EUROCORES Programme
European Collaborative Research

Final FoNE Conference

Miraflores de la Sierra, Madrid, Spain
9-13 September 2009

BOOK OF ABSTRACTS

FoNE
Fundamentals of NanoElectronics

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Final FoNE Conference

Miraflores de la Sierra, Madrid, Spain
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CONTENTS

CONFERENCE PROGRAMME	**6**
ABSTRACTS	**11**
Oral Presentations	**12**
Poster Presentations	**51**
LIST OF PARTICIPANTS	**64**

SCIENTIFIC PROGRAMME

Day 1	Wednesday 9 September	
15.00-18.00	**Arrival**	
15.00-18.00	**Registration in Residencia la Cristalera (Miraflores de la Sierra)**	
18.00-20.30	**OPERNING+ Session DEWINT**	
18.30-19.30	Klaus Kern (invited speaker, 50+10 min)	**Nanoscale Electronic Contacts: From Single Molecule Junctions to Graphene Doping**
19.30-20.00	Alessandro Betti (25+5 min)	**Enhanced shot noise in Carbon Nanotube Field Effect Transistors**
20.00-20.30	Giuseppe Iannaccone (25+5 min)	**Exploration of the perspectives of graphene-based transistors in terms of device performance and large-scale integration**
21.00	**Dinner at Cristalera Residence**	

Day 2	Thursday 10 September	
09.00-13.00	**Session 1: SPINTRA**	
09.00-9.30	Michael Coey (25+5 min)	**Domain wall noise in nanostructured hard magnets**
9.30-10.30	Bogdan R. Bułka (25+5 min)	**Threshold effects in transport in three-terminal ballistic junctions**
	Procolo Lucignano (SPINTRA, 20+5 min)	**Kondo conductance in metallic nanocontacts with magnetic impurities**
10.30-11.00	Chris van Haesendonck (25+5 min)	**Electronic and magnetic properties of self-organized Co islands on Au(111)**
11.00-11.30	**Coffee Break**	**Poster Set up**
11.30-12.00	Farkhad Aliev (25+5 min)	**Magnetization dynamics and noise in spintronic devices**
12.00-12.30	Arturo Tagliacozzo	**Competition between Rashba spin-orbit coupling and Hund's ferromagnetic exchange interaction in**

	25+5 min)	**the Kondo correlations of a quantum dot with four electrons**
12.30-13.00	Vit Novak (25+5 min)	**GaMnAs: model material for spintronics**
13.00-14.30	**Lunch at Cristalera Residence**	
14.30-18.00	**Session 2: SPINCURRENT**	
14.30-16.00	Maxim Tsoi (invited speaker 50+10 min)	**Spintronics: from ferromagnets to antiferromagnets**
	Michel Viret (invited speaker (25+5 min)	**Domain wall resistance and spin torque in constrictions down to atomic contacts**
16.00-16.30	**Coffee Break**	
16.30-17.00	Phillipp Eib (25+5 min)	**Vortex domain wall dynamics in NiFe nanowires**
17.00-17.30	Igor Kuzmenko (25+5 min)	**Canted magnetization texture in ferromagnetic tunnel junctions**
17.30-18.00	Serban Lepadatu (25+5 min)	**Resonant Domain Wall Movement in Pinning Potentials**
18.00-19.00	Dieter Weiss (invited speaker, 50+10 min)	**Phase coherent phenomena in ferromagnetic (Ga,Mn)As**
19.00-20.30	**POSTER SESSION 1** **Scientific Meeting FONE**	
21.00	**Dinner at Cristalera Residence**	

Day 3	Friday September 11	
09.00-11.00	**Session 3: DEWINT**	
09.00-10.00	S. Jejurikar and M. De Souza (50+10 min)	**Carbon based Electronics: A Perspective from Theory and Experiment**
10.00-10.30	Shu- Pei Oei (25+5 min)	**CNTs vs. SiNWs for Future Electronics**
10.30-11.00	Hanz Kosina (25+5 min)	**Transport modeling for Nanowires and Nanotubes**
11.00-13.00	**Coffee break and poster session 2**	
13.00-14.00	**Lunch at Cristalera Residence**	
afternoon (from, 14-30)	**Visit to Medieval city of Segovia with Conference Dinner**	

Day 4	Saturday September 12	
09.00-11.00	**Session 4: SpiCo**	
09.00-09.30	Yashar Komijani (25+5 min)	**0.7-feature in p-GaAs Quantum Point Contacts**
09.30-10.00	Stefano Chesi (25+5 min)	**Quantum Hall ferromagnetic states and spin-orbit interactions in the fractional regime**
10.00-10.30	Mircea Trif (25+5 min)	**Relaxation of hole spins in quantum dots via two-phonon processes**
10.30-11.00	Silvano De Franceschi 25+5 min)	**Spin-dependent transport in bottom-up semiconductor nanostructures**
11.00-11.30	**Coffee break + poster session**	

11.30-12.20	Robert Stamps (invited speaker, 40+10 min)	**Exchange anisotropy, exchange bias and exchange springs**
12.20-13.00	Vitali Metlushko (invited speaker 35+5 min)	**Problems and Solutions with Integrating Magnetic Nanostructures into Functional 3-D Devices**
13.00-15.00	**Lunch at Cristalera Residence**	
15.00-16.00	**Session 5 IMPRESS**	
15.00-15.30	Jamie Warner (25+5 min)	**Electron spin resonance studies of purified nanotubes separated into metallic and semiconducting varieties.**
15.30-16.00	Kuzmany Hans (25+5 min)	**Towards an Engineering of Spin Chains Inside SWCNTs with Controlled Spin Separation**
16.00-16.25	**Cofee Break**	
16.25-18.00	**Session 6 Young Research ORAL SESSION**	
16.25-16.50	Maciej Misiorny (SPINTRTA 25+5min)	**Spin effects in transport through a single-molecule magnet in the Kondo regime**
16.50-17.30	David Herranz (SPINTRA, 15+5 min)	**Asymmetric dependence of 1/f noise on bias in fully epitaxial Fe/MgO/Fe magnetic tunnel junctions**
	Ahmad Awad (SPINTRA, 15+5 min)	**Spin wave modes in circular soft magnetic dots in vortex-state under in-plan magnetic field**
17.30-18.00	M. Mucha-Kruczynski (SpiCo,. 25+5 min)	**Theory of magneto-optical measurements of bilayer graphene**
18.00-18.30	**Coffee break + Poster session**	
18.30-20.00	**Scientific Meetings of FONE Projects**	
21.00	**Dinner at Cristalera Residence**	

Day 5 Sunday September 13

	Session 7
9.00-10.00	**Discussion/wrap-up session on the outcome and impact of the FoNE programme and future perspectives**

CLOSING	
13.00-14.00	**Lunch at Cristalera Residence and DEPATURES**

ABSTRACTS

ORAL PRESENTATIONS

Klaus Kern **Presentation type :** Invited Max Planck Institute for Solid State Research Nanoscale Science Department 70569 Stuttgart Germany Tel: +49 711 689 1660 Fax: +49 711 689 1662 Email: k.kern@fkf.mpg.de **FONE Project:** Invited	**Nanoscale Electronic Contacts:** **From Single Molecule Junctions to Graphene Doping** Klaus Kern (Max-Planck-Institut für Festkörperforschung, Heisenbergstr. 1, D-70569 Stuttgart, Germany and Ecole Polytechnique Fédérale de Lausanne – EPFL, CH-1015 Lausanne, Switzerland Electron transport through metal-molecule contacts greatly affects the operation and performance of electronic devices based on organic semiconductors and is at the heart of molecular electronics exploiting single molecule junctions. Much of our understanding of the charge injection and extraction processes in these systems relays on our knowledge of the potential barrier at the contact. Despite significant experimental and theoretical advances in our understanding of electron transport in atomic and molecular junctions, a clear rationale of the contact barrier at the single atom/molecule level is missing. We exploit scanning tunneling microscopy to probe directly the nanocontact between single atoms and molecules and a metal electrode. For single cobalt atom contacts we find a dependence of the Kondo scattering on the local atomic geometry, which can be related to the delicate interplay between the structural relaxations and the electronic properties in the near-contact regime. For metal-molecule nanocontacts, contrary to the common assumption of a uniform barrier, our experiments reveal a substantial variation on the sub-molecular scale. This behaviour is ascribed to the interaction between specific molecular groups and the metal electrode. Guided by this result we introduce a novel scheme to locally manipulate the potential barrier of molecular nanocontacts. Metal contacts are also crucial for the operation of graphene based devices. Scanning photocurrent microscopy reveals that these contacts lead to potential steps that act as transport barriers. In this technique, the short-circuit photocurrent detected at zero drain-source bias is a measure of the local-electric-potential gradient. Evaluation of the gate-dependent short-circuit photocurrent at the contacts shows that gold as a high-work-function metal leads to local p-type doping of the sheet, whereas the low-work-function metal titanium imparts local n-type doping. Photoemission and transport experiments further reveal that the gold contacts not only provide an efficient route for hole doping of graphene but also effect the localization properties of the Dirac-like states by spin-orbit coupling.

Alessandro Betti

Presentation type : Oral

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Project
05-FONE-FP-008 /Device Electronics based on nanoWIres and NanoTubes (DEWINT)

Enhanced shot noise in Carbon Nanotube Field Effect Transistors

Alessandro Betti (1), Gianluca Fiori (1), Giuseppe Iannaccone (1,2)

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We present a numerical investigation of shot noise in Carbon Nanotube Field Effect Transistors, based on statistical quantum transport simulations of randomly injected electrons from the contacts and the self-consistent solution of the electrostatic and transport equations [1]. In order to consider both the effects of Pauli exclusion and Coulomb repulsion among charge carriers, an analitical formula for the noise power spectral density has been derived by introducing statistical properties of the scattering matrix within a second-quantization many-body description[2].

Through Monte Carlo simulations on an ensemble of different configurations of occupied states injected from the contacts, our model predicts a shot noise enhancement in ballistic (25,0) CNT-FETs due to a positive correlation between holes trapped in bound states in the channel and thermionic electrons injected from the source reservoir, which can lead to a Fano factor at room temperature up to 1.22.

Such enhancement, which can only be captured considering Coulomb interaction among charge carriers, arises from the small energy gap in (25,0) CNT-FETs, which, for large drain-to-source bias, allows band-to-band tunneling at the drain contact even for devices biased near the threshold voltage, when thermionic electrons may enter the channel from the source. In such a situation, holes incoming from the drain are trapped in bound states in the device region, lowering the barrier height and therefore increasing the injection of thermionic electrons. Thus a positive correlation between fluctuations of the number of electrons and holes is the device regions is caused by localized states in the valence band.

