DEPARTMENT OF SOLID STATE PHYSICS F-5

Head:
Prof. Igor Muševič

Our research program is focused on the study of the structure and dynamics of disordered and partially ordered condensed matter at the atomic and molecular levels, with a special emphasis on phase transitions. The purpose of these investigations is to discover the basic laws of physics governing the behaviour of these systems, which represent the link between perfectly ordered crystals, on the one hand, and amorphous matter, soft condensed matter and living systems, on the other. Such knowledge provides the key to our understanding of the macroscopic properties of these systems and is an important condition for the discovery and development of new, multifunctional materials, nanomaterials and biomaterials for new applications. An important part of the research program is devoted to the development of new experimental methods and techniques in the field of magnetic resonance, magnetic resonance imaging, fluorescence microspectroscopy, scanning tunnelling, electronic and atomic force microscopy, as well as dielectric relaxation spectroscopy and dynamic specific heat measurements.

The experimental techniques used are:
- One (1D) and two (2D) dimensional nuclear magnetic resonance (NMR) and relaxation, as well as quadrupole (NQR) resonance and relaxation,
- Multi-frequency NMR in superconducting magnets of 2T, 6T and 9T, as well as the dispersion of the spin-lattice relaxation time T_1 via field cycling,
- Nuclear double resonance and quadrupole double resonance such as ^{17}O–H and ^{14}N-H,
- Fast field cycling NMR relaxometry,
- Frequency-dependent electron paramagnetic resonance (EPR) and 1D and 2D pulsed EPR and relaxation
- MR imaging and micro-imaging
- Measurement of the electronic transport properties
- Magnetic measurements.
- Fluorescence microscopy and microspectroscopy
- Linear and non-linear dielectric spectroscopy in the range 10^{-2} Hz to 10^{9} Hz,
- Electron microscopy and scanning tunnelling microscopy,
- Atomic force microscopy and force spectroscopy,
- Dynamic specific heat measurements.

The research program of the Department of Solid State Physics at the "Jožef Stefan Institute" is performed in close collaboration with Department of Physics at the Faculty of Mathematics and Physics of the University of Ljubljana, Institute of Mathematics, Physics and Mechanics and the J. Stefan International Postgraduate School. In 2011, the research was performed within three research programs:
- Magnetic resonance and dielectric spectroscopy of smart new materials
- Physics of Soft Matter, Surfaces and Nanostructures
- Experimental Biophysics of Complex Systems

I. Research programme "Magnetic resonance and dielectric spectroscopy of smart new materials"

The research of the program group **Magnetic Resonance and Dielectric Spectroscopy of Smart New Materials** has focused on the study of the structure and dynamics of disordered and partially ordered condensed matter at the atomic and molecular levels with a special emphasis on phase transitions. The purpose of the investigations was to discover basic laws of physics governing the behaviour of these systems, which represent a link between perfectly ordered crystals, on the one hand, and amorphous matter, soft condensed matter and living systems, on the other. The knowledge provides the key to the understanding of the macroscopic properties of these systems and is an important condition for the discovery and development of new, multifunctional materials and nanomaterials for new applications.

In 2011, the investigations were directed to the following research fields:

The group has investigated important open issues in the physics of unconventional superconductivity in strongly correlated electron systems, the physics of magnetically frustrated systems, the magnetism of dodecagonal approximant phases and transport phenomena in heavy-fermion conductors. The group has also discovered novel multiferroic-, relaxor- and liquid-crystalline materials and developed and optimized techniques for the detection of explosives, drugs and pharmaceutical substances by magnetic resonance methods.

Quasicrystals and complex metallic alloys

The tetragonal σ phase and the hexagonal (*hex*) phase in the Mn–Si–V(Cr) transition-metal alloy systems are stable approximant phases of a dodecagonal (12-fold) quasicrystal that can be prepared in bulk quantities. We have synthesized samples of the σ and *hex* phases of the composition $Mn_{76}Si_{18}Cr_6$ and determined their magnetic properties. In σ-$Mn_{76}Si_{18}Cr_6$, a spin-freezing transition to a canonical spin glass phase was detected below $T_f \approx 8$ K, characterized by a maximum in the zero-field-cooled susceptibility, a frequency-dependent cusp in the ac susceptibility, $M(H)$ hysteresis and ultraslow time decay of the thermoremanent magnetization. In contrast, no spin glass transition was observed in the *hex*-$Mn_{76}Si_{18}Cr_6$ phase down to the lowest investigated temperature of 2 K. The analysis of the susceptibility has shown that the coupling of spins in both phases is antiferromagnetic (AFM), but the coupling strength is considerably stronger in the σ phase. Since both phases are structurally described by the triangle–square tiling scheme related to that of the dodecagonal quasicrystal, which imposes geometric frustration of the AFM-coupled spins on triangles, the absence of a spin-glass transition in the *hex*-$Mn_{76}Si_{18}Cr_6$ could be due to the shifting of this transition below the lowest temperature of our experimental setup, as a consequence of weaker spin coupling and the smaller moment sizes in the *hex* phase. In both investigated samples, tiny Mn_3O_4 inclusions that undergo a transition to a ferrimagnetic phase at $T_C \approx 42$ K were detected in the magnetic signal. Geometric frustration of the interactions between the AFM-coupled spins placed at the vertices of the triangle–square tiling should be a general feature of dodecagonal quasicrystals and their approximants, so that spin-glass-type ordering is expected to occur quite commonly in the dodecagonal phases. The work was published in Kashimoto et al., *Phys. Rev. B* **84**, 224201(2011).

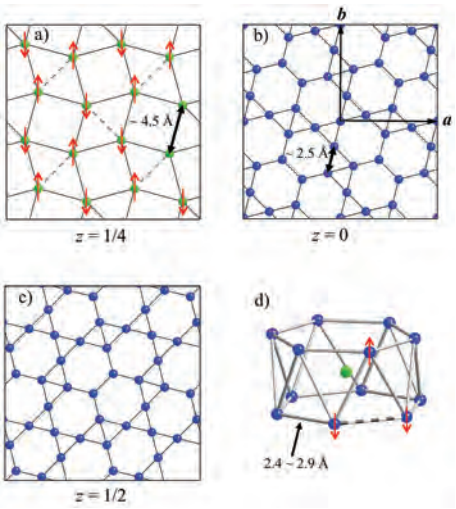

Figure 1: Traingular distribution of Mn and Cr spins in the dodecagonal approximant phase in Mn-Si-Cr.

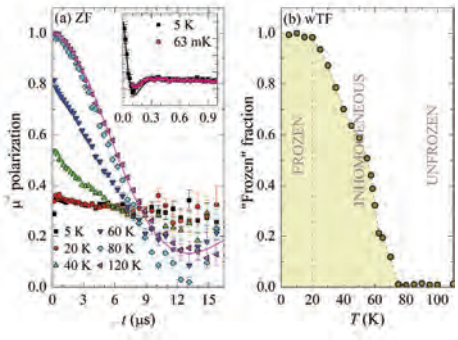

Figure 2: (a) Disappearance of the muon polarization at t = 0 results from a graduate spin freezing in CuNCN below 80 K. (b) Temperature dependence of the frozen-spin fraction reveals an unusually broad region of the inhomogeneous phase.

Geometrical frustration on triangular lattices

The geometrical frustration of spin lattices leads to exotic collective magnetic ground states. A. Zorko and collaborators from Institut Néel, CNRS and Université Joseph Fourier, Grenoble, France investigated the ground state and magnetic excitations of a triangular lattice of triangles, realized in $Ba_3NbFe_3Si_2O_{14}$. This spin-5/2 iron system features a unique single-domain, double-chiral ground state (triangular chirality of the order on each triangle and helicity of the order between planes). Employing inelastic neutron scattering they have discovered an unprecedented dynamical signature of the chiral ground state – a magnetic excitation branch that is completely chiral in the whole energy range. The paper was published in M. Loire et al., *Phys. Rev. Lett.* **106**, 207201 (2011). Using electron spin resonance they have also unveiled the microscopic mechanism responsible for the selection of the ground state in this system. The discovery was published in A. Zorko et al., *Phys. Rev. Lett.* **107**, 257203 (2011). A. Zorko and coworkers from IJS in collaboration with Institute of Inorganic Chemistry, RWTH Aachen University, Aachen, Germany also investigated the ground state of the spatially anisotropic triangular lattice CuNCN. In this novel quantum spin system, the magnetism is surprisingly suppressed. Local-probe studies including muon spin relaxation, electron spin resonance and nuclear magnetic resonance have shown that magnetic ordering is missing in this system down to the lowest experimentally accessible temperatures and that the magnetism is inhomogeneous. These findings were published in A. Zorko et al., *Phys. Rev. Lett.* **107**, 047208 (2011).

Superconductivity in iron-based systems

We studied the family of high-temperature, iron-based superconductors Na_xFeAs characterized by different sodium contents. We found that below 45 K all members of the family undergo a transition into the spin-density-wave magnetic ordered state, where the portion of the Fermi surface remains gapless. This portion is directly related to the superconducting fraction, as deduced from the bulk susceptibility under 12 K. Our findings are consistent with the theories of coexisting magnetic order and superconductivity. The work was published in M. Klanjšek et al., *Phys. Rev. B* **84**, 054528 (2011).

Spin ladders and chains

M. Klanjšek with colleagues from the international collaboration of groups (IJS, University of Geneva, PSI Villingen etc.) continued to study the material $(C_5H_{12}N)_2CuBr_4$ containing spin ladders and thus belonging to the family of one-dimensional antiferromagnets. They developed a theory that successfully captures the whole phase diagram of the material obtained from measurements of nuclear magnetic resonance, neutron diffraction and specific heat. The work was published in P. Bouillot et al., *Phys. rev. B* **83**, 054407 (2011). M. Klanjšek with colleagues from LNCMI Grenoble studied the magnetic order in the natural mineral azurite containing diamond chains of spins and thus belonging to the family of one-dimensional antiferromagnets. They focused on the region of low temperatures and high magnetic fields, between the one-third magnetization plateau and full magnetization. They found that the magnetic order is not determined by the incommensurate longitudinal correlation function as predicted by some theories. Instead, the spins order antiferromagnetically in a direction perpendicular to the magnetic field. The work was published in F. Aimo et al., *Phys. Rev. B* **84**, 012401 (2011).

