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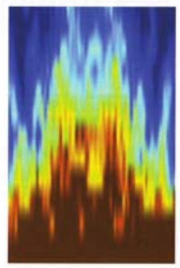
TOP PAPERS 2005 SHOWCASE



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## PAPERS



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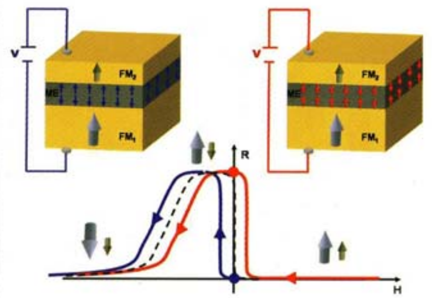
## Magnetoelectronics with magnetoelectrics

Magnetoelectronics with magnetoelectrics
Ch Binek and B Doudin
J. Phys.: Condens. Matter
17 (2005) L39–L44




*Schematics of the magnetoresistance curve of a TMR device involving an ME film as a tunnel barrier. Half-hysteresis curves are shown, after saturation at positive field values. The arrows denote the magnetization directions, with the bottom layer FM1 being harder (or pinned) than the top one FM2. The dashed curve is the expected TMR behaviour. The change of voltage polarity changes the direction of the net magnetization of the ME layer, adding an exchange bias magnetic field to the resistance curve. The two colours indicate shifting of half-hysteresis curves towards positive or negative fields, depending on the polarity of the applied voltage. At zero magnetic field, the change of voltage polarity changes the resistance value of the device (dots).*

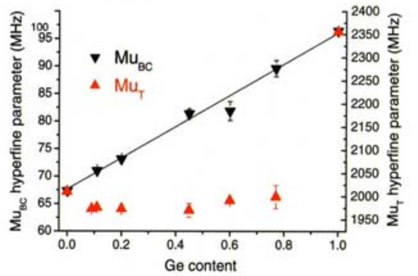
Applications of spintronics such as magnetic read-heads and sensors use giant magnetoresistance (GMR) and tunnel magnetoresistance (TMR) effects. The next generation of spintronics devices should combine memory and logical functions.

Ch Binek and B Doudin from University of Nebraska propose combining a GMR or TMR device with a magnetoelectric (ME) film. They propose an antiferromagnetic ME thin film as a dielectric tunnel junction between two ferromagnetic metallic layers. A tunnel barrier is the ideal system for sustaining very high electric fields, so they expect a significant net magnetization to occur in an ME barrier. The device exploits the exchange field between the magnetized ME layer and the two adjacent ferromagnetic films. This creates a shift of the magnetization curves of both ferromagnetic layers proportional to the magnetization in the ME layer, or the applied voltage in the device. The figure shows a TMR device made of a soft magnetic layer FM2 and a hard bottom layer FM1. An exchange field value of the order of the saturation field of the soft magnetic layer will provide control of the magnetization direction of the soft layer, allowing the resistance state of the device to be set by the electric field in the ME film. They also proposed a similar device based on spin valves used in GMR systems.

Pure electrical control of magnetic configurations of giant magnetoresistance spin valves and tunnelling magnetoresistance elements is achievable. Estimates based on documented ME tensor values show that exchange fields reaching 100 mT can be obtained. They propose a mechanism alternative to current-induced magnetization switching, providing access to a wide range of device impedance values and opening the possibility of simple logic functions.

## Muonium observations of SiGe alloys

Characterization of hydrogen-like states in bulk $Si_{1-x}Ge_x$ alloys through muonium observations
P J C King, R L Lichti, S P Cottrell, I Yonenaga and B Hitti
J. Phys.: Condens. Matter
17 (2005) 4567–4578




*Variation with alloy composition of the average value of the isotropic component of the $Mu_{BC}$ HP, with straight line fit, together with the $Mu_T$ HP*

Hydrogen is a common impurity in semiconductors but its study can be difficult because of its high reactivity. The light hydrogen-like atom muonium, formed of a positive muon and an electron, is electronically almost identical to hydrogen, and so provides a good guide to its electronic states.

In silicon and germanium two muonium states are formed at low temperatures: an immobile, bond-centred species $Mu_{BC}$, and a rapidly-diffusing tetrahedral-site centre $Mu_T$.