[1] A. Betti, G. Fiori and G. Iannaccone, "Shot noise suppression in quasi one-dimensional Field Effect Transistors", submitted to IEEE-TED http://arxiv.org/abs/0812.5034

[2] A. Betti, G. Fiori and G. Iannaccone, "Statistical theory of shot noise in quasi-1D Field Effect Transistors in the presence of electron-electron interaction", submitted to Phys. Rev. B http://arxiv.org/abs/0904.4274

Giuseppe Iannaccone

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Project

05-FONE-FP-008 /Device Electronics based on nanoWIres and NanoTubes (DEWINT)

Exploration of the perspectives of graphene-based transistors in terms of device performance and large-scale integration

Giuseppe Iannaccone (1,2), Gianluca Fiori (2)

(1) IEIIT-CNR (2) University of Pisa, Italy

The perspective of graphene-based electronics ranks high among the many reasons for the explosive growth of interest in graphene in recent years. Graphene has very promising and intriguing transport properties, but also a serious drawback for electronics: it has no native energy gap, precluding the possibility of shutting off device current.

We have explored, with numerical and analytical modeling, several different options to induce a gap in graphene and to realize transistor structures, in order to assess the actual potential of the material in electronics.

Among the different options for inducing a gap we have considered lateral confinement in graphene nanoribbons [1,2] symmetry breaking due to a vertical electric field in bilayer graphene [3,4,5], symmetry breaking in epitaxial graphene in SiC substrate [6]. As far as device structures are concerned we have considered standard MOSFETs [1,3,4,6,7], Schotty Barrier MOSFETs [2] and Tunnel FETs [5].

In the talk we shall discuss the relative advantages and disadvantages of the different options. The small energy gap still remains the main problem of graphene channels manufacturable with present-day technology. The Tunnel FET with a bilayer graphene channel is the most promising device structure for low-power operation.

[1] G. Fiori, G. Iannaccone, "Simulation of Graphene Nanoribbon Field-Effect Transistors", IEEE-EDL Vol. 28 (8), pp. 760-762, 2007

[2] Y. Yoon et al. "Performance Comparison of Graphene Nanoribbon FETs With Schottky Contacts and Doped Reservoirs", IEEE-TED, Vol. 55 (9), pp. 2314-2323, 2008.

[3] M. Cheli, G. Fiori, G. Iannaccone, "An analytical model of Bilayer-Graphene Field Effect Transistor", submitted to IEEE-TED

[4] G. Fiori, G. Iannaccone, "On the Possibility of Tunable-Gap Bilayer Graphene FETs", IEEE-EDL, Vol. 30 (3), pp. 261-264, 2009

[5] G. Fiori, G. Iannaccone, "Ultra-low-voltage bilayer graphene tunnel FET", submitted to IEEE-EDL, (http://arxiv.org/abs/0906.1254v1)

[6] M. Cheli, P. Michetti, G. Iannaccone "Physical Insights on Nanoscale FETs based on epitaxial graphene on SiC", to be presented at ESSDERC 2009.

[7] P. Michetti, G. Mugnaini, G. Iannaccone, "Analytical model of nanowire FETs in a partially ballistic or dissipative transport regime", IEEE-TED, in Print.

Thursday 10 September

Dieter Weiss

Presentation type :
Invited

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Phase coherent phenomena in ferromagnetic (Ga,Mn)As

Weiss Dieter

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The discovery of ferromagnetic III-V semiconductor materials like (Ga,Mn)As has generated a lot of interest as these materials combine ferromagnetic properties, typical for metals, with the versatility of semiconductors. The resistance in these materials displays, as a function of temperature or magnetic field ***B***, a rich phenomenology and allows, e.g., to extract the Curie temperature from transport measurements. Despite the high crystalline quality of the material, (Ga,Mn)As is a quite disordered conductor on the verge of the metal-insulator transition (MIT). For Mn concentrations on the metallic side of the MIT the typical mean free path l_e of the holes is a few lattice constants. Hence it was until recently an open issue whether phase coherent phenomena can be observed in this material.

In my talk I will mainly focus on experiments which allow to explore phase coherent phenomena in (Ga,Mn)As. The analysis of the amplitude of universal conductance fluctuations allows extracting both, the phase coherence length and its temperature dependence which follows a $T^{-1/2}$ law [1]. The observation of Aharonov-Bohm-oscillations in suitably small ring geometries confirms the size of the phase coherence lengths which is typically of order 100 nm at 20 mK. In addition, the observation of weak localization/anti-localization provides an independent means to determine the phase coherence length [2,3]. Fits of the low B magneto-conductance corrections permit to extract the spin-flip length L_{SO} as a second characteristic length scale of charge transport in (Ga,Mn)As. While we used different methods to extract the phase coherence lengths, the experiments delivered consistent results. At low temperatures the resistance increases in metallic one- two- and three-dimensional (Ga,Mn)As samples. This effect can be described to electron-electron interaction (EEI) [4]. By analyzing the conductivity correction due to enhanced EEI the electrical diffusion constant was extracted for (Ga,Mn)As samples of different dimensionality. Using the Einstein relation allows to deduce the effective density of states of (Ga,Mn)As at the Fermi energy. The result suggests that the Fermi energy in metallic (Ga,Mn)As is located in the valence band and not in an impurity band of high effective mass.

Work was done in close collaboration with Daniel Neumaier, Konrad Wagner, Janusz Sadowski, Ursula Wurstbauer and

	Werner Wegscheider. Financial support by the German Science Foundation (DFG) via SFB 689 is gratefully acknowledged. [1] K. Wagner, M. Reinwald, W. Wegscheider, D. Weiss, 'Dephasing in (Ga,Mn)As nanowires and rings', Phys. Rev. Lett. 97, 056803 (2006) [2] D. Neumaier, K. Wagner, S. Geißler, U. Wurstbauer, J. Sadowski, W. Wegscheider, and D. Weiss, 'Weak Localization in ferromagnetic (Ga,Mn)As nanostructures', Phys. Rev. Lett. 99, 116803 (2007) [3] V. K. Dugaev, P. Bruno, and J. Barnaś , Comment on 'Weak Localization in Ferromagnetic (Ga,Mn)As Nanostructures' , Phys. Rev. Lett. 101, 129702 (2008); D. Neumaier, K. Wagner, S. Geißler, U. Wurstbauer, J. Sadowski, W. Wegscheider, D. Weiss, Reply, ibid [4] D. Neumaier, M. Schlapps, U. Wurstbauer, J. Sadowski, M. Reinwald, W. Wegscheider, D. Weiss, 'Electron-electron interaction in 2D and 1D ferromagnetic (Ga,Mn)As', Phys. Rev. B 77, 041306 (2008)

Bogdan R. Bułka

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Project
SPINTRA

Threshold effects in transport in three-terminal ballistic junctions

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The interesting transport characteristics of three-terminal ballistic junctions (TBJs) are recently investigated due to possible applications of such devices in electronic and spintronic circuits.
In this work we report on theoretical studies, fabrication and low temperature transport measurements of **T**-shaped tree-terminal devices, based on a high mobility 2D electron gas. Modeling shows the Wigner singularities in the source-drain conductance, when a new conduction channel opens to transport in a side terminal [1]. The shape of the singularity can be changed by tuning the gate voltages. The threshold effect can be also seen in voltage changes measured in the floating electrode for different source-drain bias in linear and non-linear regime. Experimental results, obtained for GaAs/AlGaAs devices, indicate that apart from ballistic transport, in the central part of the junction quasibound states are formed and a certain asymmetry is present in the cavity region. Measurements also show bend resistance for asymmetric TBJs, which is in agreement with our modeling. Moreover, the non-linear transport was studied in the typical for TBJs, the so-called *push-pull* bias regime, when equal but opposite in sign *dc* voltages are simultaneously applied to the input terminals. For the first time we have shown that output voltage can assume either negative or positive values as a function of Fermi energy. This behavior was previously predicted theoretically for **Y**-shaped device [2] and our calculations (for symmetric and non-symmetric **T**-junction) show that for such geometry it is in fact the bend resistance effect, which is responsible for a positive value of the output voltage.
We investigated also the transport properties of 3-terminal nanojunctions based on PbTe/PbEuTe quantum well, where the superconducting indium film was evaporated on side walls of the mesa structure. We find that, in spite of the complicated nature of the interface, In/PbTe contact is very transparent leading to a pronounced conductance maxima associated with the Andreev reflection.

[1] B.R. Bulka, A. Tagliacozzo, Phys. Rev. B79, 075436 (2009).

[2] D. Csontos and H. Xu, Phys. Rev B., vol 67, 235322 (2003).

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FONE Project: SPINTRA

Electronic and magnetic properties of self-organized Co islands on Au(111)

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(3) Faculty of Physics, Moscow State University, 119992 Moscow, Russia

Magnetic Co islands of only a few nanometer in size were grown by atomic deposition on atomically flat Au(111) films. The morphologic, electronic and magnetic properties of the islands were studied *in situ* by scanning tunneling microscopy (STM) and spectroscopy (STS), including spin-polarized STS, under ultra-high vacuum conditions and at low temperatures.
At low coverages, Co islands self-organize in arrays of mono- and bilayer nanoscale hexagonal structures, a process induced by the Au(111) herringbone reconstruction [1, 2]. By means of mapping of the local density of states (LDOS) with lock-in detection, electron standing wave patterns are resolved on top of the atomically flat Co islands. The surface state electrons are observed to be strongly confined laterally inside the Co nanosized islands, with their wavefunctions reflecting the symmetry of the islands [3, 4].
The standing wave patterns can be fitted to the calculated wave functions for a single electron in a box having the corresponding island symmetry [5]. The observed standing wave patterns are identified either as individual eigenstates or as a mixture of two or more energetically close-lying eigenstates of the cobalt island. The small size of the Co islands under study (down to 9 nm^2) has lead to a strong discretization of the energy levels as revealed in STS measurements, with extreme energy separations between the eigenstates on the order of 100 meV.
Complementary to the standard STS experiments, state-of-the-art spin-resolved STS experiments, using a Cr coated STM tip with a perpendicularly oriented magnetization [6], revealed that the Co islands exhibit a net magnetization perpendicular to the substrate surface due to the presence of spin-polarized ***d***-states. A random distribution of islands with either upward or downward pointing magnetization was observed, without any specifc correlation of magnetization orientation with island size or island height, as expected for non-interacting magnetic particles on a nonmagnetic substrate. The maxima and minima observed in the STS spectra qualitatively agree with theoretical calculations of the spin-up and spin-down density of states for Co ***d***-state electrons.