Investigations of dielectric response of relaxors in dc bias electric fields

Changes in the dynamic processes of relaxors due to a dc bias electric field have been studied in the reduced P(VDF-TrFE), a copolymer system where relaxor-like behaviour in the crystalline part can be separated from the glassy processes in the amorphous matrix, and which is very interesting as its melting point is at about 200°C (100 degrees higher than in any previously known relaxor polymer). Strong electric field dependence of the Vogel-Fulcher temperature and the activation energy has been detected. A comparison of the results with those obtained in a classical inorganic relaxor, PLZT ceramics, revealed that the nonlinear dielectric susceptibility dominantly influences the dielectric dynamics of relaxors in dc bias electric fields. We have additionally found that even a low bias voltage effectively blocks the ac electrical conductivity of the studied copolymer. Published in V. Bobnar et al., *Phys. Rev. B* **83**, 132105 (2011).

Investigations of the influence of preparation conditions on the dielectric behaviour of CCTO thin films

The influence of the preparation conditions on the dielectric properties of $CaCu_3Ti_4O_{12}$ (CCTO) thin films was studied by detailed dielectric investigations in broad temperature and frequency ranges. Experimental results, obtained in various CCTO thin films prepared by chemical solution deposition, and analyses in terms of the equivalent circuit reveal that the preparation conditions govern the distinctive contributions of insulating grain boundaries and semiconducting grains in different temperature and frequency ranges. With a proper post-annealing process, a dielectric constant over 3000 was obtained in films with a thickness below 500 nm. In addition, the electrical conductivity results reveal that one-dimensional variable range hopping is the dominating transport mechanism in CCTO thin films. Published in A. Eršte et al, *J. Am. Ceram. Soc.* **94**, 3900 (2011).

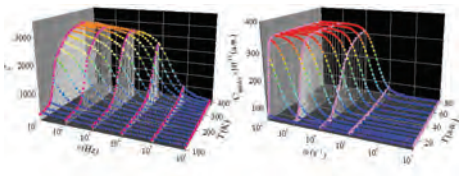

Figure 3: Dielectric constant of CCTO thin films as a function of the temperature and frequency: experimental results (left) and response modelled in terms of the equivalent electrical circuit (right).

High-temperature dielectric investigations of inorganic relaxor systems

We have continued high-temperature dielectric investigations of classical inorganic relaxors, which revealed astonishing results, i.e., they contradict widely accepted dogmas on relaxor properties. The results clearly reveal that polar nanoregions do not form at the so-called Burns temperature (approx. 600 K), but are continuously formed in a broad temperature range, starting well above 800 K. Furthermore, a detailed analysis of the critical behaviour undoubtedly shows that the mean-field description, used up to now, can be rejected with a high level of confidence. Published in (invited paper) V. Bobnar et al., *IEEE Trans. Ultrason. Ferroelectr. Freq. Control* **58**, 2270 (2011).

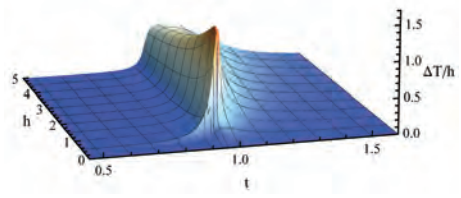

Figure 4: Electric-field and temperature dependence of the electrocaloric responsivity in the vicinity of the critical point.

Study of nanostructural materials and materials with large electrocaloric and thermomechanical effects

By using high-resolution calorimetry we show, via direct measurements, that the electrocaloric responsivity is maximal in the vicinity of the critical point in bulk perovskite relaxors (Figure 4) and that a secondary pyroelectric effect significantly enhances the electrocaloric response. These findings are important for the future engineering of enhanced electrocaloric materials. In a book chapter we show how to influence the thermomechanical response of the liquid crystal elastomers by changing the crosslinker density and the crosslinking temperature. We continue with the experimental and theoretical research of the liquid crystal third blue phase stabilization in a broad temperature range by the addition of the functionalized nanoparticles. Results have been published in 17 articles in international scientific journals.

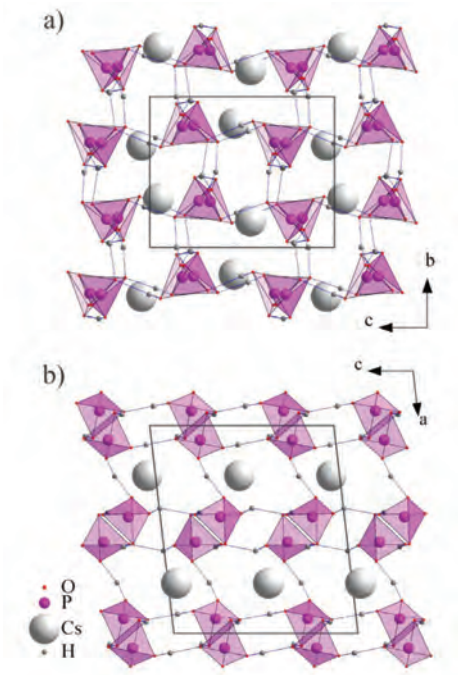

Figure 5: Structure of $CsH_5(PO_4)_2$.

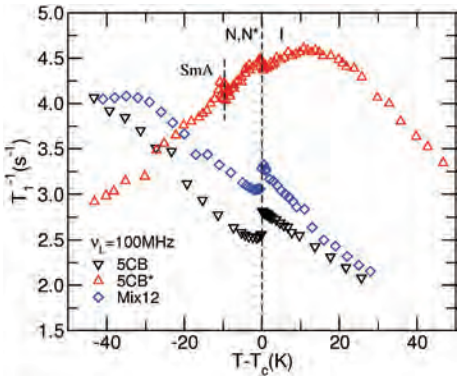

Figure 6: Temperature dependencies of the spin-lattice relaxation times of all three samples at a Larmor frequency 100 MHz.

Hydrogen-storage materials

As a part of the investigations of hydrogen-storage materials, we have studied the Ti-Zr-Ni system, where it was discovered, that the atomic ratios influence the hydrogen-absorption properties. Although these systems typically absorb around 1.5 mass % of hydrogen, we found a so-called "zero zone" area in the phase diagram, where the absorption is essentially zero. An analysis revealed that the surface oxide layer in the samples from the zero zone is significantly thicker in comparison to the samples outside the zone. By means of nuclear magnetic resonance, we have demonstrated that the electron density of state does not differ between both types of samples, therefore the differences in the electronic structure cannot account for the different oxide layer formation. The work was published in A. Kocjan et al., *Int. J. Hydrogen Energy.* **36,** 3056 (2011).

Superionic conductors

We have studied hydrogen dymamics in caesium pentahydrogen diphosphate, $CsH_5(PO_4)_2$. Our goal was to find out why this particular system does not enter the superprotonic phase upon heating, in contrast to many related compounds that exhibit such a phase. The analysis of spin-lattice relaxation time revealed activatione energies for different dynamic processes in the crystal (hydrogen hopping between hydrogen bonds and hydrogen hopping, assisted by PO_4 tetrahedra rotations). Because of the peculiar structure, the crystal melts upon heating even before the superprotonic phase appears. Published in A. Gradišek et al., *J. Phys. Condens. Matter.* **23**, 085901 (2011).

NMR studies of liquid crystals

We have investigated the effects of chiral molecules on molecular dynamics to the model 5CB liquid crystal. We have measured the temperature and frequency dependence of the spin-lattice relaxation time using a superconducting and fast field-cycling magnet. Three systems were studied: pure 5CB, pure chiral 5CB*, and a mixture of 12% 5CB* in 5CB. The analysis revealed the changes in the molecular dynamics after the addition of chiral molecules (Figure 6). In the isotropic phase, there are two mechanisms contributing to the relaxation – molecular rotations and self-diffusion. In the nematic phase, these two processes are joined by fluctuations of the order parameter. After the addition of chiral molecules, another mechanism takes effect, namely rotations mediated by translational displacements along the helical axis. The correlation time for this motional process can be connected to the helical pitch of the system that can be independently determined using polarizing optical microscopy. Published in P. J. Sebastiao, *J. Phys. Chem. B* **115**, 14348 (2011).

NMR double-resonance studies of organic compounds

In 2011 we studied organic ferroelectrics and antiferroelectrics, hydrogen bonds and pharmaceutical substances. We published two papers related to organic ferroelectrics and antiferroelectrics. In the paper entitled "^{17}O NQR and ^{13}C NMR study of hydrogen bonded ferroelectric croconic acid" (J. Seliger, J. Plavec, P. Šket, V. Žagar, R. Blinc, Phys. Status Solidi B **248**, 2091-2096 (2011)) we report on the results of an NQR study of proton order in hydrogen bonds O-H...O in croconic acid, an organic ferroelectric with the largest spontaneous polarization known till now. In the second paper entitled "A 14N nuclear quadrupole resonance study of phase transitions and molecular dynamics in hydrogen-bonded organic antiferroelectrics 55DMBP–H2ca and 1,5-NPD–H2ca" (J. Seliger et al. Phys. Chem. Chem. Phys., 2011, **13**, 9165–9172), prepared together with prof. Tetsuo Asaji from Tokyo and his coworkers, we investigated antiferroelectric phase transitions in two binary hydrogen-bonded organic antiferroelectrics where chloranilic acid is the hydrogen bond donor whereas bipyridine and naphthyridine are the hydrogen-bond acceptors. We measured the proton order parameter in the bifurcated hydrogen bonds and studied a conformational exchange in bipyridine. In 3,5-pyridine dicarboxylic acid we have by ^{14}N ^{17}O in ^{2}H NQR investigated the short N...H...O hydrogen bond where a phonon-driven proton transfer occurs. We determined the proton position in the hydrogen bond as a function of the temperature. The results are published in the paper entitled "Phonon-Driven Proton Transfer in 3,5-Pyridine Dicarboxylic Acid Studied by ^{2}H, ^{14}N, and ^{17}O Nuclear Quadrupole Resonance" (J. Seliger, V. Žagar, J. Phys. Chem. A 2011, **115**, 11652–11656). In a review paper entitled "Nuclear Quadrupole Resonance Study of Hydrogen Bonded Solid Materials" (J. Seliger, *Acta Chim. Slov.* 2011**, 58**, 471–477)) we report on the 17O and 14N NQR studies of hydrogen bonds and on the correlations observed between the structural and NQR parameters. We investigated two pharmaceutical substances by clioquinol and cloxiquine NQR. In the paper entitled "Supramolecular synthon pattern in solid clioquinol and cloxiquine (APIs of antibacterial, antifungal, antiaging and antituberculosis drugs) studied by ^{35}Cl NQR, ^{1}H-^{17}O and ^{1}H-^{14}N NQDR and DFT/QTAIM" (J. N. Latosińska et al. J. Mol. Model 2011, **17**, 1781–1800) we together with dr. Jolanta Latosinska and her coworkers from Poznan report on the study of these compounds

by NQR and quantum chemical calculations in relation to the differentiation between crystal polymorphs and to the study of intermolecular hydrogen bonds.

