TT 6 Solids At Low Temperature: Amorphous and Tunnel Systems, Glasses, ...

Time: Monday 10:30–13:00 Room: HSZ 105

Keynote Talk

TT 6.1 Mon 10:30 HSZ 105

Nuclear quadrupoles and magnetic-field effects in amorphous solids — •Alois Würger — CPMOH, CNRS - Université Bordeaux 1, 351 cours der la Libération, 33405 Talence, France

In recent years, the low-temperature dielectric properties of various insulating glasses (silica based materials, glycerol, mixed crystals) have been shown to depend on an applied magnetic field B [1]. The amplitude of dielectric echoes of tunnel systems oscillates with B, with a period of about 20 milliTesla, and attains the maximum value above 1 Tesla. At temperatures below 1 Kelvin, both the real and imaginary parts of the dielectric function vary with the magnetic field.

These findings are not accounted for by standard theory for diamagnetic and insulating solids. Several models have been proposed that are based on the Aharanov-Bohm phase of atoms on circular trajectories, or on nuclear spins [2]. We show that experiments clearly speak in favor of the latter, and point out the crucial role of nuclear quadrupole moments.

In particular, we discuss the magnetic-field dependence of the dielectric function. There is strong evidence that it arises from Debye relaxation.

[1] P. Strehlow et al., PRL 84, 1938 (2000); S. Ludwig et al., PRL 88, 075501 (2002); C. Enss and S. Ludwig, PRL 89, 075501 (2002); R. Haueisen and G. Weiss, Physica B 316, 555 (2004); P. Nagel et al., PRL 92, 245511 (2004);

[2] S. Kettemann, P. Fulde, P. Strehlow, PRL 83, 4325 (1999); A. Würger, PRL 88, 075502 (2002); A. Würger, A. Fleischmann, C. Enss, PRL 89, 237601 (2002)

TT 6.2 Mon 11:00 HSZ 105

Investigating the microscopic nature of tunnelling processes in amorphous glycerol — •Masoomeh Bazrafshan[1], Marek Bartkowiak[1], Herbert Zimmermann[2], Andreas Fleischmann[1], and Christian Enss[1] — [1]a) Kichhoff-Institut fuer Physik, Universitaet Heidelberg, Germany — [2]b) Max-Planck-Institut fuer medizinische Forschung, Heidelberg, Germany

At temperatures below a few kelvin the properties of amorphous solids are dominated by atomic tunnelling systems. Over the past few years it was shown that the unexpected magnetic field effects, observed in many non-magnetic multicomponent glasses, originate from a coupling of the tunnelling motion to nuclear quadrupole moments present in the system. In dielectric polarisation echo experiments a strong magnetic field dependence of the echo amplitude as well as a periodic modulation of the echo decay, the so-called quantum beating, can be observed. The frequency of the quantum beating corresponds to the energy splitting of the quadrupole levels.

In this work we present dielectric echo measurements on partially deuterated glycerol, a system wich allows to introduce nuclear quadrupoles at specific sites of the molecule. By comparison with numerical calculations of the transition amplitudes we are able to suggest possible microscopic scenarios for tunnelling processes in amorphous glycerol. We believe that this work will provide important input for the development of a microscopic theory of glasses.

TT 6.3 Mon 11:15 HSZ 105

Low temperature breakdown of coherent tunneling in amorphous solids by the nuclear quadrupole interaction — •Alexander Burin[1], Peter Fulde[2], and Ilya Polishchuk[3] — [1]Department of Chemistry, Tulane University, New Orleans, LA 70118, USA — [2]Max-Planck-Institut fur Physik Komplexer Systeme, D-01187*Dresden, Germany — [3]RRC Kurchatov Institute, Kurchatov Sq. 1, 123182 Moscow, Russia