[1] B. Voigtländer, G. Meyer, and N.M. Amer, Phys. Rev. B 44,

	10354 (1991) [2] J. Meyer and R. Behm, Surf. Sci. 322, L275 (1995) [3] J. Li, W.-D. Schneider, R. Berndt, and S. Crampin, Phys. Rev. Lett. 80, 3332 (1998) [4] M. Rastei, J. Bucher, P. Ignatiev, V. Stepanyuk, and P. Bruno, Phys. Rev. B 75, 045436 (2007) [5] S. Crampin, M. Nekovee, and J. Inglesfield, Phys. Rev. B 51, 7318 (1995) [6] M. Bode, M. Dreyer, M. Getzlaff, M. Kleiber, A. Wadas, and R. Wiesendanger, J. Phys.: Condens. Matter 11, 9387 (1999)

Farkhad Aliev

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FONE Project:
05-FONE-FP-004/ Spin dependent transport and electronic correlations in nanostructures (SPINTRA)

Magnetization dynamics and noise in spitronic devices

Farkhad G. Aliev*

Dpto. Física Materia Condensada, C-III and Instituto " Nicolas Cabrera" de Ciencia de Materiales, Universidad Autónoma de Madrid, Cantoblanco, 28049, Madrid, Spain

In this talk I will review our very recent experiments on magnetization dynamics, electron transport and noise in magnetic nanostructures partially supported by ESF-FONE [1-7].

I will separately resume the research collaboration within SPINTA collaborative project [5-7]. Knowledge of dynamic magnetic properties may provide essentially new, in respect to DC measurements, information about physical processes in magnetic nanostructures. I will present measurement of complex dynamic response in arrays of Py magnetic dots and magnetic tunnel junctions at frequencies up to 8.5 GHz and temperatures down to 2K. I will also describe our recent advances in understanding of magnetotransport and low frequency noise in Fe/Cr magnetic multilayers [5] and magnetic tunnel junctions with and without nanostructuring of the barrier [6,7].

(*) In collaboration with D.Herranz, A.Awad, R.Guerrero, J.Sierra, V.V.Pryadun, R.Villar, A. Levanyuk, F.Greullet, C.Tiusan, M. Hehn, S.Russek, G.Kakazei, V.Metlushko, K.Guslienko, J.Barnas, V.Dugaev, C.van Haesendonck, R. Duine

REFERENCES

[1] F.G. Aliev, et al., Phys. Rev. B 79, 174433 (2009)
[2] J. F. Sierra, et al., Appl. Phys. Lett., 93, 172510, (2008).
[3] J. F. Sierra, et al., Appl. Phys. Lett., 94, 012506 (2009)
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Support from Spanish-French Integrated Action project (HF2006-0039), Spanish MEC (MAT2006-07196), Consolider " Molecula Nanoscuence" and Comunidad de Madrid (S-505/MAT0194) is gratefully acknowledged. This work, as a part of the European Science Foundation EUROCORES Programme 05-FONE-FP-010-SPINTRA, was also supported by funds from the Spanish MEC (MAT2006-28183-E) and the EC Sixth Framework Programme, under Contract No. ERAS-CT-2003-980409.

Arturo Tagliacozzo **Presentation type :** Oral Università "Federico II" di Napoli Department : Scienze Fisiche 80125 Napoli Italy Tel: +39081676832 Fax: +39081676431 Email: : arturo@na.infn.it **Project** 05-FONE-FP-004/ Spin dependent transport and electronic correlations in nanostructures (SPINTRA)	**Competition between Rashba spin-orbit coupling and Hund's ferromagnetic exchange interaction in the Kondo correlations of a quantum dot with four electrons** P.Lucignano(2), A.Tagliacozzo(1,2), B. R. Bulka(3) (1) Universita'di Napoli "Federico II Monte S.Angelo, via Cintia, 80125 Napoli, Italy. (2) CNR-INFM Coherentia, via Cintia, 80125 Napoli, Italy (3) Institute of Molecular Physics, Polish Academy of Sciences, ul. M. Smoluchowskiego 17, 60-179 Poznań, Poland Gate-controlled semiconductor Quantum Dots (QDs) enable manipulation of the quantum states down to the single electron level. In the recent past we have explored the quantum coherent properties of spin degrees of freedom in QDs with few electrons. The Coulomb interaction is usually strong with respect to the single particle energy spacing, therefore exact diagonalization calculations are needed. By attaching leads to the QD, transport affects its local magnetic properties and, vice versa, its magnetic properties inprint the current response with a zero bias anomaly due to Kondo correlations. The Rashba spin-orbit interaction, by acting on the dot electrons via a top gate, provides an attractive tool for tuning the conductance in the device. We have considered a QD with four electrons at zero magnetic field which is known to be in a triplet spin state, due to Hund's rule. Two of the four electrons are frozen in a singlet state. The Kondo screening competes with the Hund's ferromagnetic exchange interaction if the coupling to the leads is strong enough or temperature is low enough. On the other hand, the Hund's ferromagnetic exchange interaction is weakened by the Rashba term, as the latter does not conserve the dot spin, but just the total angular momentum component orthogonal to the dot J_z . Thus, the magnetic moment of the impurity is influenced by the coupling to the leads, which provides the mixing of the dot states belonging to $J_z = -1,0,1$. A novel Kondo physics, with an even number of electrons on the QD, can emerge, as we show on Anderson-like models by using a Numerical Renormalization Group approach to the linear quantum transport, which was succesful in realistic metal nanowires with an impurity. [1]. P.Lucignano, B.Jouault, A. Tagliacozzo, Phys. Rev. B75, 153310 (2007). [2]. B.R. Bulka and A.Tagliacozzo Phys. Rev. B 79, 075436 (2009) [3]. P. Lucignano, G. E. Santoro, M. Fabrizio, and E. Tosatti, Phys. Rev. B 78, 155418 (2008) [4]. P.Lucignano, B.Jouault, A.Tagliacozzo and B.L. Altshuler, Phys.Rev. B71,121310(R)(2005).

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FONE Project:

05-FONE-FP-010
Spin-dependent transport and electronic correlations in nanostructures (SPINTRA)

GaMnAs: model material for spintronics

Vit Novak (1), Zbynek Soban (1,2), Kamil Olejnik (1), Miroslav Cukr (1), Tomas Jungwirth (1), Sam Owen (3), Joerg Wunderlich (3), Richard Campion (4), Bryan Gallagher (4)

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GaMnAs has been the most intensely studied example of diluted magnetic semiconductors in the recent years. As a well established model material It has helped to better understand the basic physics related to ferromagnetism in semiconductors, and it allowed to verify the viability of various spintronic application concepts.

In this contribution we survey the technological achievements which have led to the high critical temperatures of the ferromagnetic transition. Further, based on a series of optimally grown and annealed samples we report a systematic study of the transition from a low-doped diamagnetic semiconductor to a heavily doped metal-like ferromagnetic semiconductor. Finally, we demonstrate an all-semiconductor device with gated ferromagnetic layer, exhibiting a controllable anisotropic magnetoresistance.

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FONE Project: invited

Spintronics: from ferromagnets to antiferromagnets

Maxim Tsoi

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Spintronics is built on a complementary set of phenomena in which the magnetic configuration of a system influences its transport properties and vice versa. In ferromagnetic (F) systems these interconnections are exemplified by Giant Magnetoresistance (GMR) – where the system's resistance depends on the relative orientation of magnetic moments in constituent F parts [1, 2], and Spin Transfer Torque (STT) – in which a large electrical current density j can perturb the system's magnetic state [3-5].

Recently, corresponding effects were proposed [6] to occur in antiferromagnetic (AFM) systems where F components are replaced by AFMs. First, it was predicted that resistance of an AFM spin valve – where two AFM layers are separated by a nonmagnetic (N) spacer – could depend upon the relative orientations of magnetic moments in the two AFM layers (antiferromagnetic GMR). Second, injection of a strong enough j into AFM was predicted to affect its magnetic state (antiferromagnetic STT).

In this talk I will focus on two experiments which highlight the interconnections between magnetic state and transport in (i) F and (ii) AFMsystems:

(i) It is well known that STT associated with an electric current traversing a magnetic domain wall can drive it into motion [7]. The inverse effect, in which an emf is induced by a moving domain wall, has also been predicted [8-10]. Here I will describe the first experimental observation of an emf induced in a Permalloy nanowire by a field-driven domain wall [11]. Over a range of driving fields, we detect a small voltage generated during the motion of a single domain wall monitored by high-bandwidth scanning Kerr polarimetry. Our observations confirm the theoretical predictions, from which information about the wall motion can be extracted.

(ii) I will also discuss our experimental search for the new AFM effects – antiferromagnetic GMR and STT – which may potentially lead to a new all-antiferromagnetic spintronics where antiferromagnets are used in place of ferromagnets. In particular I will focus on our experiments with exchange-biased spin valves [12] where extreme current densities were found to affect the exchange bias at F/AFM interface. We find that, depending on the polarity of the electrical current flowing across F/AFM interface the strength of the exchange bias can either increase or decrease. As exchange bias is known to be associated with interfacial AFM magnetic moments, our observation can be taken as the first evidence of STT effect in AFM materials.

In collaboration with (i) S. A. Yang, G. S. D. Beach, C. Knutson, D. Xiao, Q. Niu, J. L. Erskine, and with (ii) Z. Wei, A. Sharma, J. Basset, A. S. Nunez, P. M. Haney, R. A. Duine, J. Bass, and A. H.

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FONE Project:
05-FONE-FP-004 / Domain Walls and Spin-Polarised Currents (SPINCURRENT)

Domain wall resistance and spin torque in constrictions down to atomic contacts

CEA Saclay, DSM/IRAMIS/SPEC, Gif sur Yvette, France.

In bulk materials, domain walls (DWs) contribute only a tiny amount to the electrical resistance because the magnetisation rotates very smoothly over 'long' lengthscales (typically several tens of nanometers). When a strong current is driven through the DWs, the flux of polarised carriers applies a pressure which tends to push the walls. However, this pressure is also rather small because most of the torque applied on the wall is in the wrong direction to push efficiently.

The situation would be very different if the DWs were very thin. In that case, both their resistance and current induced pressure would be large. The DWs could then be used as topological solitons easily measurable (through their resistance) and movable (with the current induced pressure). They could be the basis for efficient bits of information in magnetic memories.

An interesting way of making DWs thinner is by using nanometer sized constrictions where the DW width are expected to scale with the constrictions diameter. I will present here our results in break junctions where a controlable breaking of a narrow neck allows to define constrictions of any size down to a single atom. In this regime, the nature of conductance changes and local magnetism is also affected by the reduced dimensionality. The variation of DW resistance, anisotropic magneto-resistance (AMR) and spin torque effects will be presented and discussed in the light of ab-initio and tight-binding calculations.

Phillip Eib

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Project

05-FONE-FP-004 /Domain Walls and Spin-Polarised Currents (SPINCURRENT)

Vortex domain wall dynamics in NiFe nanowires

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Current-induced propagation of single domain walls (DW) in NiFe nanowires plays a key role in the recently proposed information storage devices [1]. Crucial to the development of a practical technology is the understanding of the role of joule heating in the nanowire due to the high current densities necessary to move DWs.