NQR excitation sequences for portable devices

Nuclear quadrupole resonance has a great potential for applied use. Its main advantages are: the technique is non-invasive, has a big specificity for the identification of various solid materials and requires relatively simple equipment, especially when compared to nuclear magnetic resonance. The biggest element which is required for standard NQR operation is the RF amplifier, with typical powers of 500 W for small coils and up to 10 kW for very large coils. To reduce the size and power requirements of this element, and thus increase portability, we have been developing several techniques of non-standard excitation. The most effective method found so far is excitation with WURST pulses, which require up to 100 times less power than conventional rectangular pulses. We have experimentally demonstrated the efficiency of the sequence by using only 2.5 W for a successful detection of the explosive TNT with ^{14}N NQR. Published in A. Gregorovič et al., *J. Mag. Res.* **209**, 79 (2011).

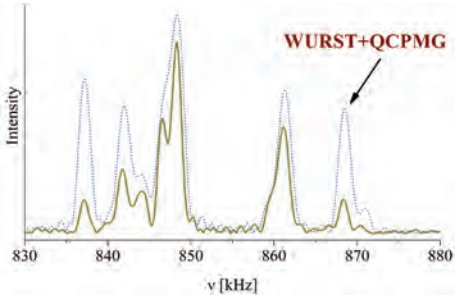

Figure 7: ^{14}N NQR spectra of the explosive TNT when detected with 2.5 W of RF power. The full spectrum is excited with WURST pulses (dashed line), whereas only a partial excitation is achieved with standard, rectangular pulses (solid line).

New method for synthesizing Au nanoparticles

A new method of synthesizing nanoparticle-functionalized nanostructured materials via Aerosol-Assisted Chemical Vapour Deposition has been developed. The co-deposition of Au nanoparticles with WO_3 nanoneedles has been used to deposit a sensing layer directly onto gas sensor substrates providing devices with a six-fold increase in the response to low concentrations of ethanol (1.5 ppm at °C). Published in S. Vallejos et al., *Chemical Communications* **47**, 565(2011).

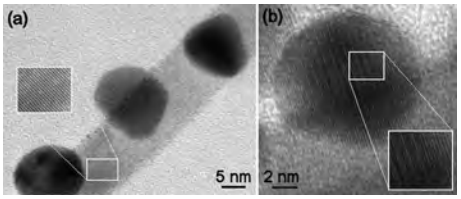

Figure 8: HRTEM images of (a) WO_3 nanoneedle with Au nanoparticles on the surface and (b) close-up of Au nanoparticles.

Nanoscale spectroscopy with polarized X-rays by NEXAFS-TXM

Near-edge X-ray absorption spectroscopy (NEXAFS) is an essential analytical tool in material science. Combining NEXAFS with scanning transmission X-ray microscopy (STXM) adds spatial resolution and the possibility to study individual nanostructures. In this work, we described a full-field transmission X-ray microscope (TXM) that generates high resolution, large-area NEXAFS data with a collection rate that is two orders of magnitude faster than is possible with STXM. The TXM optical design combines a spectral resolution of E/DE5 13104 with a spatial resolution of 25 nm in a field of view of 15–20 mm and a data acquisition time of ~1 s (Figure 9). As an example, we present image stacks and polarization-dependent NEXAFS spectra from individual anisotropic sodium and protonated titanate nanoribbons ((Na,H)TiNRs, HTiNRs)). The combined NEXAFS-TXM technique has the advantage that one image stack visualizes a large number of nanostructures and therefore already contains statistical information. This new high-resolution NEXAFS-TXM technique opens the way to advanced nanoscale science studies. This was recognized by the editors of *Nature Photonics*, who accepted the paper entitled "Nanoscale spectroscopy with polarized X-rays by NEXAFS-TXM" for publication.

Liquid-crystalline elastomers

A new type of liquid single-crystal elastomer forming a chiral smectic A* phase has been prepared using chiral lactic acid derivative as a comonomer. This elastomer possess orthogonal paraelectric SmA* and ferroelctric SmC* phases over a broad temperature interval. We also synthesized and characterized composites of liquid single-crystal elastomers and MoO_{3-x} nanowires, homogeneously distributed across the surface of the soft matrix. We have demonstrated that, using a conventional two-step polymerization approach, the nanowires are preferentially aligned along the nematic director. Published in V. Domenici et al., *J. Mater. Sci*. 46, 3639 (2011).

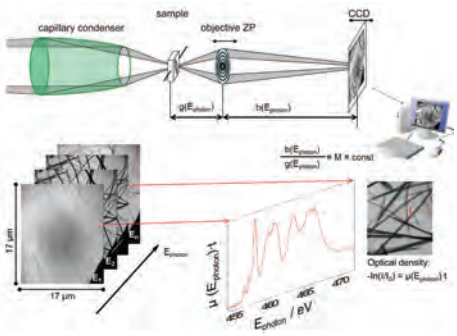

Figure 9: Workflow for NEXAFS-TXM measurements.

Polymer dynamics studied by NMR

The velocity autocorrelation spectrum of the polybutadiene polymer segmental motion has been worked out according to the Rouse and the tube/reptation model to compare it to the experimental results obtained by the new NMR modulated gradient spin-echo method. The analysis of polybutadiene shows the segmental autocorrelation spectrum typical for the reptation-like motion of a polymer in a "tube". Published in *Macromol. Symp*. **305**, 55(2011).

II. Research programme "Physics of Soft Matter, Surfaces, and Nanostructures"

The investigations of the research program "Physics of Soft Matter, Surfaces, and Nanostructures" are focused on novel complex soft-matter systems and surfaces with specific functional properties. We investigated in particular liquid-crystalline elastomers and dendrimers as novel multifunctional materials, nematic colloids, molecular motors, soft-matter photonic crystals and novel synthetic or self-assembled micro- and nano-structures. The aim of the program is to understand the structural and dynamical properties of these systems, their interactions, their function at the molecular level, and self-assembly mechanisms in soft matter. The underlying idea is that it is possible to understand complex mechanisms, such as self-assembly, on a macroscopic level, using a simplified physical picture and models. In order to provide a comprehensive approach to the problem, the program combines both experimental and theoretical investigations, supported by modelling and simulations. Special emphasis is given to the possible electro-optic and medical applications.

In 2011, an important achievement was the discovery of knots and links in chiral nematic colloids. The group has investigated skyrmion defects in liquid-crystal blue phases, studied the stabilization of blue phases by colloidal dispersion, and has investigated the topological properties of nematic braids. Members of the group have also investigated a ciliary beating pattern, analysed the optical properties of exfoliated MoS_2 nanotubes and developed liquid-crystal technology.

Knots and links in chiral nematic liquid crystals

In a paper entitled "Reconfigurable Knots and Links in Chiral Nematic Colloids", U. Tkalec et al, *Science* 333, 62(2011), we report on an experimental observation and theoretical interpretation of knots and links in a colloidal mixture of glass microspheres in a chiral nematic liquid crystal. We have found that defect loops can spontaneously form a variety of knotted and linked structures. We have used laser tweezers to analyse the structure of these microscopic knots and links, and we could change their configuration by applying a strong and localized laser light. A theoretical approach, combing a phenomenological theory and topology has been used to explain and analyse the structure of the observed knots and links. We have observed that knots and links of arbitrary complexity could be formed in the chiral nematic colloids. Knots and links are objects studied within the mathematical discipline of mathematics, topology, and have always played an important role in human history. They were used in building, sailing, handcraft and art. The work of Tkalec et al. is not only a rare example of the realization of an abstract mathematical theory in Nature, but also has a potential practical impact. The authors are considering liquid-crystal knots and links to be used for the binding and fabrication of photonic microstructures that could control the flow of light in soft matter.

Figure 10: President of the Republic of Slovenia, Dr Danilo Türk, visited J. Stefan Institute and the Soft Matter Physics Laboratory of the Solid State Physics Department on October 17, 2011. The President met and congratulated the authors of the Science paper on knots and links in liquid crystals for their success.

Stabilization of blue phases with dispersed colloidal particles: Modelling and simulations show that the dispersion of colloidal particles in blue phases (BPI & BP II) leads in principle to 3D colloidal crystals exhibiting the same symmetry as the underlying orientational ordering lattice. Using particles with weak surface anchoring the blue phase stability range substantially increases (Fig.SZ1). Such colloidal arrays are in fact photonic crystals that would have an advantage over pure blue phases because particles with specific optical, electric, and magnetic properties introduce possibilities for additional manipulation. Published in Ravnik et al., *Proc. Nat. Acad. Sci. U. S. A.* 108, 5188(2011).

Skyrmion lattices in confined blue phases: We showed theoretically, with the aid of numerical methods, that a highly chiral nematic liquid crystal can accommodate a quasi-two-dimensional Skyrmion lattice as a thermodynamically stable state, when it is confined to a thin film between two parallel surfaces imposing normal alignment (Fig.SZ2). A chiral nematic liquid-crystal film can thus serve as a model Skyrmion system, allowing a direct investigation of their structural properties by a variety of optical techniques at room temperatures that are far less demanding than for Skyrmion systems discussed previously in two-dimensional electron gases exhibiting the quantum Hall effect, chiral ferromagnets, and Bose–Einstein condensates. Published in J. Ichi Fukuda, S. Žumer, *Nature Communications* 2, art. no. 246(2011). We expect these soft-matter structures to be relevant for photonic applications.