We consider the effect of the internal nuclear quadrupole interaction on quantum tunneling of complex multi-atomic two-level systems. Two distinct regimes of strong and weak interactions are found. They depend on the relationship between the characteristic energy of the internal interaction λ_*, which is directly proportional to the number of tunneling atoms per tunneling system, and a bare tunneling coupling strength Δ_0. When $\Delta_0 > \lambda_*$, the internal interaction is negligible and tunneling remains coherent, being defined by the strength of Δ_0. When $\Delta_0 < \lambda_*$, coherent tunneling breaks down and the effective tunneling amplitude decreases by an exponentially small overlap factor $\eta^* \ll 1$ between the internal ground states of the left and right well, affecting thermal and kinetic properties of tunneling systems. The theory is applied to interpret the anomalous behavior of the resonant dielectric susceptibility in amorphous solids for $T \leq 5mK$ in terms of the nuclear quadrupole interaction. We suggest clarifying experiments using external magnetic fields to test the theories predictions and to shed some light on the internal structure of tunneling systems in amorphous solids.

TT 6.4 Mon 11:30 HSZ 105

Effect of Nuclear Quadrupole Interaction on the Relaxation in Amorphous Solids — •Ilya Polishchuk — Kurchatov Institute, 123182 Moscow, Russia

Recently it has been experimentally demonstrated that certain glasses display an unexpected magnetic field dependence of the dielectric constant. In particular, the echo technique experiments have shown that the echo amplitude depends on the magnetic field. The analysis of these experiments results in the conclusion that the effect seems to be related to the nuclear degrees of freedom of tunneling systems. The interactions of a nuclear quadrupole electrical moment with the crystal field and of a nuclear magnetic moment with magnetic field transform the two-level tunneling systems inherent in amorphous dielectrics into many-level tunneling systems. The fact that these features show up at temperatures T ¡ 100mK, where the properties of amorphous materials are governed by the long-range dipole - dipole interaction between tunneling systems, suggests that this interaction is responsible for the magnetic field dependent relaxation. We have developed a theory of many-body relaxation in an ensemble of interacting many-level tunneling systems and show that the relaxation rate is controlled by the magnetic field. The results obtained correlate with the available experimental data. Our approach strongly supports the idea that the nuclear quadrupole interaction is just the key for understanding the unusual behavior of glasses in a magnetic field.

TT 6.5 Mon 11:45 HSZ 105

The Mystery of Quantitative Universality - Resolved? — •Reimer Kühn — King's College London, UK

We present a simple explanation of the mysterious so-called quantitative universality of glassy low-temperature physics in terms of solutions of microscopic glass-models obtained earlier.

TT 6.6 Mon 12:00 HSZ 105

Thermal Conductivity of Glasses and the "Boson Peak" — •Walter Schirmacher — Technische Universität München, Phys. Dept. E13, D-85747 Garching

A theory for the anomalous vibrational and thermal properties of disordered solids based on the model assumption of randomly fluctuating transverse elastic constants is presented. Mean-field expressions for the vibrational density of states and the energy diffusivity are derived with field theoretical techniques. As in previous approaches of this type the boson peak (enhancement of the low-frequency density of states) is explained as a result of the frozen-in disorder and compares well with the experimental findings. The plateau in the temperature variation of the thermal conductivity and the behavior beyond the plateau is shown to arise from the enhanced scattering in the boson peak regime and to be essentially a harmonic phenomenon.

TT 6.7 Mon 12:15 HSZ 105

Properties of transition-metal nanoclusters on biological substrates — •T. Herrmannsdörfer[1], A. D. Bianchi[1], T. P. Papageorgiou[1], F. Pobell[1], J. Wosnitza[1], S. Selenska-Pobell[2], K. Pollmann[2], M. Merroun[2], and J. Raff[2] — [1]Institut Hochfeld-Magnetlabor Dresden (HLD) and — [2]Institut für Radiochemie, Forschungszentrum Rossendorf, P.O.-Box 51 01 19, D-01314 Dresden, Germany