We have built and characterized a time resolved magneto-optical Kerr effect setup similar to the one reported in Ref. 2 that uses a combination of RF magnetic field pulses and current pulses with sub-nanosecond risetime to propagate and detect the DW motion. The setup is also used in a time-resolved reflectometry configuration to measure the evolution of the temperature of the nanowire on a nanosecond time scale with a spatial resolution of 3 µm. Combining this measurement technique with careful sample design, multiple effects of the current on DW motion can be discerned, namely the temperature rise and the induced torques.

The high sensitivity of the setup allows recording of the partial magnetization reversal of the wire under the laser spot. DW nucleation is achieved using the Oersted field generated by a current pulse traveling in a conductor bridging over the wire. The width of the bridge and that of the magnetic wire are both equal to 1 µm. Surprisingly DW propagation was observed to continue for time intervals longer than the current pulse duration in magnetic fields as small as 0.3 Oe. The coercive field of the wire was measured to be 4 Oe. This low propagation field after the nucleation current pulse is attributed to Joule heating in the bridge and subsequent heat diffusion into the magnetic nanowire on the nanosecond time scale.

We will report on the progress towards studying the dynamics of DW propagation in nanowires with this setup.

[1] S. S. P. Parkin et al., Science 320, 190 (2008).

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Project

05-FONE-FP-004 / Domain Walls and Spin-Polarised Currents (SPINCURRENT)

Canted magnetization texture in ferromagnetic tunnel junctions

Igor Kuzmenko

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The possibility of the formation of inhomogeneous magnetization texture in the vicinity of a highly transparent tunnel junction caused by ferromagnetic coupling of magnetic moments on opposite sides of the junction is investigated. As an example, it is considered a device consisting of a tunnel junction between two easy-axis ferromagnets magnetically biased at the ends. It is found that a canted magnetization state can form if the ferromagnetic tunneling coupling, t', exceeds some critical value t_0 determined by the interplay between crystalline anisotropy and magnetization rigidity in the ferromagnet. A tunnel junction with $t'<t_0$ can be viewed as an atomically sharp magnetic domain wall, whereas the increase in the junction transparency above t_0 gradually transforms it into a broad texture typical for a domain wall in a bulk ferromagnetic material. For $t'>t_0$, the evolution of the texture upon application of an external magnetic field is considered and a parametric diagram for distinct magnetization regimes is constructed. When the magnetic field exceeds some critical value, B_0, the domain wall is pushed away toward the magnetically biased end of the ferromagnetic metal. When a magnetic field is swept back and its sign changes, the domain wall returns back to the tunnel junction. The resulting hysteresis in

the magnetization state of the device leads to a hysteresis loop in its magnetoresistance (MR), which is analyzed, taking into account the formation of the texture near the tunnel junction.

[1] I. Kuzmenko and V. Fal'ko, Phys. Rev. B. 78, 184425 (2008)

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FONE
Project: SPINCURRENT
Domain Walls and Spin-Polarised Currents

Resonant Domain Wall Movement in Pinning Potentials

S. Lepadatu[1], O. Wessely[2,7], A. Vanhaverbeke[3], R. Allenspach[3], A. Potenza[4], H. Marchetto[4,5], T.R. Charlton[6], S. Langridge[6], S.S. Dhesi[4], C.H. Marrows[1]

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Linear and parabolic notches provide a pinning potential and hence give rise to a restoring force acting on a domain wall trapped at the notch. The structures under study are defined by e-beam lithography with 1μm arm width, 100nm constriction width, 20nm NiFe thickness and various notch profiles, including linear pinning potentials labeled L1 through to L5 and parabolic pinning potentials labeled P1 through to P5 in order of increasing steepness (see Ref. [1] for details). By varying the pinning potential profile the restoring force is changed. The domain wall pinning behavior is investigated using spin-SEM and PEEM imaging and we find that the pinning position is dependent on the profile of the notch. Thus for the pinning profiles L1 to L3 and P1 to P5 we have a domain wall pinned at the centre of the notch, whilst for the pinning profiles L4 and L5 we have a domain wall pinned towards one side. Using a vector network analyzer the resonance frequency is measured at zero magnetic field as a function of pinning profile, hence restoring force, and current density. We observe a resonance peak in the reflection data only when a domain wall is trapped at the centre of the notch, arising due to the amplified movement of the domain wall at the resonance frequency. We find that at a fixed current density the resonance frequency increases with the steepness of the pinning profile. Moreover, for the linear pinning profiles L1 through to L3, the resonance frequency decreases linearly with increasing current density. Using a 1D model of domain wall movement where the restoring force is determined by the spatial derivative of the cross sectional area, the non-harmonic behaviour of domain wall oscillation in the linear pinning profiles is explained by noting that for a linear notch the restoring force is not proportional to the DW displacement from equilibrium. On the other hand for the parabolic pinning potentials, where the restoring force is proportional to the domain wall displacement from equilibrium, we obtain a near harmonic domain wall

	movement [2], where the resonance frequency is nearly independent of the excitation current density. References [1] S. Lepadatu, A. Vanhaverbeke, D. Atkinson, R. Allenspach and C. H. Marrows, Phys. Rev. Lett. 102, 127203 (2009) [2] E. Saitoh et al., Nature 432, 203 (2004)

Michael Coey **Presentation type :** Oral Name of University Trinity College Dublin Department :Physics Zip code :Dublin 2 Country : Ireland Tel: 353 1 8961470 Fax: 353 1 6711759 Email: jcoey@tcd.ie **FONE Project:** Name of the Project 05-FONE-FP-004 / Domain Walls and Spin-Polarised Currents (SPINCURRENT)	**Domain wall noise in nanostructured hard magnets** Zhu Diao, E. R. Nowak*, G Feng and J. M. D. Coey School of Physics and CRANN, Trinity College, Dublin 2, Ireland The anomalous Hall effect of wires patterned from $(Co_{90}Pt_{10}/Pt)_n$ multilayers, with $10 \leq n \leq 50$ allows determination of the magnetization process in a small volume of material from measurememnts of the transverse electrical resistivity. The domain structures are determined by atomic force microscopy, and maze domains are observied with a donain width od 100 – 200 nm. The pink, 1/f noise appears in samples with quality factor Q < 1 at points on the hystersis loop where the magnetization reverses continuously. (Q is defined as $2K/\mu_0 M_s^2$) The magnetic noise is associated with reversible excursions of segments of domain wall of approximate length 100 nm. The fluctuating volume is readily deduced from time sequences, as the noise associated with the anomalous Hall voltage is 1 – 2 orders of magnitude greater than the Johnson noise floor associated with the resistance of the lithographically-patterned Hall bars. This noise is quite different from the Barkhausen noise close to the coercive field, where distinct jumps are observed, which correspond to the abrupt reversal of a significant fraction of the sensitive volume. * Permanent Address, Department of Physics and Astronomy, University of Delaware, Newark, Delaware 19716, USA

Friday September 11

S. Jejurikar and M. De Souza Two presentations each of 30 mins. **Presentation type :** Oral University of Sheffield Department : Electrical and Electronic Engineering S13JD United Kingdom Tel: 44-114-2225167 Fax: 0114-2225143 Email: m.desouza@sheffield.ac.uk **Project** DEWINT	**Carbon based Electronics: A Perspective from Theory and Experiment** M. M. De Souza, Premlal B. Pillai, D. Casterman, S. Jejurikar and O. Petrenko. University of Sheffield. We present an update on our progress on **(i)** The extraction of key parameters (bandgap, effective mass) relevant to transport mechanisms in CNTFETs using a combination of experiment and theory and (ii) Exploration of the properties of graphene on epitaxied SiC. **Results:** (I) CNTFETs: Transport in CNTFETs is limited by the Schottky Barrier Height at the contact. For small diameters, the impact of hybridization on the Schottky Barrier Height (SBH) at a metal/nanotube contact is a deviation from the conventional "1/d" rule, where "d" is the diameter of the CNT. Hybridization causes a difference between the effective mass of electrons and holes highlighting limitations of the tight binding approximation in modeling CNT bandstructure. A strong family pattern in the effective mass is obtained. Corrections to the bandgaps of CNTs and graphene nano-ribbons for large supercells, now calculated within the GW framework [2] using a novel Wannier Function Approach proposed by Umari et al [3] allow even more accurate estimates of the bandgap and thereby the Schottky Barrier Height. An analysis of measured electrical characteristics of CNTFETs fabricated by partners at Cambridge will be presented. In collaboration with DuPont USA, Sheffield are also exploring FETs using chirality separated DNA-wrapped CNTs. Progress on this front will be reported at the meeting. (II) Graphene: The effects of gold deposition on monolayer graphene epitaxied on SiC (0001) substrate were examined via Scanning Tunneling Microscopy (STM) in collaboration with CNRS Mulhouse. Two types of surfaces with distinctive topography were demonstrated, (i) Intercalated gold clusters having no interaction with graphene and (ii) 13 X 13-G reconstruction attributed to a Moiré pattern arising from the intercalation of one monolayer of gold between a monolayer graphene and the underlying SiC substrate. This surface also displays a $2\sqrt{3}\times2\sqrt{3}R30$-Au (111) surface reconstruction interpreted as surface corrugation. The STS curve shows a possible hole-doping effect in the latter case. Theoretical models examined via Density Functional Theory in support of experiment will be presented [5]. **Conclusion:** Benefiting from the progress in CNT separation techniques worldwide allows the exploration of a methodology to link CNT structure and its electrical properties. Novel

	nanostructures of graphene on epitaxied SiC are demonstrated. **Acknowledgements**: **We thank external collaborators P. Umari, SISSA, Italy; S. Taioli, University of Trento, Italy; M. Cranney, F. Vonau, D. Aubel, L. Simon all from CNRS Mulhouse, France and DuPont USA. We thank the ESF and HPCX Europa for exchange visits for Mr. Premlal Pillai (Sheffield) to Mulhouse France, and HPCX-Europa for O. Petrenko (Sheffield) to Trieste, Italy.** [1] D. Casterman, M. M. De Souza, A. Tahraoui, C. Durkan, W.I. Milne "Role of hybridization on the Schottky barrier height of carbon nanotube field effect transistors", Phys Rev B 79,125407 (2009), also selected by the AIP for March 16, 2009 issue of the virtual journal of nanoscale science and technology. [2] S.Taioli, P. Umari and M. M. De Souza, "Electronic Properties of extended graphene nanomaterials from GW calculations", submitted to Physica Status Solidi ; Presented at the Kirchberg meeting Electronic Properties of novel materials molecular nanostructures, Kirchberg Austria, 2009. [3]. P. Umari, G. Stenuit, and S. Baroni, Phys. Rev. B 79,201104 (2009). [4] B. Premlal, N. Cranney, F. Vonau, D. Aubel, D. Casterman, M. M. De Souza and L. Simon, " Surface Intercalation of gold underneath a graphene monolayer on SiC (0001) studied by Scanning Tunnelling microscopy (STM) and Scanning Tunneling Spectroscopy", submitted to APL. [5].D Casterman, P. B. Pillai, M.M. De Souza, M. Cranney, F. Vonau, D. Aubel, L.Simon "*Ab initio* investigation of the doping effect of epitaxial graphene via intercalation of a Gold monolayer", NT2009 Beijing.