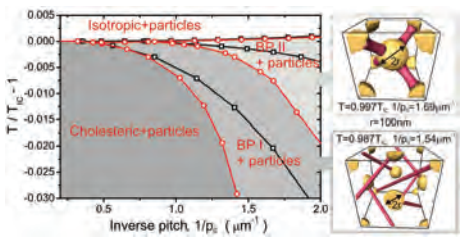

Figure 11: Increase of the stability range of colloidal BPI & BPII phases (red lines and circles) in comparison to pure BPI & BPII phases (black lines and circles).

Topological invariants of nematic braids: Coupling geometrical and topological aspects of disclination loops that are in fact ribbons with the three fold symmetry led to the introduction of a new topological invariant - self-linking number as the sum of writhe and twist. We also unveil a simple rewiring scheme for the orthogonal crossing of two 3-fold ribbon disclinations, based on

a tetrahedral rotation of two relevant disclination segments, which allows us to predict possible nematic braids and calculate their self-linking numbers. Complex nematic braids with knots and links of disclinations with three-fold symmetry that can entangle homeotropic colloidal particles in nematic and chiral nematic phases can be with this formalism completely classified. Published in S. Čopar and S. Žumer, *Phys. Rev. Lett.* **106**, 177801(2011).

Early-stage domain coarsening of the isotropic-nematic phase transition: We performed a Brownian molecular dynamics simulation of the early-stage domain-coarsening dynamics of the temperature-driven isotropic-nematic liquid-crystal phase transition. We show that soon after the transition a bimodal distribution of domains appears, where the shorter branch gradually vanishes. The behaviour of the system is in accordance with the predictions of the Kibble-Zurek mechanism, which was originally introduced to model conditions in the early universe. Published in Z. Bradač et al., *J. Chem. Phys.* **135**, 024506(2011).

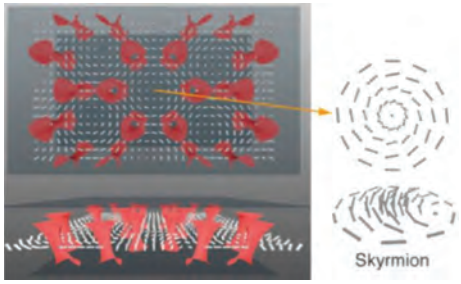

Figure 12: Blue-phase skyrmion defect lattice. In red are the defect areas of depressed order, while white and grey bars denote nematic director field.

Finding the ciliary beating pattern with optimal efficiency: Many biological processes work with an extremely high energetic efficiency, but at first glance this does not hold for ciliary propulsion, reaching about 1%. We have re-examined the problem at the level of a single cilium and an infinite ciliated surface. We numerically determined the optimal shape of the ciliary beating pattern and showed that the optimal collective stroke is remarkably similar to that observed in microorganisms (Fig. AV1). For Paramecium we showed that the experimentally measured hydrodynamic efficiency reaches about 50% of the theoretically possible optimum. Published in N. Osterman, I. Vilfan, *Proc. Natl. Acad. Sci. U. S. A.* **108**, 15727(2011).

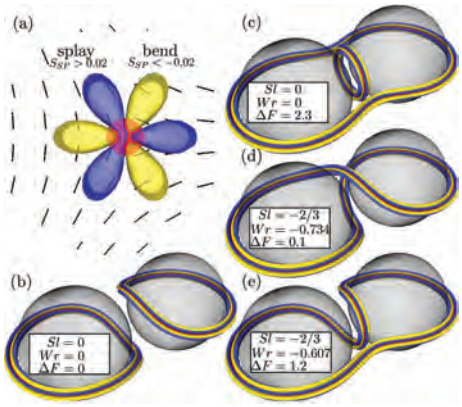

Figure 13: (a) represents a threefold disclination profile visualized using the splay-bend parameter. (b–e) are the well-known entangled dimers characterized by the self-linking number, writhe, and free-energy differences from the ground state.

Optical properties of exfoliated MoS[sub]2 coaxial nanotubes - analogues of grapheme: We have exfoliated MoS_2 nanotubes for the first time. The resulting material in the shape of sub-nanometre-thick single layers was stable for weeks. The monolayers represent an inorganic analogue of grapheme. We have evidenced the quantum-confinement effect from a shift of optical absorption peaks. The results are applicable in optics and nanoelectronics. Published in Višić et al., *Nanoscale Research Letters* 6, 593(2011).

EU and US patents for the synthesis of tungsten- and molybdenum-based nanotubes: A European patent was granted for the synthesis of electrically conductive nanowires of W_5O_{14} (Remškar et al. 2011). The nanowires show up to eight orders of magnitude higher conductance than the stoichiometric WO_3 compound and belong to photochromic materials. They represent a starting material for the synthesis of WS_2 nanobuds, where hollow WS_2 nanospheres are attached on the surface of the WS_2 nanotubes. In parallel a US patent was also granted for the synthesis of MoS_2 nanotubes and Mo_5O_{14} nanowires (Mrzel et al. 2011). The patent also protects geometry, where MoS_2 nanospheres are situated inside the MoS_2 nanotubes. The MoS_2 nanotubes are an excellent lubricant and added to oils and greases they decrease friction by up to 50 % and wear by up to 90 %.

Low-temperature STM microscopy of surfaces in a ultra-high vacuum

In the field of surface physics we are currently performing low-temperature experiments on and the corresponding calculations of the Bi and Sb (111) surfaces, which we intend to cover with sub- and mono-atomic layers of Se. Our goal is to construct very thin islands and layers of the topological insulators Bi_2Se_3 and Sb_2Se_3. In 2011, we have started the construction of our first apparatus for experiments with ultra-cold atoms. Cold atoms offer an exciting possibility to study strongly correlated systems, which can be used as quantum simulators of other complicated systems, e.g., high-temperature superconductors. The one-dimensional conductor $(NbSe_4)_{10/3}I$ was examined by x-ray diffraction and high-resolution transmission electron microscopy (HRTEM). By calculating its electronic properties and by simulation of the X-ray and electron diffraction patterns it was shown that the disorder detected is a result of a mismatch between the infinite $NbSe_4$ chains. The structural phase transition at 285 K was attributed to a Jahn-Teller distortion. Published in A. Prodan et al. *Proc. 22. IUCr, Acta Cryst.*, 67, C512(2011). The structural relaxation around individual hydrogen atoms and their binding energies were studied for a few hydrogenated TiBx structures by means of density functional theory methods. Starting with the symmetric hydrogen sites a random structure searching has revealed all energetically stable adsorption sites. Published in R. Žitko et al., *Int. J. of Hydrogen Energy* 36, 12268 (2011).

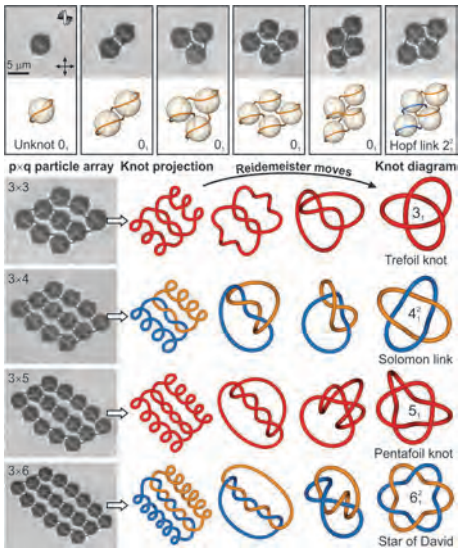

Figure 14: Knots are formed in the dispersion of glass microspheres in a chiral nematic liquid crystal. The knots are formed from closed defect loops. The liquid crystal has reduced order in the core of the defect loops and is therefore visible.

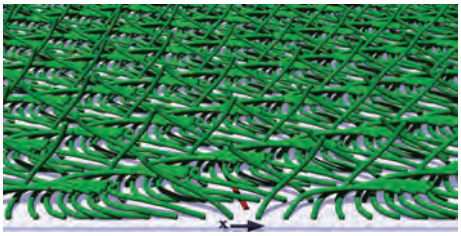

Figure 15: Optimal ciliary beating pattern. The calculated beating pattern of cilia densely covering a surface strongly resembles the dynamics of biological cilia. The stroke is asymmetric: stretched in one direction and sweeping along the surface in the other. The phases of cilia form metachronal waves.

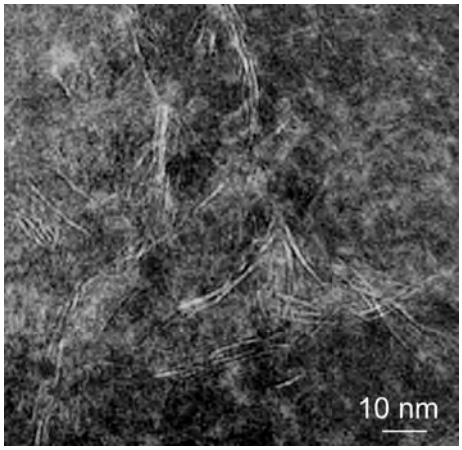

Figure 16: Figure shows differently oriented MoS_2 flakes produced by the exfoliation of MoS2 nanotubes. The flakes are thinner than one nanometre.

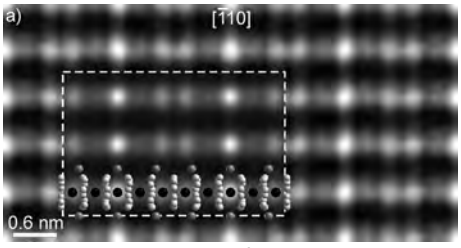

Figure 17: HRTEM image of a (NbSe4)10/3I crystal, recorded with the electron beam parallel to the [110] direction; an overlapped corresponding simulated image and a structural model are shown in the inset.

