.6}Fe_{0.4}Al

G. Jakob, F. Casper, V. Beaumont, S. Falk, H.J. Elmers, C. Felser, and H. Adrian
accepted for publication in J. Mag. Mag. Mat. (2004)

Magnetic tunnelling junctions with the Heusler compound Co₂Cr_{0.6}Fe_{0.4}Al

A. Conca, S. Falk, G. Jakob, M. Jourdan, and H. Adrian
accepted for publication in J. Mag. Mag. Mat. (2004)

Ultrafast optical and magneto–optical dynamics in colossal–magnetoresistance (CMR) manganites

V. Dorosinets, P. Richter, G. Jakob, and H.G. Roskos
accepted for publication in Acta Phys. Pol. (2004)

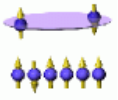
Pulsed laser deposition of Sr₂FeMoO₆ thin films

D. Sánchez, N. Auth, G. Jakob, J.L. Martínez and M. García–Hernández
accepted for publication in J. Mag. Mag. Mat. (2004)

Magnetic order in thin films of the heavy fermion superconductor UNi₂Al₃

M. Jourdan, A. Zakharov, A. Hiess, T. Charlton, N. Bernhoeft, and D. Mannix,
submitted to Eur. Phys. Journ. B

Publications:



Extremely slow Drude relaxation of correlated electrons

M. Scheffler, M. Dressel, M. Jourdan, and H. Adrian,
accepted for publication, Nature (2005)

Transport anisotropy and $B_{c2}(\Theta, T)$ of UNi_2Al_3 thin films

A. Zakharov, M. Jourdan, M. Foerster and H. Adrian,
Physica B **359**, 1108 (2005)

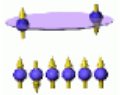
Preparation of superconducting thin films of UNi_2Al_3

M. Jourdan, A. Zakharov, H. Schneider and H. Adrian,
PhysicaB **359**, 1153 (2005)

Evidence for multiband superconductivity in the heavy fermion compound UNi_2Al_3

M. Jourdan, A. Zakharov, M. Foerster and H. Adrian,
Phys. Rev. Lett. **93**, 097001 (2004)

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Diploma theses (2003–2004) of the AG Adrian, KOMET 333–0

Kopplungseffekte und Formanisotropie in magnetischen Nanostrukturen hergestellt durch Elektronenstrahlithographie

Milan Gacic, (November 2004)

Supraleitung von $CePt_3Si$ und UNi_2Al_3 : Oberes kritisches Feld und Tunnelspektroskopie

Horst Schneider, (xxxx 2004)

Tunelmagnetowiderstandselemente auf Basis von $Co_2Cr_{0.6}Fe_{0.4}Al$ -Schichten

Stefan Falk, (September 2004)

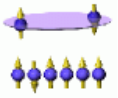
Versuchsaufbau zur Geometrischen Optik unter dem besonderen Gesichtspunkt der Didaktik für Medizinstudenten

Melanie Tiator (March 2004, Staatsexamen)

Supraleitende dünne Schichten der Schwere-Fermionen Verbindung UNi_2Al_3

Michael Förster, (December 2003)

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Ph.D. theses (2003–2004) of the AG Adrian, KOMET 333–0

Präparation, Charakterisierung und elektronische Eigenschaften von dünnen Schichten des Hochtemperatursupraleiters $\text{HgReBa}_2\text{Ca}_{n-1}\text{Cu}_n\text{O}_y$
Abouelwafa Salem, (December 2004)

Vortex dynamics in superconductors in the presence of anisotropic pinning
Oleksiy K. Soroka, (November 2004)

Electronic transport properties of $\text{YBa}_2\text{Cu}_3\text{O}_{7-x}/\text{PrBa}_2\text{Cu}_{2.9}\text{Ga}_{0.1}\text{O}_{7-y}$ trilayers and superlattices perpendicular to the layer structure
Hernan Rodriguez, (Juli 2004)

Magnetic properties of selected 3d- and 4f- systems on $\alpha\text{-Al}_2\text{O}_3$ substrates
Jens Oster, (December 2003)

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