Shu- Pei Oei

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FONE Project:
Name of the Project
Device Electronics Based on NanoWIres and NanoTubes(DEWINT)

CNTs vs. SiNWs for Future Electronics

S.P. Oei[1], A.Tahraoui[1], A. Colli[2], Y. Zhang[1], S. Hofmann[1], S. Jejurikar[3], M. De Souza[3], W.I. Milne[1]

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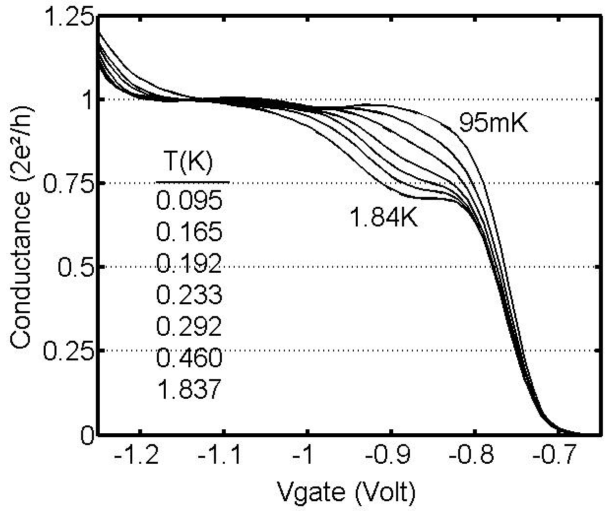
Since their identification in 1991 by Iijima[1] carbon nanotubes (CNTs) have been touted for use in next generation devices and circuits, including transistors, diodes, inverters, transparent contacts, vias and interconnects etc, but because of problems with chirality, diameter and positional control they have yet to be utilized. On the other hand one-dimensional silicon nanowires (SiNWs)[2] may be more attractive, due to the central role of silicon in the semiconductor industry. At the nanometer scale Si can become a direct band gap semiconductor due to quantum confinement. This makes SiNWs also very promising for optoelectronics. Unlike nanotubes, which naturally occur as a mixture of metals and semi-conductors, SiNWs are always semiconductors and they can be doped during or after deposition. Of course whether a “bottom up” approach can supersede standard “bottom down” technology is still a moot point.

In this presentation, I will describe the growth of CNTs and SiNWs using chemical vapour deposition (CVD) techniques with respect to controlling their yield, placement, crystallinity and in the case of CNTs, their chirality. The fabrication of bottom and top- gate transistors will be reported. In addition, I will describe the use of Oxide- Assisted Growth (OAG)[3] for the SiNW depositions which allows for the fabrication of top-gated SiNW transistors in single-step patterning[4] via dose-modulated e-beam lithography using a naturally formed 10−15 nm SiO_2 shell as the gate dielectric.

[1] S.Ijima Nature 354, 56, 1991
[2] S. Hofmann, et al., *J. Appl. Phys.* 94 (2003) 6005.
[3] A. Colli et al, J. Appl. Phys. 102, 034302 (2007)
[4] A. Colli et al, ACS Nano, Article ASAP

Hans Kosina **Presentation type :** Oral TU Wien, Institute for Microelectronics Gusshausstrasse 27-29/E360 Austria phone: +4315880136013 Fax: +4315880136099 email: kosina@iue.tuwien.ac.at **FONE Project:** DEWINT	**Transport modeling for Nanowires and Nanotubes** Quasi-onedimensional nanostructures have attracted much interest as they are recognized as promising building blocks for future nanoelectronic devices. A model for electronic transport in these structures has to address various physical effects: Quantum mechanical confinement, tunneling and interference, coupling of the semiconductor region to the contacts (open systems), non-equilibrium conditions (voltage applied to the contacts, irradiation), electron-phonon scattering and electron-photon interaction. The non-equilibrium Green's function (NEGF) technique has proven well suited for the numerical study of such problems. A device simulator based on the NEGF method and a tight-binding model for the band structure has been developed. We present a numerical analysis of the thermoelectric properties of scaled silicon nanowires, and of the opto-electronic response of CNT-based photodetectors.

Saturday September 12

Yashar Komijani **Presentation type :** Oral ETH Zurich Solid State Physics Laboratory 8093 Zurich Switzerland Tel : **+41 44 633 22 45** Fax: **+41 44 633 11 46** Email: **komijani@phys.ethz.ch** **Project** **SpinCo** **(group of Prof. Ensslin)**	**0.7-feature in p-GaAs Quantum Point Contacts** Yashar Komijani(1), Miklos Csontos(1), Ivan Shorubalko(1), Thomas Ihn(1), Klaus Ensslin(1), Dirk Reuter(2) and Andreas D. Wieck(2) (1) Solid State Physics Laboratory, ETH Hönggerberg, CH-8093 Zürich, Switzerland. (2)Angewandte Festkörperphysik, Ruhr-Universität Bochum, 44780 Bochum, Germany Conductance of narrow constrictions in two-dimensional electron/hole systems is quantized in units of $2e^2/h$. This is a universal effect which has been widely studied and well understood. Besides quantization in units of $2e^2/h$, electrical conductance spectroscopy measurements carried out on various p-type quantum point contacts (QPCs) revealed a rich variety of 0.7-like features, an onset of strong, spin-dependent electron-electron correlations. As displayed in the figure, an additional plateau at $0.7\times 2e^2/h$ emerges at higher temperature which gradually disappears with decreasing temperature on the contrary to standard conductance plateaus.  According to the most widely accepted explanation[1], the 0.7-plateau appears due to reduced spin-dependent transmission arising from Coulomb-blockade effect trough a quasi-localized state which forms in the middle of the QPC. As an electron passes through the quasi-localized state it reduces the transmission probability of another electron with opposite spin due to on-site Coulomb repulsion. The formation of the quasi-localized state in a QPC with a bare saddle-point potential is attributed to the oscillatory screening potential of the two-dimensional electron gas and is found to be a generic feature of the correlated electron system. In a two-dimensional hole gas (2DHG) the larger effective mass of holes compared to electrons leads to stronger screening of the bare QPC potential which is essential for the formation of such a quasi-localized state. This makes 2DHGs more suitable for studying the 0.7-feature.

	Although the above model explains many experimental results successfully, the presence of the quasi-bound state has not yet been proven experimentally. Here we report results of low temperature magnetotransport measurements on p-GaAs QPCs which provide experimental evidence for the formation of a quasi-localized state in the QPC. The experimentally observed 0.7 plateaus in our 2DHGs have been extensively studied as a function of the gate configuration, QPC bias, in-plane- and perpendicular magnetic field as well as temperature. By asymmetric in-plane gate biases we can apply an in-plane transverse electric field to the QPC. This results in the lateral displacement of the QPC channel, thus the generic 0.7-plateau can be distinguished from resonances arising from interactions with impurity states or with random imperfections of the background potential. Bias spectroscopy measurements at finite magnetic field reveal a considerable in-plane – out-of-plane anisotropy of the hole g-factor as expected from two-dimensional spin 3/2 systems. [1] Y. Meir, Journal of Applied Physics: Condensed Matter **20**, 164208 (2008).

Stefano Chesi	Quantum Hall ferromagnetic states and spin-orbit interactions in the fractional regime
Presentation type : Oral University of Basel Department : Physics Zip code : CH-4056 Country : Switzerland Tel: +41 61 267 3695 Fax: +41 61 267 1349 Email: stefano.chesi@unibas.ch **FONE Project:** Name of the Project (example : 05-FONE-FP-004 / Domain Walls and Spin-Polarised Currents (SPINCURRENT)	Stefano Chesi and Daniel Loss Department of Physics, University of Basel, CH-4056 Basel, Switzerland The competition between the Zeeman energy and the Rashba and Dresselhaus spin-orbit couplings is studied for fractional quantum Hall states. A transition of the spin-polarization direction is predicted to occur at a small value of the Zeeman energy. For a given fractional state, the phenomenon can be accurately described in the perturbative limit of high magnetic fields. We consider the Laughlin wavefunctions and the Pfaffian state as specific examples and show that this phenomenon allows one to obtain valuable information about the nature of the correlated ground-state, and in particular about its pair-correlation function. We discuss indications of non-analytic features around the fractional states and include significant effects of the nuclear bath polarization in the relevant regime of temperatures and magnetic fields. References [1] S. Chesi and D. Loss, Phys. Rev. Lett. **101**, 146803 (2008)

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FONE Project:

Relaxation of hole spins in quantum dots via two-phonon processes

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We investigate theoretically spin relaxation in heavy hole quantum dots in low external magnetic fields. We demonstrate that two-phonon processes and spin-orbit interaction are experimentally relevant and provide an explanation for the recently observed saturation of the spin relaxation rate in heavy hole quantum dots with vanishing magnetic fields. We propose further experiments to identify the relevant spin relaxation mechanisms in low magnetic fields.

References

[1] Mircea Trif, Pascal Simon, Daniel Loss, arXiv:0902.2457

Silvano De Franceschi **Presentation type :** Oral - CNR-INFM TASC - CEA Grenoble Zip code : 38054 Country : France Tel: +33 4 3878 5480 Fax: +33 4 3878 5096 Email: silvano.defranceschi@cea.fr **FONE Project:** Spin-coherent transport and control in quantum nanostructures (SpiCo)	**Spin-dependent transport in bottom-up semiconductor nanostructures** G. Katsaros (1), P. Spathis (1) , M. Stoffel (2), F. Fournel (1), M. Mongillo (1), A. Rastelli (2), O. G. Schmidt (2), E. Storace (3), J. Weis (3), K. von Klitzing (3), F. Jabeen (4), S. Rubini (4), F. Martelli (4), F. Capotondi (4), S. De Franceschi (1,4) (1) CEA Grenoble, 17 rue des Martyrs, F-38054 Grenoble, France (2) IFW Dresden, Helmholtzstrasse 20, D-01069 Dresden, Germany (3) MPI Stuttgart, Heisenbergstrasse 1, D-70569 Stuttgart, Germany (4) CNR-INFM TASC, S.S. 14 Km 163.5, I-34012 Basovizza (TS), Italy Nanostructured materials such as self-assembled semiconductor quantum dots and nanowires are currently investigated as potential building blocks for a wide range of applications, from (opto)electronics to biochemical sensing. At the same time, such nanomaterials offer unique opportunities to create relatively simple and tunable electronic systems in which complex quantum phenomena can be explored. In this talk, I will focus on quantum-dot devices obtained by contacting individual semiconductor nanostructures such as SiGe self-assembled islands and (In,Ga)As nanowires. In particular, I will present tunneling spectroscopy measurements in a magnetic field. These measurements provide accurate information on the quantum-dot electronic properties and, in particular, on the field-induced Zeeman splitting of the confined electronic states. In the case of silicon-germanium islands, our measurements reveal strong g-factor anisotropy as well as a pronounced gate-voltage dependence of the g-factor. Such a gate tunability of the g-factor opens an opportunity for performing all-electrical spin coherent manipulations.