Technology of optical shutters based on liquid crystals

The concept of STN LCD light shutters and their angular compensation by means of the negative c-plate birefringence (EP 1883854) has been developed at the JSI in previous years. During this year it was upgraded to allow for the simultaneous use of the small positive in-plane birefringence, the formation of which is inherent to its production process. This upgrade is the subject of a CIP patent application US 13/208,378. In 2011 USPTO also granted the patent US 8,026,998 describing the continuous variation of the protective shade with automatic LCD protective filters. The introduction of the above technical solution in the JSI's spin-off company Balder's production process allows the latter to be the only producer in the world capable of producing active LCD welding filters with the highest optical quality (1/1/1/1), as specified by the international Standard EN 379. As a result the International Standard Organization (ISO) invited the JSI and Balder to participate in its expert group (ISO/TC94/SC6/WG2 in WG4) preparing the new world Standard for Eye and Face protection. The contribution of JSI/Balder within the ISO Expert group is as follows. Draft of the ISO Standard: "Occupational Eye and Face Protection" (co-authors) has been prepared. The draft has already been approved on the first level of international verification and will be accepted in its final form at the occasion of the next ISO meeting (June 2012). A new standardization measuring process for the light sensitivity determination of automatic welding filters has been developed. The new method will be published by the German Standardization Institution "TÜV Reinland". An "artificial plasma light source" simulating TIG welding has been developed; likewise the draft ISO Standard, it will be accepted at the occasion of the next ISO meeting (June 2012) as the new ISO standard light source.

Detection of low levels of vapour concentration in explosives

In collaboration with the Faculty of Electrical Engineering and the Faculty of Chemistry and Chemical Technology of the University of Ljubljana, we have developed a miniature and portable device for the detection of low concentrations of the vapours of explosives. We have used a differential pair of chemically functionalized microcapacitors together with ultrasensitive and low-noise detection electronic circuits to detect 1 molecule of TNT in 10^{+12} molecules of a carrier gas N_2. The work was published in D. Strle et al., *IEEE Sens. J.*, in press 2011, doi: 10.1109/JSEN.2011.2168203.

The group has been awarded two EU patents in the field of liquid-crystal-based materials and devices

In 2011 the members of the programme group have been awarded two patents from the field of materials and devices, based on liquid crystals. European patent EP 1975656B1 "Metamaterials and resonant materials based on liquid-crystal dispersions of colloidal particles and nanoparticles" authored by I. Muševič, M. Škarabot, S. Žumer and M. Ravnik is protecting the method of fabrication of composite materials made of a liquid crystal, colloidal particles and nanoparticles. In this multicomponent dispersion, the nanoparticles are trapped into the core of the disclination defect lines. The electric properties of such hierarchical structures are similar to the ring microresonators and the material exhibits a negative magnetic response, which is the property of metamaterials. The second EU patent EP 1927885B1 "Multistable liquid crystal device" by Th. Rasing, S. Lazarenko, I. Muševič, M. Škarabot and M. Uplaznik, is from the field of microconfined liquid crystals, where the nematic liquid crystal is trapped into a geometrically regular confining structure, formed by optical or electronic lithography. Because of the topological constraints of the ordering field, such a device exhibits a multitude of stable optical states. These can be addressed either by an electric field or by a strong laser light.

III. Research programme "Experimental Biophysics of Complex Systems"

Within the program "**Experimental Biophysics of Complex Systems**" we explore processes and structures of various complex systems (from model systems to the structures in living cells, tissues and even small animals) including the effects of various bioactive molecules like toxins, drugs, etc., as well as of various materials like nanomaterials and medical materials on these systems. Our research is focused on the investigation of the structural properties of different membrane structures such as membrane domains, membrane proteins and the glycosaccharide matrix as well as their interactions with various materials that enter into their native environment. Novel

spectroscopic and microspectroscopic techniques contribute to the understanding of the organization of these supramolecular systems, complex cell and tissue responses as well as opening up new possibilities to design new medical materials, like scaffolds for tissue regeneration as one of the most relevant problems in the current aging population of developed countries. Besides, we focus on medical methods of optimization, like tumour treatment methods, magnetic resonance imaging and mathematical modelling of trombolisis, magnetic resonance microscopy in forestry, wood science and food processing as well as on restricted diffusion research.

Figure 18: Image on the left. Eye-protecting helmet using an active and fast LCD shutter, produced by the JSI spin-off company Balder d.o.o. The right image shows the prototype of an artificial plasma light source, used for measuring the eye-protecting characteristics of welding filters.

One of the hottest topics in biophysics is the study of the **interactions between novel materials and cells**, especially from the bioactivity and biocompatibility point of view. The recent developments in **fluorescence microspectroscopy** (FMS) enabled the acquisition of the fluorescent spectra within very small volume elements and the characterization of a local molecular environment of fluorophore molecules. FMS was applied to localize the response of the cells to the presence of various materials, especially nanomaterials used for the antimicrobial protection of the surfaces. In addition, FMS was used to unravel the interaction between the cells and macrostructured materials like medical materials. The bleaching problem was solved with a special algorithm developed to neutralize the bleaching effect in spectral analysis. The FMS system was optimized and upgraded with a system for micromanipulation to enable measurements of the force between the cells and the scaffolds.

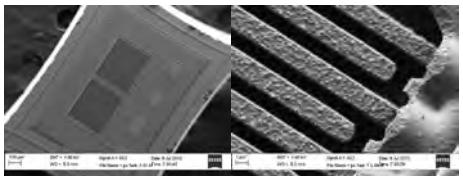

Figure 19: SEM image of a differential pair of microcapacitors, fabricated in CMOS technology. The pair serves as a precise molecular detector.

On the segment of the **development and synthesis of various molecular probes** (nitroxides, fluoprophors and the probes that combine both groups in the same molecule) our research was focused on amphiphilic fluorescent probes with NBD (as an environmentally sensitive probe) inside a membrane environment to enable sensitivity to local environment (polarity). We showed sensitivity to the cholesterol concentration, but only between the gel and liquid-crystalline phases. The structure optimization of the new molecular tool opens up new opportunities in the combined exploration of the same sample with fluorescence microspectroscopy and electron paramagnetic resonance spectroscopy at the same time.

Within the research of the **interaction between** biologically active materials and cells we focused on the investigation of **cancerostatic alkylphospholid** (perifosine, OPP) with **cell membranes** using EPR spectroscopy and an in-house developed computer program for the simulation of EPR spectra (EPRSIM). Anticancer agents OPP directly target the cell membrane but not the DNA. It shows a selective apoptotic response in tumour cells, sparing normal cells and was found to be promising for breast-cancer therapy. An antitumor effect was found for estrogen receptor negative (ER-) tumour cells (MT-3 cell line) *in vivo*, while no effect was found for receptor positive (ER+) tumour cells (MCF-7).

Publication of the article "Ferri-liposomes as an MRI-visible drug-delivery system for targeting tumours and their microenvironment" in the *Nature Nanotechnology* journal. We showed that new ferri-liposomes can be used as a very effective T2 MR contrast agent and for the targeting of therapeutic agents to a specific location in the body using an external magnetic field.

Spin labelled OPP (SL-OPP) was used to identify that the difference between MCF7 cells MT-3 cells in the transport of SL-OPP across the plasma membrane can be assigned to the low accumulation in MCF7 cells. Liposomal OPP formulations with a low CH concentration quickly release entrapped spin probe when mixed with breast-cancer cells, while the release is much slower for liposomes with 50 or more mol% cholesterol. At room temperature the release is the same for MT-3 and MCF7 cells. However, at physiological temperature the amount of released content increases for the OPP sensitive MT-3 cells, but remain in the same range for MCF7 cells. In collaboration with the Biotechnical Faculty the **membrane characteristics of a new class of liposomes prepared from dietherarcheal lipids** and their mixtures with standard dipalmitoyl-phosphatidylcholine (DPPC) lipids, we found that these two types of lipids mix well in different molar ratios and form liposomes upon hydration. Their stability decreases with a higher ratio of conventional lipids; however, new characteristics emerge. For arheosomes prepared from dietherarcheal lipids isolated from *Aeropyrum pernix* K1 grown in the medium with different pH (from pH 6 to 8) it was found that the average membrane fluidity was not influenced by the pH of the growth medium significantly.

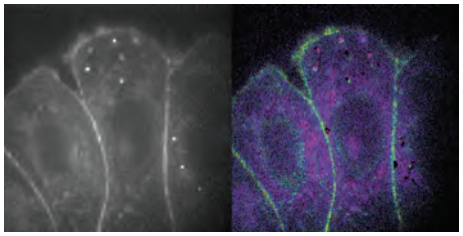

Figure 20: Application of fluorescence microspectroscopy (right) enables the spectral identification of fluorescein-labelled polystyrene latex nanoparticles (50 nm diameter, violet) incubated within cancer cells labelled with lipophilic molecules with NBD dye partitioning in the membranes (green). Classic intensity image (left) can resolve membranes and particles due to substantial spectral overlap.

One of our main activities is the study of membrane structuring. In this respect it is important to note that different time and distance scales of the methods can lead to very different conclusions regarding the stability of the heterogenous structure of the membranes. For an integral view one has to use an appropriate set of methods. A collaboration with foreign partners allows us to use different biophysical methods that are complementary to the methods available in our lab. So besides the method of attenuated total reflection Fourier transform infrared spectroscopy (ATR-

FTIR) we also used calorimetry and x-ray scattering to study the effect of ceramide on the structure and properties of membranes. We showed that **these complementary methods allow an efficient examination of phase diagrams of model membranes composed of different lipid mixtures**. In this way we were able to classify different types of membrane heterogeneity as stable or unstable.

To improve the **protein structure determination** based on the conformational space modelling of the protein side chains (CSM), we set-up a cluster based on 8000 graphical processor cores. Together with improved sampling methods this enabled us to confirm that the energy topology of the spin-probe conformational space is environment insensitive, i.e., not sensitive to the neighbouring amino acids as well as lipids or a water local environment. On the contrary, those conditions affect the rotational diffusion. This enables us to speed up the calculation of the restrictions in conformation spaces within the appropriate time window of the EPR spectroscopy and a simple generalization of the inverse problems in protein-structure determination.