P J C King at Rutherford Appleton Laboratory and co-workers at Texas Tech University, Tohoku University, and TRIUMF, Vancouver, have measured the $Mu_T$ and $Mu_{BC}$ hyperfine parameters (HP) in bulk $Si_{1-x}Ge_x$ alloy by implantation of spin-polarized, positive muons, and observation of the muon polarization inside the sample through detection of the positrons emitted when the muons decay.

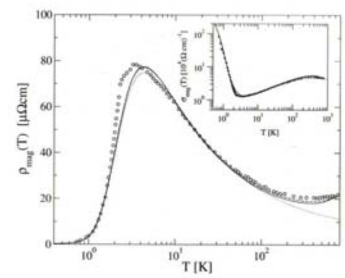
The figure shows the observed linear variation of the isotropic component of the $Mu_{BC}$ HP with $x$. Within bulk $Si_{1-x}Ge_x$ alloys there is a random site occupancy of Ge and Si atoms. Also, the Ge–Ge, Ge–Si and Si–Si bond lengths are different and vary linearly with alloy composition. Implanted muons adopting an immobile, bond-centred position therefore experience a random selection of bonding environments which overall show a linear variation with alloy composition.

The figure also shows the very non-linear behaviour of the $Mu_T$ HP with $x$. The T-site to T-site hop rate of the Mu atom is much faster in Ge than in Si. The expected path between adjacent T-sites is through the centre of the puckered six-member ring separating adjacent tetrahedral cages, which is larger in Ge than in Si. Further, the electronic charge distribution and the overall energy landscape within which a Mu atom moves are considerably flatter for Ge than for Si.

The temperature dependence of the $Mu_T$ HP in $Si_{1-x}Ge_x$ alloys is more complex than has been previously suggested for pure Si, and suggests it is governed by interaction with phonon modes in a more involved way than has been described by previous models. A more complete model is needed to provide an accurate description.

## Heavy fermions

Dynamics and transport properties of heavy fermions: theory
Optical and transport properties of heavy fermions: theory compared to experiment
David E Logan and N S Vidhyadhiraja
J. Phys.: Condens. Matter
17 (2005) 2935–2958 and 2959–2976




*Comparison of experimental $\rho^{exp}_{mag}(T)$ for $CeB_6$ with theory, on a log–linear scale. Inset: the dc conductivity $\sigma^{mag}(T) \equiv 1/\rho_{mag}(T)$ on a log–log scale*

Heavy electron materials have been extensively investigated, yet even their 'normal' paramagnetic phase, be it metallic or insulating, has eluded a unified microscopic description on all temperature ($T$) and/or frequency ($\omega$) scales. Within the general framework of dynamical mean-field theory David Logan and N S Vidhyadhiraja (Oxford) have developed a non-perturbative local moment approach to paramagnetic metallic phases of the periodic Anderson model (PAM), with a focus on dc transport and optics, focusing on the Kondo lattice regime relevant to strong correlated heavy fermion (HF) metals, where the problem is characterized by a single, exponentially small coherence scale $\omega_L$. All relevant energy/temperature scales are handled by the theory, from the low-energy coherent Fermi liquid domain out to large multiples of $\omega_L$ where incoherent many-body scattering dominates; followed by the crossover out of the scaling regime to non-universal, high-energy/temperature scales dictated by 'bare' model/material parameters. While the emphasis has been on strong correlations, all interaction strengths are encompassed by the LMA, so intermediate valence behaviour can also be addressed.

In the second paper they make a direct comparison with the dc transport and optical conductivities of $CeB_6$, $YbAl_3$, $CeAl_3$ and $CeCoIn_5$. $YbAl_3$ is an intermediate valence material, and the others typify heavy fermion behaviour, from the strongly correlated Kondo lattice regime of $CeAl_3$ and $CeB_6$ to the somewhat weaker coupling case of $CeCoIn_5$. Most features of the optics and transport of these materials are captured, the natural exception, omitted from the model itself, being crystal field effects which may (or may not) show up in the experimental resistivity as a reduction below one-channel behaviour at suitably high temperatures. The theory performs well quantitatively, and also captures notable features specific to individual systems, e.g. the existence of a low-frequency shoulder in the optics of $YbAl_3$, or the absence of any significant direct gap/mIR absorption in $CeAl_3$. The model thus appears to provide quite a comprehensive and successful description of experiment. This the authors attribute both to the dominance of the local electron scattering inherent to the model itself and the need to provide an adequate theoretical

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16 March 2006

Dear Dr Binek

**Journal of Physics: Condensed Matter Top Papers 2005 Showcase**

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Yours sincerely

Richard Palmer

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