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FONE Project:
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Exchange anisotropy, exchange bias and exchange springs

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Exchange anisotropy appears in a number of interesting dynamic problems in ferromagnet/antiferromagnet coupled systems. The key idea is that the ferromagnet is only affected by exchange coupling across the interface to a magnetic moment somehow induced at the interface of the antiferromagnet. In this talk some of the interesting dynamics unique to the ferromagnet/antiferromagnet interface are described including rotatable anisotropy, domain wall mass enhancement and pinning, and spin wave and resonance frequency shifts. Emphasis is placed on how measurement of dynamic processes can be used to determine important physical parameters. In this talk, specific examples will be given for domain wall dynamics [1], ferromagnetic resonance and spin wave propagation [2,3], and the switching of single-domain ferromagnetic particles [4]. Interesting and unusual results appear in systems with high levels of frustration and disorder. This is illustrated with a discussion of a peculiar bias reversal observed in spin glass exchange biased multilayers [5].

Interface exchange phenomena are discussed also for two novel systems that are not well understood at present. In one case we present preliminary results for a bilayer composed of a ferromagnet in contact with a multiferroic. A second example is exchange spring behavior observed in a lateral superlattice.

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FONE Project:
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Problems and Solutions with Integrating Magnetic Nanostructures into Functional 3-D Devices

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Most of magnetic nano-structures today are ultrathin or nanostructured films and multilayers. The main challenge is to find a suitable technology to integrate and to contact nanostructures in a reliable manner. Here, we investigate the problem of contact integration into functional 3-D devices and evaluate the influence of 3-D magnetic layer geometry on performance of magneto-electronic devices. Real devices are truly 3-dimensional structures. Their topography must absolutely be taken into consideration during the design phase since their inherent non-planarity will profoundly affect their magnetization profile. Our initial results strongly indicate that the “non-flatness” of magnetic layer strongly influences the possible magnetic states, alters the switching mechanism and leads to totally new behavior, which was not observed in classic 2-D thin film magnetic structures. Our experimental results will be compared with detailed micromagnetic simulations.

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Project

Intermolecular propagation of electron spin states (IMPRESS)

Electron spin resonance studies of purified nanotubes separated into metallic and semiconducting varieties.

Jamie Warner (1), Mujtaba Zaka (1), John Morton (1), Andrew Briggs (1)

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Carbon nanomaterials such as fullerenes, nanotubes and graphene have potential in spintronic devices. Their unique structure enables the construction of solid state electronic devices that exhibit quantum behaviour. However, understanding the intrinsic properties of electron spin in ensembles is often complicated by the presence of impurities, such as metal catalysts, amorphous carbon and graphitic carbon. There has been considerable debate over the spin resonance properties of carbon nanotubes. This has been fuelled primarily by measurements on ensembles containing mixed species of metallic and semiconducting nanotubes, along with impurities. We shall present our latest results on the electron spin resonance studies of carbon nanotubes that have been highly purified and also separated into metallic (98%) and semiconducting (98%) varieties using density gradient ultracentrifugation.

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Project
05-FONE-FP-002 / Intra-Molecular Propagation of Electron Spin States (IMPRESS)

Towards an Engineering of Spin Chains Inside SWCNTs with Controlled Spin Separation

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Linear arrangements of molecules which carry a spin are of fundamental interest and may eventually provide useful systems for quantum information processes. We performed experiments where the electron spin was provided from a nitrogen atom which was either encapsulated in a C_60 cage (N@C_60) or substituted a carbon atom on the cage (C_59N).
In both cases the separation of the spins was uncontrolled which called for the engineering of new structures where the spin separation is controlled. This can be done by functionalizing the fullerenes in a controlled manner. We analyzed such functionalized fullerens outside and inside the tubes by X-ray diffraction, Raman scattering and quantum-chemical calculations.
Examples of such systems were C_60 molecules functionalized with polyarenes as they were provided by the University of Nottingham. Raman scattering confirmed the successful filling and revealed information on the electronic structure of the functionalized molecules. X-ray diffraction allowed determining the averaged molecular distances inside the tubes. In agreement with quantum-chemical calculations the distances obtained were smaller than expected and subjected to strong fluctuations. This is due to molecular overlap of the functional groups and variations in molecular orientation. With respect to this problem bis-functionalized fullerenes with symmetric side groups such as were found to yield more controlled fullerene-fullerene distances. Details of the filling behaviour of such structures are in progress. Special attention is presently paid to SWCNTs where semiconducting and metallic tubes were separated by density gradient ultracentrifugation.

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Project

05-FONE-FP-010 / Spin-dependent transport and electronic correlations in nanostructures (SPINTRA)

Spin effects in transport through a single-molecule magnet in the Kondo regime

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Due to their peculiar physical properties such as an energy barrier for the spin reversal or long spin relaxation times, single-molecule magnets (SMMs) are inherently predestined for applications in novel molecular electronic and spintronic devices [1]. Several different physical phenomena associated with SMMs have been theoretically considered. It has been shown that the SMM's spin can be reversed by means of spin polarized current pulse [2] or by applying a spin bias [3]. Moreover, when bridged between two nonmagnetic metallic electrodes, a SMM can work as a spin filter [4].

Since spin-polarized current flowing through a SMM can affect the magnetic state of the molecule, it may become a key feature to be utilized in future SMM-based devices, and therefore the understanding of transport processes through SMMs is of major importance. So far, the main efforts have been focused on studying transport in the regime of weak coupling between electrodes and the molecule [5]. In the present work we analyze the opposite limit of the strong coupling, where under certain conditions new effects, such as the Kondo phenomenon, can occur.

We consider a SMM between two metallic ferromagnetic electrodes with collinear magnetic moments, which are also parallel to the easy axis of the molecule. Electronic transport is assumed to take place via the lowest unoccupied molecular orbital (LUMO) level of the molecule. The flexible density matrix renormalization group approach [6] is used for calculation of the LUMO level spectral function as well as the conductance of the system.

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Project

SPINTRA

Kondo conductance in metallic nanocontacts with magnetic impurities

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The electrical conductance of atomic metal contacts represents a powerful tool to detect nanomagnetism. Conductance reflects magnetism through anomalies at zero bias -- generally with Fano lineshapes -- due to the Kondo screening of the magnetic impurity bridging the contact. A full atomic-level understanding of this nutshell many-body system is of the greatest importance, especially in view of our increasing need to control nanocurrents by means of magnetism. Disappointingly, zero bias conductance and its anomalies are not presently calculable from atomistic scratch. Standard density functional theory (DFT) would be quantitative but does not describe many body effects; methods such as the numerical renormalization group do yield the correct many body conductance but apply (as is done e.g., in quantum dots) to very simplified Anderson impurity models (AIMs), treated so far essentially as toy models.

We demonstrate[1] a working route connecting approximately but quantitatively the two approaches and leading to a first-principles Kondo conductance calculation for a nanocontact, exemplified by a Ni impurity in a Au nanocontact.

A Fano-like conductance lineshape is re-obtained microscopically, and shown to be controlled by the impurity s-level position. We also find a relationship between conductance anomaly and geometry, as the two equilibrium positions of the Ni atom, bridging and substitutional, possess different bare spins (S=1/2 and S=1, respectively) with opposite antiferromagnetic and ferromagnetic Kondo screening - the latter exhibiting a totally different and unexplored zero bias anomaly. The present matching method between DFT and NRG should permit the quantitative understanding of this larger variety of Kondo phenomena at more general magnetic nanocontacts.

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FONE Project:

European Science Foundation EUROCORES Programme 05-FONE-FP-010-SPINTRA

Asymmetric dependence of 1/f noise on bias in fully epitaxial Fe/MgO/Fe magnetic tunnel junctions

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Dynamic conductance and low frequency noise in epitaxial Fe(100)/Fe-C/MgO(100)/Fe(100) (MTJ-A) and Fe(100)/Fe /MgO(100)/Fe(100) (MTJ-B) magnetic tunnel junctions have with R*A product (resistance by area) below 1 MOhm*μm² been studied as a function of the magnetic states in MTJs at biases up to 1.5V [1,2]. In the parallel state our epitaxial MTJs exhibit record low normalised 1/f noise (Hooge factor) being at least one order of magnitude smaller than previously reported, indicating low concentration of structural defects and good epitaxy. We have found that the Hooge factor asymmetry between parallel and antiparallel states may strongly dependent on the applied bias and its polarity both at room and low temperatures. The assymetric behavior of the low frequency noise as a function of bias polarity is in general reflects dependence of TMR on bias. Recent investigations [3] show that the asymmetric conductivity in respect to polarity of the applied bias voltage could be a consequence of the diffusion of the Oxigen atoms from MgO barrier to the top ferromagnetic electrode.

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FONE Project:

05-FONE-FP-010 /Spin-dpendent transport and electronic correlations in nanostructures (SPINTRA)

Spin wave modes in circular soft magnetic dots in vortex-state under in-plan magnetic field

Ahmad A. Awad[1], Konstantin Y. Guslienko[2,3] , Juan F. Sierra[1], Gleb N. Kakazei[4], Dong-Soo Han[5], Sang-Koog Kim[5], Vitali Metlushko[6], and Farkhad G. Aliev[1]

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Special interest in the magnetic vortices is inspired by the possibility of easy dynamical switching of the vortex core magnetization direction [1] that has been suggested as a new route to create nanoscale memory cells for data storage. Precise mapping of the high frequency spin excitation eigenmodes, especially the eigenmodes breaking axial symmetry, is of great importance because they are modes expected to define the vortex switching times. In the talk we report on broadband measurements of the spin dynamics in circular Permalloy dots excited by in-plane rf with the variable angle between the excitation and bias (H) fields.

Two sets of square arrays of Py circular dots were fabricated by lithography and lift-off techniques on a Si(100) substrate [2]. The first set includes 3 samples with same thickness and diameter and different dot center-to-center distance, d. The second set included two arrays of Py dots with different thickness and diameters. The excited SW were probed by broadband spectrometer based on vector network analyzer [2,3]. The dots are in the vortex ground state. We identify the vortex nucleation (H_n) and annihilation (H_a) fields. Fig. 1a shows the typical hysteresis for in-plane H (H_n and H_a marked by vertical arrows).In-plane bias magnetic filed (H) up to above the dot saturation field was applied. The dots were excited by in-plane rf with the variable angle between the excitation and bias fields.