Titanate nanomaterials generate short-lived radicals in the processes of photocatalysis, thus preventing the growth of bacteria. We synthesised titanate nanomaterials (TiNTs) with a high specific surface area and a significant antimicrobial activity. Photogeneration of primary hydroxyl radicals by TiNTs was detected in the laboratory with the electron paramagnetic resonance method with spin trapping in the presence of 30% of ethanol. The stable deposition of TiNTs on polymer surfaces was achieved even after soaking in different conditions (neutral, acid, and base) for up to six times. A reduction in the colony-forming units of non-pathogenic Listeria Innocua was observed independent of the wavelength of the illuminating light. The highest reduction was achieved at lower wavelengths on TiNTs covered surfaces.

We confirmed our assumption that **thrombolysis is not just a biochemical process** in which there is a complete degradation of fibrin, but under the influence of rapid blood flow it leads to the formation of strong mechanical forces to the surface of a blood clot that result from blood viscosity. These forces cause the breakage of large parts of the clot formed by the fibrin network and blood cells (primarily erythrocytes). These torn pieces may range in size from individual cells, to clusters of several hundred cells. With optical microscopy experiments, we also showed that the size of these clusters largely depends on the blood flow. In a slow stream of blood only small clusters were formed, while at a higher speed significantly larger pieces of the clot were torn. These results also explain why the thrombolysis is much faster in a faster flow than in a slow flow. The promotion of thrombolysis in the rapid blood flow is greater than expected due to better permeation of the clot with the thrombolytic agent and significantly larger forces of the streaming blood to the surface of the clot. Based on the results of this study a computer simulation of the microscopic processes of thrombolysis was developed. Its results are in good agreement with our measurements.

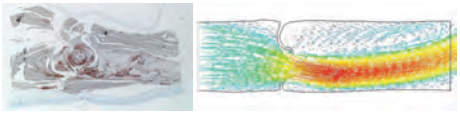

Figure 21: Histological image of a venous blood clot behind a venous valve (left) and the simulation of the blood flow behind the valve (right). Simulation of the flow indicates the possibility of the occurrence of vortex flow, which may contribute to platelet activation and consequently to the formation of a blood clot.

By MRI, we monitored the **freezing dynamics of different types of vegetables** and showed the differences between rapid and slow freezing. We have shown that MR imaging is an efficient tool for monitoring the freezing process, because it can clearly distinguish between fresh and frozen food areas. MRI also reflects the differences in NMR relaxation times and the diffusion characteristics of food before and after freezing.

Controlled drug-delivery systems are widely used in the pharmaceutical industry because of their numerous advantages. For hydrophilic polymers, it is generally accepted that, once in contact with body fluids, they hydrate and swell, forming a gel layer that regulates the penetration of body fluids into the tablet and the dissolution of the incorporated drug. Therefore, a knowledge of the gel layer's characteristics is of crucial importance for the use of controlled drug-delivery systems. A combination of different MRI methods enables an accurate determination of the medium penetration into the tablet as well as hydrogel formation *in situ*. This approach has been used to determine the influence of temperature on the kinetics of medium penetration and hydrogel formation in xanthan tablets. The swelling dynamic is independent of the temperature in the range between 20°C and 40°C.

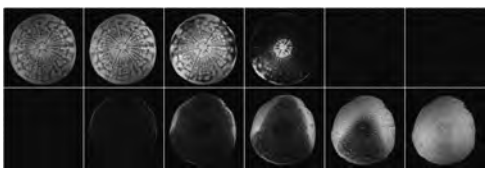

Figure 22: Series of dynamically acquired T2-weighted images (in 11-min intervals) of a carrot sample undergoing slow freezing and thawing. A complete loss of the sample structure after thawing is apparent.

The+MRI contrast properties of **a new contrast agent based on cobalt ferrite nanoparticles** were tested. Most of the MR contrast agents based on the ferrite nanoparticles have very large r2 relaxivities, i.e., the T2 significantly shortens already at low nanoparticle concentrations, while the r1 relaxivity (the contrast agent shortens the spin-lattice (T1) relaxation time) is much lower and can therefore be only used as a negative (T2) MR contrast agent. The negative T2 effect is very strong. The MR signal diminishes in the vicinity of the presence of the contrast agent on the T2-weighted MR images and the dark region on the T2-weighted images can be confused with the dark region originating from other causes, such as calcification or metal deposits. Therefore, the contrast agent that would enable a simultaneous detection of the probe on T1-weighted and T2-weighted MR images would solve the problem. By using

T1-weighted images the confusion with the dark regions originating from other causes can be excluded. The contrast properties were tested using 1% agarose with relaxation times that are similar to those of some tumour tissues. The results show that the cobalt ferrite nanoparticles can be used as positive T1 and negative T2 MRI contrast agents and their unique double T1 and T2 contrast properties could provide the possibility for their use in MRI diagnostics, both as positive and negative contrast agent.

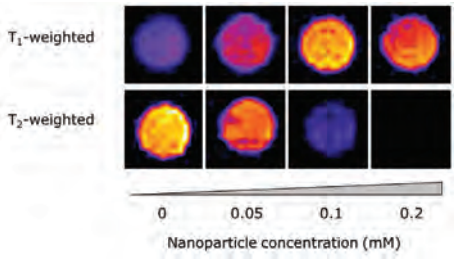

Figure 23: T1- and T2-weighted MR images of different concentrations of cobalt ferrite nanoparticles in 1% agarose.

Part of our research was focused to a study of the ability of NMR-modulated gradient spin echo (MGSE) to provide information about the **translational dynamics of polymer segments** via the measurement of segmental velocity autocorrelations. Since the method requires the formulation of dynamics in the frequency domain, at first we derived the expression for the velocity autocorrelation spectrum (VAS) of the segmental motion according to Rouse and deGennes the tube/reptation model. The resulting VAS can be fitted well to the results of the measurement on the samples of molten polybutadiene and polyethylene. Thus, they represent a first direct experimental verification of the snake-like motion in a "tube" of entangled polymer chains. It appears that this new understanding of macromolecular motion makes it possible to also explain the unusual results of our previous MGSE measurement of bulk water as a kind of Rouse-type motion in a network of hydrogen bonds in water. In the next study we have shown the ability of the NMR pulsed gradient spin echo to provide information about molecular self-diffusion in nanopores. The method was successfully tested on the sieve of a polyamide membrane.

The above research has been supported by a number of international projects financed by the European Union within the Fifth and Sixth Frameworks as well as NATO. It was also supported within the bilateral Slovenian–USA, Slovenian–German and Slovenian–Greek and other scientific cooperations. International cooperations with
– The high magnetic field centres in Grenoble, France, and Nijmegen, The Netherlands
– The high magnetic field centre at the University Florida, Tallahassee, Florida, USA
– The ETH, Zürich, Switzerland
– The Ioffe Institute in St. Petersburg, Russia
– The University of Duisburg, the University of Mainz and the University of Saarbrucken in Germany
– The University of California, the University of Utah and the Liquid Crystal Institute, Kent, Ohio, USA,
– National Institute for Research in Inorganic Materials, Tsukuba, Japan
– NCSR Demokritos, Greece
– Institut für Biophysik und Nanosystemforschung OAW, Graz, Austria
– Bioénergétique et Ingénierie des Protéines, CNRS Marseille, France
– Architecture et Fonction des Macromolécules Biologiques, CNRS Marseille, France
– The Max Delbruck Center for Molecular medicine in Berlin
– The Dartmouth Medical School, Hanover, NH, USA
– The Mayo Clinic, Rochester, USA
made the above studies possible.

Some outstanding publications in 2011

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Some outstanding publications in 2010

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6. Jun-ichi Fukuda, S. Žumer. Novel defect structures in a strongly confined liquid-crystalline blue phase. *Phys. Rev. Lett.* **104**, 017801-1-017801-4(2010).
7. M. Humar, I. Muševič. 3D microlasers from self-assembled cholesteric liquid-crystal microdroplets. *Opt. Express* **18**, 26995-27003(2010)
8. Vilfan, A. Potočnik, B. Kavčič, N. Osterman, I. Poberaj, A. Vilfan, D. Babič. Self-assembled artificial cilia. *Proc. Natl. Acad. Sci. U. S. A.* **107**, 1844-1847(2010).
9. A. Kavalenka, I. Urbančič, S. Kure, J. Štrancar. Conformational analysis of the partially disordered measles virus $N_{(TAIL)}$-XD complex by SDSL EPR spectroscopy. *Biophys. J.* **98**, 1055-1064(2010).

Patents granted

1. Metamaterials and resonant materials based on liquid crystal dispersions of colloidal particles and nanoparticles
   Igor Muševič, Miha Škarabot, Slobodan Žumer, Miha Ravnik
   EP1975656 (B1), European Patent Office, 8.6.2011.
2. Multistable liquid crystal device
   Theo Rasing, Sergiy Lazarenko, Igor Muševič, Miha Škarabot, Marko Uplaznik
   EP1927885 (B1), European Patent Office, 27.7.2011.
3. Procedure for synthesis of threadlike tungsten oxide W5O14
   Maja Remškar, Marko Viršek, Miha Kocmur, Adolf Jesih
   EP2114827 (B1), European Patent Office, 16.2.2011.
4. Process for the synthesis of nanotubes and fullerene-like nanostructures of transition metal dichalcogenides, quasi one-dimensional structures of transition metals and oxides of transition metals
   Aleš Mrzel, Maja Remškar, Adolf Jesih, Marko Viršek
   US8007756 (B2), United States Patent and Trademark Office, 30.8.2011.