Micro- and nanogranular materials can reveal strongly altered properties compared to their bulk counterparts. In particular, their magnetic and superconducting behaviour can be drastically changed. We have investigated transition-metal clusters with a well defined size of 1 to 1.5nm which are isolated and separated from each other. These metal nanoclusters have been deposited on a regular square lattice of a biological template. In more detail, this template is a purified self-assembling paracrystalline surface layer (S-layer) of *Bacillus sphaericus* JG-A12 which exhibits square symmetry and is composed of identical protein monomers. These S-layer proteins are capable of selective and reversible binding of high amounts of metals, making the metallic nanocluster covered S-layer also interesting for technological applications. The transition-metal nanoclusters were investigated using EXAFS spectroscopy and SQUID magnetometry. The magnetization of Pd and Pt nanoclusters at $0 \leq B \leq 7$ T and 1.8 K $\leq T \leq$ 350 K reveal interesting magnetic properties. The Stoner enhancement factor of the d conduction-electron susceptibility of the nanoclusters is clearly reduced compared to the one of the bulk transition metals.

TT 6.8 Mon 12:30 HSZ 105

Thermal conductivity of suspended silicon nanowire at low temperature — •Olivier Bourgeois, Thierry Fournier, and Jacques Chaussy — CRTBT-CNRS, laboratoire associé à l'UJF et à l'INPG, 25 avenue des Martyrs, BP 166, 38042 Grenoble, Cedex 9, France

We report sensitive thermal conductivity measurement (down to few femtoW/K) at low temperature by means of the 3ω method of silicon suspended nanowires. The silicon nanowires have a square shape cross sections and are made by e-beam lithography. They are suspended between two electrically isolated pads, and hence thermally isolated from the heat bath. A thin film of niobium nitride, a highly resistive thermometric element, is deposited on top of the wire in order to measure the thermal conductivity using the 3ω method. The geometry of the nanowire section is designed to match the order of magnitude of the dominant phonon wave length in silicon at low temperature which is expected to be of the order of 100 nm at 1K. The width of the nanowires varies between 100 nm and 200 nm for a thickness 130 nm and a length ranging from 5μm to 10 μm. The mean free path of the phonons is much larger than the length of the wire, hence these nanowires can be considered as ballistic quasi 1D thermal conductors at sufficientlt low temperature. Under these conditions, the thermal conductivity of the Si nanowire is expected to be strongly influenced by the reduced dimensions. Below 0.9K a clear deviation from the classical cubic law is observed in the 200nm wide wires which is associated to the universal behavior of the thermal conductance.

TT 6.9 Mon 12:45 HSZ 105

Low-temperature investigation of phase transition in $SrTiO_3$ (001) single-crystal plate — •Alexander A. Levin, Dirk. C. Meyer, and Peter Paufler — Institut für Strukturphysik, TU Dresden

A (001) $SrTiO_3$ single-crystal plate is investigated in a temperature range 300 K...25 K by means of wide-angle X-ray scattering (WAXS) under vacuum conditions. Depending on the quality of surface preparation, the plates exhibited different structural characteristics and low-temperature phase-transition and domain behaviour.

At the polished surface of the single-crystal plate, in a cooling cycle a cubic (C-phase, space group Pm-3m) - tetragonal (T-phase, space group I4/mcm) phase transformation is recorded at a temperature of approx. 107.5 K close to the known C-T-phase transition temperature of bulk $SrTiO_3$ (105 K - 108 K). When cooling, the formation of domains of T-phase with different orientation ([110] and [001]) was observed starting from a temperature of 80 K. The volume fraction of the orientation domains mentioned above changed step-wise with decrease of temperature.

The non-polished surface remained in a single-domain state down to a temperature of 25 K. Considerable decrease of the profile parameters of the X-ray reflection of non-distorted cubic phase were recorded below a temperature of about 90 K referred to C-T phase transition. The lowering the temperature of C-T transition can be attributed to non-bulk plate constraint conditions and coexistence of ideal perovskite and distorted regions in the non-polished side of the plate.

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