The measured spectra of the dots with L=25 nm and D=1035 nm are shown in Fig. 1 for parallel (Fig. 1b) and perpendicular (Fig. 1c) rf drive. The dynamic response remains qualitatively unaffected by the interdot dipole-dipole interaction ensuring that we are observing a single dot eigenmodes. Dots with aspect ratio β (height to dot radius) varied from 0.03 to 0.1 were explored. We found that for β exceeding approximately 0.05 variation of spin wave eigenfrequencies with β deviates from the predicted for magnetostatic modes $\sqrt{\beta}$ dependence. The frequency splitting of two lowest azimuthal modes was observed. The experimentally observed dependence of the frequency splitting on the dot aspect ratio was reasonably well described by dynamic splitting model accounting the spin wave –vortex core interaction.

Increasing H reveals three main field regions in the excitation spectra: (i) only single vortex is stable (SV); both the quasi-uniform and vortex states are stable (metastable vortex, MV); and the quasi-uniform or saturated state (US). In the SV regime ($H<H_n$) two

frequency doublets are observed with the eigenfrequencies being independent on the orientation of rf field (see Fig. 1b,c). The spin waves are described by integers (n, m), which indicate number of nodes of the dynamic magnetization along radial (n) and azimuthal (m) directions. For in-plane rf excitation field the azimuthal SW with m = ±1 and the gyrotropic mode can be excited. These low-field doublets can be described as azimuthal SW with the indices m=±1, n=0 [5], indicated in Fig. 1 as (1), and with the indices m=±1, n=1. The eigenmodes (n, m) classification can be approximately used up to H ≈ Hn. The m=±2 modes are responsible for formation of the frequency branch (2) observed with parallel pumping. The “soft” mode (3) exists also only with parallel pumping when the vortex core is close to the dot edge at Hn<H<Ha and disappears at H ≥ Ha. Increasing H with the perpendicular pumping also suppresses the modes |m|=1 at H>Hn. The lowest mode (m=+1, n=0) reveals an additional splitting at low H for both the pumping schemes, which is unexpected because this mode is not degenerate.

The modes observed in the MV state (Hn<H<Ha) are qualitatively different when excited with perpendicular or parallel pumping [2]. A strongly field dependent mode (3) is observed for the MV in parallel configuration (Fig. 1b). Its frequency decreases with increasing H. In contrast, in the perpendicular scheme a strong parabolic-like mode (3´) is excited in the MV state (Fig. 1c). Near Ha the most contrast eigenmode (3´) transforms abruptly into the almost uniform mode (4) existing at H>Ha in the US. To interpret the excited SW we conducted the micromagnetic simulations for a single dot. The main SW eigenmodes, namely the first, second azimuthal and first radial SW modes, have been detected and studied in Py magnetic dot arrays as function of the dot aspect ratio in the range 0.03 - 0.1 at H=0. The observed splitting (Fig. 2b,c) of the degenerated azimuthal doublets (n=0,1, m=±1) is in good agreement with the model of the magnetostatic modes in the vortex state dots that takes into account dynamical origin of the azimuthal modes frequency splitting [4]. In contrast to the first doublet, the azimuthal mode frequency splitting of the second doublet shows a maximum as function of the dot aspect ratio.

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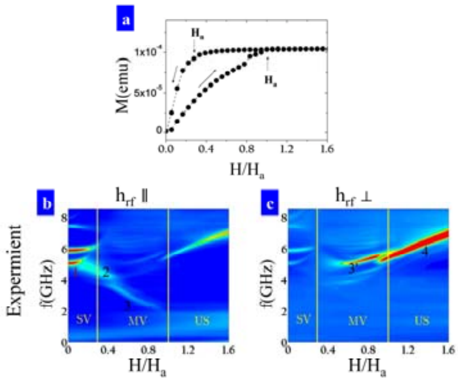

Figure 1

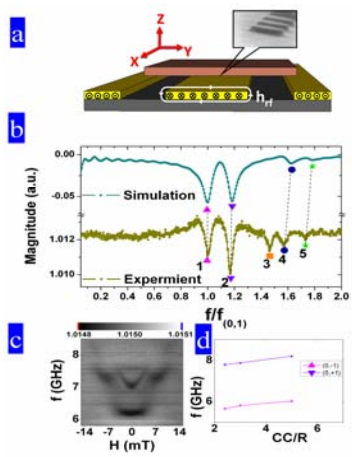

Figure 2

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Project

05-FONE-FP-006 / Spin-coherent transport and control in quantum nanostructures (SpiCo)

Theory of magneto-optical measurements of bilayer graphene

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Recently, graphene materials attracted a lot of theoretical and experimental attention. In particular, peculiar low-energy behaviour of transport carriers has been found to give rise to fascinating new physical phenomena [1]. In this work, we use the tight-binding approximation to investigate the magneto-optical properties of bilayer graphene. First, we study the influence of lattice-symmetry breaking parameters on the Landau level (LL) structure and the robustness of selection rules for inter-Landau-level transitions [2]. Next, we incorporate into our model an external electric field perpendicular to the graphene layers. We present a self-consistent calculation of the resulting interlayer asymmetry [3]. We show how this asymmetry influences the Landau level spectrum in bilayer graphene and the observable inter-Landau level transitions when they are studied as a function of high magnetic field at fixed filling factor as measured experimentally [4]. We also analyse the magneto-optical spectra of bilayer flakes in the photon-energy range corresponding to transitions between degenerate and split bands of bilayers.

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Project

Spin-Dependent Transport and Electronic Correlations in Nanostructures (SPINTRA)

Spin Filtering and TMR in Presence of Electron Interactions

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We consider quantum transport and tunneling magnetoresistance (TMR) through an interacting quantum dot in the Coulomb blockade regime, attached to ferromagnetic leads [1]. We show that there exist two kinds of anomalies of TMR, which have different origin. One kind has the single particle origin and can be interpreted in the frame of non interacting electrons model. The second kind of anomalies is caused by electron interactions. The TMR minima (and its sign change) of single particle origin appear at the conductance resonances for asymmetric dot-lead coupling. They are robust to the temperature increase and gradually transform into local maxima when the symmetry of the dot-lead coupling increases. The anomalies associated with electron interactions appear at Coulomb blockade, in-between conductance resonances. The TMR maximum at Coulomb blockade, far exceeding 100 % is of this origin. It appears when in antiparallel (AP) configuration both the current the dot occupancy are spin unpolarized. This maximum survives at typical temperatures of experiment. We also predict the TMR sign change at Coulomb blockade, caused by electron interactions. It appears due to the rapid polarization switching of the current [2] in (AP) configuration and the enhancement of the conductance in one of the (AP) spin channels by the dot-leads coupling asymmetry. It is very sensitive to the increase of temperature and depends on the initial polarization of the current coming from the leads. We also show that the nature of the discussed anomalies can be experimentally resolved by the change of the dot-leads coupling asymmetry and/or temperature. The results are presented in the context of recent experiments on semiconductor quantum dots in which similar features of TMR have been observed.

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FONE Project:
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The intrinsic domain wall resistance of Fe films with a periodic domain pattern

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The intrinsic domain wall resistance (DWR) of 180° Néel walls in a polycrystalline Fe film is determined by creating a periodic domain pattern, obtained by locally inducing exchange bias with a template of antiferromagnetic CoO lines on top of the film [1]. After field cooling, the coercivity is spatially modulated, resulting in 180° domain walls. To determine the intinsic DWR, a rotating magnetic field is used to reversibly create and annihilate the domain walls. After correcting for the anisotropic magnetoresistance, the extracted DWR is positive and can be interpreted in terms of the giant magnetoresistance mechanism.

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Project

05-FONE-FP-010/ Spin-dependent transport and electronic correlations in nanostructures (SPINTRA)

Contact superconductivity at In/PbTe interfaces: weak links and Andreev reflection

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Development of transparent superconductor-semiconductor (S-Sm) interfaces is crucial for entangled electron pair production in solid by means of Cooper pair injection [1]. In the present work, we study the microscopic nature of the interface between indium and lead telluride (In/PbTe) [2]. The samples have been obtained by thermal evaporation of In on MBE-grown PbTe quantum wells embedded between $Pb_{1-x}Eu_xTe$ barriers. E-beam lithography-defined S-Sm junctions have dimensions covering the range from 200 μm to 0.5 μm.
For all S-Sm structures studied, we have confirmed lack of Schottky barriers and metallic conductance across the junctions. However, the real junction areas are much smaller than apparent ones, pointing to the formation of weak links between In and PbTe. These links exhibit superconducting transitions in the temperature range between 4 to 7 K, well above the usual transition in the indium layer [3,4]. Thus, they give rise to additional superconducting phases, whose presence we have confirmed by direct magnetic susceptibility measurements. Furthermore, differential conductance as a function of the DC voltage shows zero-bias peaks much higher than those expected for Andreev reflection. We assign them to critical-current effects in the weak links. The weak-link superconductivity persists up to magnetic fields as high as several Tesla, suggesting nanometer scale diameters of the links. We show experimental evidences that dislocations acting as fast diffusion paths for In and/or Pb may be responsible for the link formation. However, at temperatures lower than T_c of the indium layer, the interface conduction becomes determined by the Andreev reflection. From our data, we estimate the interface transmission to be at least 30%. Therefore, despite the complex interface physics, our system is useful for studying Cooper-pair injection-related phenomena at low temperatures assuming a simple S-Sm interface.

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Project

SPINTRA

Transport in T-shape ballistic junction: Back action in linear and non-linear regime

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Multi-terminal ballistic junction systems attract much attention for their interesting physical properties and as candidates for high speed logic gates with a very low power consumption [1]. Recent experiments [2] on such system show that a current switching is accompanied by voltage oscillations in floating channels. Here we want to present modelling of three-terminal T-shape ballistic junction (TBJ) and explain back action of the floating channels. We assume that the device consists of three perfect leads and a ballistic coupling region. Transport properties are determined by means of the non-equilibrium Green function formalism for a tight binding model [3]. In the first part, our procedure is used to the linear regime when the applied bias voltage is small. We present two different device configurations at low temperature limit. The applied model explains conductance characteristics with dips and peaks as a result of back action in a voltage terminal (in the floating electrode with a net current I=0). Bend resistance and threshold effect play a significant role in this case. Voltage fluctuations in the floating electrode are related to asymmetric changes of transmissions between leads. In the second part, the applied voltage is large (non-linear regime) and the temperature is low. Operating the voltage between left (V_L=V/2) and right (V_R=-V/2) branch, the TBJ shows a strong non-linear behavior of the potential in the detector electrode. Different model parameters, i.e., hopping integrals, number of channels, local potentials in the leads, are varied. At most cases voltage on the detector electrode V_D is negative. For a small bias voltage, we observe that V_D becomes positive. This effect is connected with bend resistance. We study also an influence of the threshold effect on the dependence of V_D in various situations, i.e. when the conductance shows a peak or a dip.