Awards and appointments

1. Andreja Jelen, Marica Starešinič: Successful participation in the "OE-A Competition for Multifunctional Demonstrators based on Organic and Printed Electronics" by submitting the demonstrator "Security Vest". Frankfurt, Germany, Organic Electronics Association (OE-A) : a working group within German Engineering Federation VDMA.
2. Marta Lavrič: Ferbar Prize, Ljubljana, Faculty of Education, Liquid crystal elastomers.
3. Igor Muševič: Mentor of the year 2011, Ljubljana, Slovenian Society of Young Researchers

Organization of conferences, congress and meetings

1. 11th European conference on liquid crystals (ECLC 2011), Maribor, 6. 2.-11. 2. 2011

INTERNATIONAL PROJECTS

1. Light Element Molecular Superconductivity: An Interdisciplinary Approach
   LEMSUPER
   7. FP, 283214
   EC; Prof. Kosmas Prassides, University of Durham (UDUR), Durham, Great Britain
   Prof. Denis Arčon
2. Combining Innovative Portable Visual, Accoustic, Magnetic and NMR Methods with In-situ Chemical Diagnostic Tools for Effective Failure Assessment and Maintenance Strategy of Rail and Subway Systems
   DIAGNO-RAIL
   7. FP, 262207
   EC; Georgios Papavassiliou, Institute of Materials Science, NCSR Demokritos, Aghia Paraskevi, Attiki, Greece
   Prof. Janez Dolinšek
3. Underwater Coastal Sea Surveyor
   UNCOSS
   7. FP, 218148
   EC; Dominique Vilbois, Patrick Peras, ECA SA, Toulon, France
   Prof. Robert Blinc, Prof. Aleksander Zidanšek
4. Development of Wear Resistant Coatings based on Complex Metallic Alloys for Functional Applications
   appliCMA
   7. FP 214407
   EC; Andreas Merstallinger, Aerospace & Advanced Composites GmbH, Wiener Neustadt, Austria
   Prof. Janez Dolinšek, Asst. Prof. Miha Čekada, Asst. Prof. Kristoffer Krnel, Asst. Prof. Srečo D. Škapin
5. Hierarchical Assembly in Controllable Matrices
   HIERARCHY
   7. FP, 215851, PITN-GA-2008-215851
   EC; Paul Kouwer, Harry Rullmann, Radboud University Nijmegen, Faculty of Science, Nijmegen, The Netherlands
   Prof. Igor Muševič
6. ESNAM - European Scientific Network for Artificial Muscles
   COST MP1003
   EC; COST Office, Brussels, Belgium
   Prof. Boštjan Zalar, Dr. Blaž Zupančič
7. Network for Intermetallic Compounds as Catalysts for Steam Reforming of Methanol
   IMC-SRM
   COST
   EC; COST Office, Brussels, Belgium
   Prof. Janez Dolinšek
8. Designing Novel Materials for Nanodevices: From Theory to Practise (NanoTP)
   COST MP0901
   EC; COST Office, Brussels, Belgium
   Dr. Polona Umek
9. Optical Micro-manipulation by Nonlinear Photonics
   COST MP0604
   EC; COST Office, Brussels, Belgium
   Prof. Igor Muševič
10. Structure and Mechanism of Cytoplasmic Dynein
    HFSP RGP0009/2008-C
    HFSPO - International Human Frontier Science Program Organisation, Strasbourg, France; University of Leeds, IMSB FBS, Leeds, Great Britain
    Asst. Prof. Andrej Vilfan
11. Targeting AntimicroBial Activity via micro/Nano-structured surfaces for civil Applications
    TABANA
    MNT-ERA-NET II
    Univerza v Mariboru, Maribor, Slovenia
    Prof. Janez Štrancar
12. Novel States of Matter Induced by Frustration in Quantum Magnets
    PROTEUS
    BI-FR/11-12-PROTEUS-008
    Prof. Philippe Mendels, Laboratoire de Physique des Solides Universite Paris - Sud, Orsay, France
    Dr. Andrej Zorko
13. Supermolecular Organization of Polisaharides in Marine Gel Networks
    BI-HR/10-11-011
    Dr. Vesna Svetličić, Ruđer Bošković Institute, Zagreb, Croatia
    Prof. Janez Štrancar
14. Hydrogen Storage in Metal Hydrides and Nanomaterials
    BI-KR11-12-002
    Dr. Hae Jin Kim, Korea Basic Science Institute, Daejeon, Korea
    Asst. Prof. Tomaž Apih
15. Multidrug Resistance in Cancer and Membrane Domain Structures
    BI-PL/10-11-009
    Dr. Rochala Wojceich, The University of Warsaw, Warsaw, Poland
    Prof. Janez Štrancar
16. Molecular Dynamics Studies in Chiral Nematic and Smectic Phases by Proton NMR
    BI-PT/10-11-011
    Prof. Pedro Sebastiao, Cenro de Fisica da Meteria Condensada da Universidade de Lisboa, Lisbon, Portugal
    Asst. Prof. Tomaž Apih
17. Dielectric and Electocaloric Properties of Advanced Relaxor Polymer Films and Nanotubes
    BI-US/09-12-039
    Prof. Zhang Qiming, Office of Sponsored Programs, The Pennsylvania State University, PA, USA
    Asst. Prof. Vid Bobnar
18. Geometrically Frustrated Quantum Magnetism
    BI-US/09-12-040
    Dr. Johan van Tol, National High Magnetic Field Laboratory, Florida State University, FL, USA
    Dr. Andrej Zorko

R &D GRANTS AND CONTRACTS

1. Patterns, Structural Self-assemly and Multiferroic States in Mixtures of Nanoparticles and Liquid Crystals
   Prof. Samo Kralj
2. Physicochemical Processes Involved in Formation of Radioactive Nanoaerosols
   Prof. Janja Vaupotič
3. Advanced Ferroelectric Polymeric and Inorganic Materials: Giant Electrocaloric Effect and Transport Properties
   Prof. Zdravko Kutnjak
4. Hydrogen Storage in Zr-based Metallic Glasses
   Prof. Janez Dolinšek
5. New Methods for the Detection of N-14 Nuclear Quadrupole Resonance
   Asst. Prof. Tomaž Apih
6. Novel Ground States and Quantum Critical Points in Low-dimensional Quantum Spin Systems
   Dr. Andrej Zorko
7. Molecular Motors
   Asst. Prof. Andrej Vilfan
8. Superconductivity and magnetism in new iron-based superconductors
   Dr. Peter Jeglič
9. Three Dimensional Assembling of Colloidal Structures in Mesophases
   Prof. Slobodan Žumer
10. Hybrid Nanomaterials for Low-friction Polymer Composites and Energy Conversion
    Prof. Maja Remškar
11. Optical Microresonators Based on Liquid Crystals
    Prof. Igor Muševič
12. New metallic materials for thermal storage of digital information
    Dr. Andraž Kocjan
13. Design, formulation and characterization of biomimetic nanocomposite systems for effective tissue regeneration
    Dr. Mojca Urška Mikac
14. Theory of the nematic nanodroplet and ordering of DNA, encapsidated in simple viruses
    Asst. Prof. Andrej Vilfan
15. Collective and molecular dynamics of photosensitive liquid crystal elastomers
    Prof. Martin Čopič
16. Use of Nanoparticles as Additives in Lubricants and in Tribology
    Prof. Maja Remškar
17. Textured Ceramic Films for Sensors and Actuators
    Prof. Marija Kosec
18. Use of green energy sources: New functional nanomaterials on the base of polyoxometalates and TiO2 nanostrucutres for production of hydrogen by catalytic oxidation of water -NANOleaf
    Dr. Polona Umek
19. Study of the structure and the dynamics of blood clot dissolution: mathematical modeling supported by magnetic resonance experiments
    Prof. Igor Serša
20. Dentin Evolution Detected by Spectroscopic Means
    Prof. Janez Štrancar
21. Study of Food Processing and Preparation by Magnetic Resonance Imaging and Spectroscopy Methods
    Prof. Igor Serša
22. Formulation and Characterization of BF Fuzogenic Nanoparticles for Efficient Drug Delivery into Cells
    Dr. Marjeta Šentjurc
23. Oligomers of amyloidogenic proteins from a to z: biophysical properties, structure,

function and mutual interactions
Prof. Eva Žerovnik
24. Applications of Nanoparticle - Macromolecule Complexes for the Formulation of Biological Drugs
Prof. Igor Muševič
25. Wireless Networks with Radio over Optical Fiber
Prof. Jurij Franc Tasič
26. Behaviour of disipative systems under extreme termo-mechanical loading
Dr. Matej Pregelj
27. New materials for power conversion: Oxide semiconductor thermoelectrics
Prof. Danilo Suvorov
28. Biotechnological Processes of Treatment of Lignocellulosic Materials
Prof. Janez Štrancar
29. Eye Protection
Dr. Janez Pirš
30. A spectrometer for automatic 14N nuclear quadrupole resonance characterization of new substances
Dr. Alan Gregorovič

RESEARCH PROGRAMS

1. NMR and Dielectric Spectroscopy Condensed Matter
Prof. Janez Dolinšek
2. Physics of Soft Matter, Surfaces and Nanostructures
Prof. Slobodan Žumer
3. Experimental Biophysics of Complex Systems
Prof. Janez Štrancar

NEW CONTRACT

1. Development of technologies for artificial nose
Ministry of Defence
Prof. Igor Muševič

MENTORING

Ph. D. Theses

1. Biljana Govedarica, Evaluation of mechanical and surface properties of pharmaceutical materials and products on a single particle level by atomic force microscopy (mentor Stane Srčič; co-mentor Miha Škarabot).
2. Stane Pajk, Influence of some cholesterol oxidation products on the structure of model membranes (mentor Slavko Pečar; co-mentor Janez Štrancar).
3. Igor Perkon, Analysis of whisker dynamics by tracking of non rigid open curves (mentor Jurij F. Tasič; co-mentor Mathew Diamond).
4. Mojca Rangus, The study of structural characteristics and formation of microporous and mesoporous materials (mentor Gregor Mali; co-mentor Janez Seliger).

M. Sc. Thesis

1. Sweety Karta Ram, Sustainable agriculture in India : need and prospects with particular reference to the state of Punjab (mentors Ivo Šlaus, Peter Stanovnik, Matej Stopar, Gojmir Lahajnar).

