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PL-1

Quantum information processing with electron spin resonance

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The quantum spins associated with electrons and nuclei, with their discrete quantum levels and weak interactions with other degrees of freedom, offer a natural class of systems for embodying quantum information. Many possible condensed matter electron-spin-based qubits have been examined, including, for example, paramagnetic defects and bound donors in semiconductors, self-assembled and lithographically defined quantum dots, and various paramagnetic molecular systems. High spin systems (for which $S>1/2$) with anisotropy, such as artificial molecular nanomagnets, offer the possibility of higher density information storage and may host quantum algorithms locally. We have studied the phase coherence of spin states in nanomagnets and optimised the phase memory time by chemical engineering of the molecular structures. Traditionally, quantum spin states are manipulated using static and resonant magnetic fields. However, electrically-controllable spin qubits would offer substantial architectural advantages for the design of a quantum information processor because electric fields may be applied over shorter length scales than magnetic fields. Certain kinds of molecular magnets, for example those exhibiting spin frustration and broken inversion symmetry in their internal structure, may be suitable candidates.

Potential of Ferroelectric tunnel junctions

A. Chanthbouala [1], A. Crassous [1], V. Garcia [1,2], S.Fusil [1], K. Bouzehouane [1], L. Bocher [3], A. Gloter [3], C. Deranlot [1], S. Xavier [4], N. Mathur [2], M.Bibes [1] and A. Barthélémy [1]

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The phenomenon of electron tunneling has been known since the advent of quantum mechanics. Its interplay with magnetism, i.e., spin-dependent tunneling observed in magnetic tunnel junctions has aroused considerable interest and led to important advances in the field of magnetic random access memories. In 1971, Esaki *et al.* proposed to couple another ferroic order, ferroelectricity, with quantum-mechanical tunnelling in ferroelectric tunnel junctions composed of metallic electrodes with a ferroelectric tunnel barrier. The recent advances in the growth of ferroelectric thin films and the possibility to achieve stable and switchable ferroelectric polarization in nanometer-thick films have now allowed achieving this goal. In these ferroelectric tunnel junctions, large changes in the resistance are observed and correlated with the direction of the ferroelectric polarisation of the barrier [1]. This give rise to large electroresistance phenomena (TER) that amounts to 75000% for a 3nm $BaTiO_3$ tunnel barrier as revealed by scanning probe microscopy. This resistance switching in solid-state ferroelectric tunnel junctions is large, fast, stable, reproducible and reliable electroresistance offering new opportunities for ferroelectrics in future data storage [2] When a ferromagnetic counter electrode of Fe is added to obtain a ferroelectric magnetic tunnel junction, a modulation of tunnel magnetoresistance reflecting changes in the spin polarisation of the electrode when the ferroelectric polarisation is switched have been observed [3]. These junctions provide an interesting opportunity to obtain a robust room temperature magnetoelectric effect and to achieve an electric control of the spin polarisation.

1] V. Garcia et al. ; Nature 460, 81 (2009) ; A. Gruverman et al. ; Nanoletters 9, 3539(2009), A. Crassous et al. ; Appl. Phys. Lett. **96**, 042901 (2010)
2] A. Chanthbouala et al. ; to appear in Nature Naotechnology (2011)
3] V. Garcia et al. ; Science 327, 1106 (2010) ; S. Valencia et al. ; Nat. Mat. 10, 753 (2011)

PL-3

Light, Metal and Molecules

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Metal structures that resonate with electromagnetic waves and molecules or materials offer many interesting possibilities both in terms of fundamental science and applications. To illustrate this, we will focus on molecule – metal interactions and the role of surface plasmons. The possibility of coupling molecules to electromagnetic vacuum fluctuations which leads to hybrid states having strongly modified energies will be presented together with the important implications for molecular and material science.

PL-4

The graphene lattice: perfection, distortion and motion.

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The perfect hexagonal la‪ttice of graphene is not only the origin of its unique electronic properties but also an ideal realization of a purely two-dimensional crystal with not less exceptional behaviour.

Graphene has a rippled structure at any finite temperature, negative lattice expansion, is elastic up yo very large deformations but displays many anharmonic effects, has a peculiar phonon spectrum and melts in a very unusual way. These and other lattice properties due to defects, grain boundaries and edges, calculated by accurate atomistic simulations, will be the subject of this talk

Dirac Fermions in HgTe Quantum Wells

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HgTe quantum wells have a linear band dispersion at low energies and thus mimic the Dirac Hamiltonian.

Changing the well width tunes the band gap (i.e., the Dirac mass) from positive, through zero, to negative.

Wells with a negative Dirac mass are 2-dimensional topological insulators and exhibit the quantum spin Hall effect, where a pair of spin polarized helical edge channels develops when the bulk of the material is insulating.

Our transport data provide very direct evidence for the existence of this third quantum Hall effect.

Wells with a thickness of 6.3 nm are zero gap Dirac systems, similar to graphene. However, zero gap HgTe wells possess only a single Dirac valley, which avoids inter-valley scattering.