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Project
05-FONE-FP-010 / Spin-dependent transport and electronic correlations in nanostructures (SPINTRA)

Co nanowire as a strong magnetic gradient source for magnetic resonance force microscopy

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The magnetic field gradient in magnetic resonance force microscopy (MRFM) is usually created by a small probe magnet. Micromagnets with well-known magnetic properties have to be used in MRFM for reliable MRFM image deconvolution. Magnetic nanowires electrodeposited into the cylindrical pores of track-etched polymer membranes are very well suited for this purpose because such nanowires provide a very high field gradient (up to 10 MT/m). Moreover, the cylindrical shape with large aspect ratio of the magnetic nanowire is very convenient, since cylinders are the best compromise between high symmetry and strong stray field.

We propose to use a Co magnetic nanowire as source of a strong magnetic field gradient for MRFM. Using a Co nanowire (diameter ~ 100 nm) we succeeded to perform paramagnetic resonance imaging as well as ferromagnetic resonance (FMR) imaging of sub-µm size samples. The local imaging capability of MRFM is lost in the case of ferromagnetic samples due to the strong coupling between the spins. However, it is possible to excite highly localized modes to recover the local FMR imaging capability.

Piotr Trocha	Dicke and Fano effect in orbital Kondo transport through double quantum dots
Presentation type: Poster Adam Mickiewicz University Department of Physics Country : Poland Email: piotrtroch@gmail.com **Project** N. ERAS-CT-2003-980409/ SPINTRA	Piotr Trocha (1), Józef Barnaś (2) (1) Department of Physics, Adam Mickiewicz University, 61-614 Poznań, Poland (2) Institute of Molecular Physics, Polish Academy of Sciences, 60-179 Poznań,, Poland Dicke- and Fano-like resonances in electronic transport through double quantum dots in orbital Kondo regime are considered theoretically. In general, the double dot system is coupled via both Coulomb interaction and direct hoping. Moreover, the indirect hopping processes between the dots (through the leads) are also taken into account. To investigate system's electronic properties we apply slave-boson mean field technique. With help of the SBMF approach the local density of states for both dots and the transmission probability (as well as conductance) is calculated.

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Project

Spin-dependent transport and electronic correlations in nanostructures (SPINTRA)

Influence of Coulomb interactions on current auto- and cross-correlations in coupled quantum dot

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In this contribution we study dynamical correlations in electrical currents flowing through four-terminal system which consists of two large quantum dots coupled in parallel. Transport properties of the system are determined in the limit of sequential tunneling. In general, due to the Pauli exclusion principle, the Fano factor is reduced below Poissonian value and the cross-correlations are negative. We show that strong dot-dot Coulomb interactions together with assymetrical coupling to the electrodes can lead to bunching of the tunneling events which results in an enhancement of the auto-correlations above Poissonian value and to the positive cross-correlations. The strong inter-dot coupling is also responsible for the charge pumping effect: addition/extraction of one electron into/out the top QDs leads to pushing an electron out/into the bottom QDs. We have decomposed the dynamical parts of auto- and cross-correlation functions in order to show individual contributions of various dynamical processes in the charge space which are responsible for positive cross-correlations and an enhancement of auto-correlations.

Our theoretical results are inspired by recent experiment of McClure et al. in which the gate-controlled sign reversal of noise cross correlation were demonstrated [1].

References

[1] D.T. McClure et al. Phys. Rev. Lett., 98, 056801 (2007).

Stefan Krompiewski **Presentation type :** Poster Institute of Molecular Physics, Polish Academy of Sciences 60-179 Poland Tel: 004861 8695126 Fax: 004861 8684524 Email: stefan@ifmpan.poznan.pl **FONE Project:** Name of the Project 05-FONE-FP-010 Spin-dependent transport and electronic correlations in nanostructures (SPINTRA)	**Spin-sensitive transport in graphene** S. Krompiewski (1) (1) Institute of Molecular Physics, Polish Academy of Sciences, M. Smoluchowskiego 17, 60-179 Poznań, Poland This contribution reports on spin-sensitive transport properties of graphene nanoribbons sandwiched between either two ferromagnetic contacts or one ferromagnetic and the other - paramagnetic. In the former case, giant magnetoresistance (GMR) effect is discussed, whereas in the latter the attention is directed to current spin-polarization and spin-accumulation at the ferromagnetic drain-electrode. It turns out that all these phenomena depend strongly on the current direction (zigzag vs. armchair transport direction), as well as on the aspect ratio of the ribbon (width/length). On average: (i) the GMR effect for armchair-edge graphene ribbons is stronger than that for zigzag-edge graphene ribbons, and (ii) at small gate voltages the spin-polarization of conductance is correlated with the spin accumulation in the vicinity of the ferromagnetic electrode.

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FONE Project:
Name of the Project
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Tunneling Anisotropic Magnetoresistance Effect in CoPt Systems

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Tunneling anisotropic magnetoresistance (TAMR) effect, first observed in (Ga,Mn)As ferromagnetic semiconductors, originates in the dependence of tunneling density of states in a ferromagnetic layer on magnetization direction. This effect becomes remarkable in materials with a strong spin-orbit coupling and large magnetic moments. We use a tight-binding model to describe the electronic structure of a layered system consisting of Co and Pt slabs and to study the anisotropic densities of states by changing the direction of local moments in the magnetic slab. In the same way, adopting the Landauer-Buttiger scheme, we calculate also the conductance that directly defines TAMR. We discuss the role of anisotropic density of states and of the current matrix elements in TAMR and compare the results to ab initio calculations [1] and experiments [2].

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05-FONE-FP-010
Spin-dependent transport and electronic correlations in nanostructures (SPINTRA)

GaMnAs Curie Temperature Determination from Transport Data

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We present a systematic comparison of reliability and accuracy of Curie temperature determination by various transport based methods: temperature derivative of resistivity [1], Arrott-plot technique, and (planar) Hall effect due to the spontaneaous magnetization.

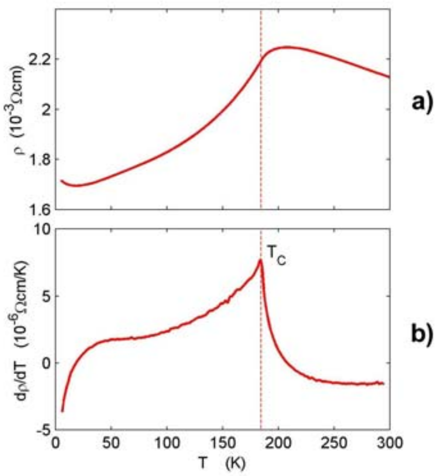

Figure 1 a) Temperature dependence of resistivity of GaMnAs sample with 13%Mn. b) Numerically determined temperature derivative of the dependence from Fig. 1a); the singularity at TC=186 K is obvious.

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FONE Project:

05-FONE-FP-010: Spin-dependent transport and electronic correlations in nanostructures (SPINTRA)

Anisotropic Magnetotransport Properties in Ferromagnetic GeMnTe

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Interest in GeMnTe has been stimulated by recent reports on ferromagnetic behavior up to 190K in epilayers of this material based on SQUID magnetometry [1]. However, a quantitative analysis of the SQUID data shows that a considerable part of Mn does not show up in the ferromagnetic component of the magnetization signal. In the present work, magneto-transport experiments were performed to elucidate the relevant amount of Mn that is ferro-magnetically coupled through the mobile holes. In particular, we investigate the influence of coercive fields on the magneto transport of GeMnTe epilayers to determine the manifestation of ferromagnetism in the samples. The structures were grown by molecular beam epitaxy on (111) BaF_2 substrates. 500 nm $Ge_{1-x}Mn_xTe$ layers were grown on 10 nm GeTe with Mn content ranging from *x*=0.1 to 0.5 and hole concentrations of about 3×10^{21} cm^{-3}. For magneto transport measurements, Hall bars were fabricated by optical lithography and etching. SQUID data of the sample with Mn content of *x*=0.5 are shown in Fig.1a, with the insert depicting hysteresis loops at T= 5K, 77K and 140K. From this data we infer a TC of around 190K and that the ferromagnetic signal coexists together with paramagnetic characteristics. In Fig. 1b anisotropic magneto resistance (AMR) measurements are shown for temperatures ranging from 60 to 95K. The current direction is along [1-10] and the magnetic field either transversal along <11-2> (blue) or longitudinal along <1-10> (red). The difference between the two in-plane AMR's dis-appears at T=85K. Below this temperature the AMR exhibits the characteristic features of a ferromagnetic metal, namely, that the transverse MR is lower than the longitudinal one. Additional measurements of the planar Hall effect (PHE) [2] yield a ferromagnetic Curie temperature of 85K. Above 85 K,

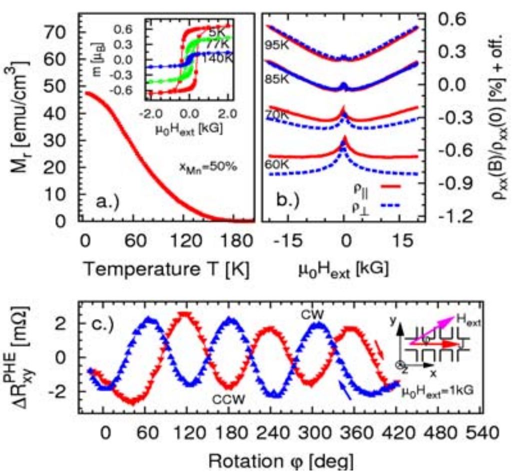

Fig. 1: *SQUID (a) and anisotropic magneto-resistance (b) for a $Ge_{0.5}Mn_{0.5}Te$ layer as a function of temperature and magnetic field. (c) Planar Hall effect of a $Ge_{0.9}Mn_{0.1}Te$ layer at 2 K and 0.1 Tesla for clockwise and counterclockwise directions.*

	the dependence of the AMR on the applied magnetic field strongly changes and the transverse MR becomes larger than the longitudinal MR. This difference vanishes only at a T of about 190K where the measured magnetic moment (SQUID) vanishes. For a sample with Mn content of *x*= 0.1, the PHE as a function of the in-plane rotation angle is shown in Fig. 1 c for an applied field of 0.1 T and T=2K. For clockwise (CW, blue) and counterclockwise (CCW, red) rotation, we see the typical reversal of the signal polarity in the PHE. Increasing the temperature leads to a disappearance of this difference in the PHE measurements, whereas the in-plane 120° symmetry remains in the magneto transport data. Our results indicate large differences in the Curie temperature depending on the analysis method, which can be explained by the existence of magnetic clusters or precipitates in the samples, in agreement with the reduced saturation magnetization. [1] Y. Fukuma, *et al.*, Appl. Phys. Lett. **93,** 252502 (2008). [2] H.X. Tang, *et al.*, Phys. Rev. Lett. **90**, 107201 (2003).

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