VISITORS FROM ABROAD

1. Dr. Mirta Herak, Institute of physics, Zagreb, Croatia, 1. 1. 2011 – 31. 12. 2011.
2. Prof. Dr. Shiro Kashimoto, Hokkaido University, Faculty of Engineering, Division of Applied Physics, Sapporo, Hokkaido, Japan, 1. 1. 2011 – 30. 9. 2011.
3. Hyun Wook Kang in Go Woon Lee, Korea Basic Science Institute, Daejeon, South Korea, 3. 1. 2011 – 4. 3. 2011.
4. Dr. Marija Raguž, School of medicine, Department of Medical Physics and Biophysics, Split, Croatia, 25. 1. 2011 – 26. 1. 2011.
5. Dr. Oksana Zaharko, ETHZ ¸& Paul Scherrer Institute, Laboratory for neutron scattering, Villingen, Switzerland, 27. 1. 2011 – 29. 1. 2011.
6. Prof. Dr. Pedro Sebastiao in prof. dr. Maria Helena Godinho, Instituto Superior Tecnico, Department of physics, Lizbon, Portugal, 30. 1. 2011 – 6. 2. 2011.
7. Mantas Šimenas, University of Villniusu, Faculty of Physics, Villnius, Lithuania, 1. 2. 2011 – 20. 7. 2011.
8. Evangelia Karatairi, NCSR Demokritos, Aghia Paraskevi, Greece, 4. 2. 2011 – 6. 2. 2011.
9. Dr. Valentina Domenici, Department of Chemistry and Industrial Chemistry, University of Pisa , Pisa, Italy, 11. 2. 2011 – 25. 2. 2011; 31. 7. 2011 – 28. 8. 2011.
10. Dr. Marco Bonora, University of Pavia, Pavia, Italy, 17. 3. 2011 – 18. 3. 2011.
11. Prof. Dr. Horst Beige, University of Martin-Luther, Halle, Germany, 21. 3. 2011 – 24. 3. 2011.
12. Dr. Jong-Hwa Kim, Korea Basic Science Institute, Analysis Research Division, Daegu Center, Daegu, South Korea, 15. 3. 2011 – 31. 12. 2011.
13. Prof. Dr. Arcady Levanyuk, Department of Condensed Matter Physics, Faculty of Science, Cantoblanco Campus, Madrid, Spain, 10. 4. 2011 – 10. 5. 2011.
14. Dr. Darija Jurašin, Institute of Ruder Bošković, Zagreb, Croatia, 31. 5. 2011 – 30. 11. 2011.
15. Dr. Magdalena Wencka, Institute of Molecular Physics, Polish Academy of Sciences, Poznan, Poland, 1. 5. 2011 – 31. 5. 2011, 1. 10. 2011 – 31. 10. 2011.
16. Surajit Dharo, University of Hyderabad, School of Physics, Hyderabad, Andhra Pradesh, India, 1. 5. 2011 – 3. 6. 2011.
17. Dr. Valentyn Laguta, Physics Institute of the Czech Academy of Sciences, Prague, Czech Republic, 2. 5. 2011 – 14. 5. 2011.
18. Prof. Dr. Pedro Sebastiao, Instituto Superior Tecnico, Department of Physics, Lisbon, Portugal, 25. 5. 2011 – 1. 6. 2011.
19. Yuji Sasaki, Tokyo Institute of Technology, Tokyo Kogyo Daigaku, Japan, 12. 6. 2011 – 19. 6. 2011, 19. 12. 2011 – 31. 8. 2012.
20. Prof. Dr. James Scott, University of Oxford, Clarendon laboratory, FRS, Oxford, United Kingdom, 12. 6. 2011 – 15. 6. 2011.
21. Dr. Vassilios Tzitzios, NCSR Demokritos, Aghia Paraskevi, Greece, 1. 6. 2011 – 26. 7. 2011.
22. Prof. Dr. Sergio Diez Berart, Technical University of Catalonia, Department of Physics and Nuclear Engineering, Barcelona, Spain, 15. 6. 2011 – 28. 6. 2011.
23. Prof. Dr. Sergey Lushnikov, IOFFE Physical Technical Institute, Sankt Petersburg, Russia, 6. 6. 2011 – 26. 6. 2011; 1. 7. 2011 – 8. 7. 2011.
24. Prof. Dr. Yoshihiro Ishibashi, Faculty of Business, Aichi Shokutoku University, Nagakute, Japan, 2. 7. 2011 – 16. 7. 2011.
25. Dr. Fabrice Bert, Universite Paris Sud 11, Laboratory of Solid State Physics, Paris, France, 19. 7. 2011 – 22. 7. 2011.
26. Dr. Tihomir Betti, University of Split, Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture, Split, Croatia, 15. 8. 2011 – 31. 8. 2011.
27. Doc. Dr. Denis Stanić, University of Osijek, Osijek, Croatia, 1. 9. 2011 – 30. 9. 2011.
28. Dr. Wolfgang Porod, University of Notre Dame, Department of Electrical Engineering, Indiana, USA, 19. 9. 2011 – 22. 9. 2011.
29. Dr. Michael Averbukh, Ben Gurion University, Beer Sheva, Israel, 1. 9. 2011 – 30. 9. 2011.
30. Prof. Dr. Kalpathy Easwaran, Indian Institute of Technology, Bangalore, India, 3. 9. 2011 – 6. 9. 2011.
31. Prof. Dr. Tim Sljuckin, Southampton University, Southampton, United Kingdom, 1. 10. 2011 – 30. 12. 2011.
32. Dr. Sebastian Turczynski, Institute of Electronic Materials Technology, Warsaw, Poland, 20. 10. 2011 – 20. 11. 2011.
33. Fabian Vaca Chavez, Instituto Superior Tecnico, Lisbon, Portugal, 20. 11. 2011 – 26. 11. 2011.
34. Dr. Lia Verhoeff, Utrecht University, Van't Hoff Laboratory for Physical and Colloid Chemistry Debye Institute, Utrecht, Netherlands, 26. 11. 2011 – 17. 12. 2011.

STAFF

Researchers

1. Asst. Prof. Tomaž Apih
2. Prof. Denis Arčon*
3. *Prof. Robert Blinc, died 26.09.11*
4. Asst. Prof. Vid Bobnar
5. *Asst. Prof. Pavel Cevc, retired 28.12.11*
6. Prof. Janez Dolinšek*
7. Dr. Cene Filipič
8. Dr. Peter Jeglič
9. Dr. Martin Klanjšek
10. Prof. Samo Kralj*
11. Prof. Zdravko Kutnjak
12. *Prof. Gojmir Lahajnar, retired 31.12.11*
13. Prof. Adrijan Levstik
14. Dr. Mojca Urška Mikac
15. **Prof. Igor Muševič*, Head**
16. *Dr. Andriy Nych, left 27.09.11*
17. *Prof. Slavko Pečar*, retired 01.11.11*

18. Dr. Janez Pirš
19. Asst. Prof. Dušan Ponikvar*
20. Prof. Albert Prodan
21. Prof. Maja Remškar
22. Prof. Janez Seliger*
23. Prof. Igor Serša
24. Prof. Janez Stepišnik
25. Asst. Prof. Miha Škarabot
26. Prof. Janez Štrancar
27. Prof. Jurij Franc Tasič*
28. Dr. Polona Umek
29. Dr. Herman Josef Petrus Van Midden
30. Asst. Prof. Andrej Vilfan
31. Prof. Boštjan Zalar
32. Prof. Aleksander Zidanšek
33. Dr. Andrej Zorko
34. Prof. Slobodan Žumer*

Postdoctorial associates

35. Asst. Prof. Zoran Arsov
36. Daniele Biglino, B. Sc.
37. Dr. Alan Gregorovič
38. Dr. Tilen Koklič
39. *Dr. Uliana Ognysta, left 27.09.11*
40. Dr. Matej Pregelj
41. Dr. Uroš Tkalec
42. Dr. Jernej Vidmar*
43. Dr. Stanislav Vrtnik
44. Dr. Blaž Zupančič
45. Dr. Erik Zupanič

Postgraduates

46. Franci Bajd, B. Sc.
47. Nina Bizjak, B. Sc.
48. Matej Bobnar, B. Sc.
49. Goran Casar, B. Sc.
50. Ana Dergan, B. Sc.
51. Andreja Eršte, B. Sc.
52. Maja Garvas, B. Sc.
53. Anton Gradišek, B. Sc.
54. Matjaž Humar, B. Sc.
55. Ivan Iskra, B. Sc.
56. Venkata Subba Rao Jampani, M. Sc.
57. Simon Jazbec, B. Sc.
58. Andreja Jelen, B. Sc.
59. Dalija Jesenek, B. Sc.
60. Andrej Kocan**
61. Marta Lavrič, B. Sc.
62. Ajasja Ljubetič, B. Sc.
63. Olga Malgina, B. Sc.
64. Bojan Marin*, M. Sc.
65. *Špela Markič Dakskobler*, B. Sc., left 01.04.11*
66. Jerneja Milavec, B. Sc.
67. Jana Milenković, B. Sc.
68. Jana Mlakar**
69. Maryam Nikkhou, M. Sc.
70. Nikola Novak, B. Sc.
71. Anton Potočnik, B. Sc.
72. Brigita Rožič, B. Sc.
73. Dr. Anna Ryzhkova
74. Dr. Yuji Sasaki
75. Bernarda Urankar, B. Sc.
76. Iztok Urbančič, B. Sc.
77. Bojana Višić, B. Sc.

Technical officers

78. Maja Češarek, B. Sc.
79. Sandra Kure, B. Sc.
80. Ivan Kvasić, B. Sc.
81. Bojan Ložar, B. Sc.
82. Alma Mehle, B. Sc.
83. Milan Rožmarin, B. Sc.

Technical and administrative staff

84. Andreja Berglez, B. Sc.
85. Barbara Hrovatin, B. Sc.
86. Dražen Ivanov
87. Janez Jelenc, B. Sc.
88. Davorin Kotnik
89. Silvano Mendizza
90. Janja Milivojević
91. Iztok Ograjenšek
92. Silvija Pirš
93. Ana Sepe, B. Sc.
94. Marjetka Tršinar
95. Veselko Tihidrag Žagar, B. Sc.

Note:
* part-time JSI member
** postgraduate financed by industry

BIBLIOGRAPHY

Original Articles

1. F. Aimo, S. Krämer, Martin Klanjšek, Mladen Horvatić, Claude Berthier, "Magnetic structure of azurite above the magnetization plateau at $\frac{1}{3}$ of saturation", *Phys. rev., B, Condens. matter mater. phys.*, vol. 84, no. 1, pp. 012401-1-012401-4, 2011.
2. Zoran Arsov, Iztok Urbančič, Maja Garvas, Daniele Biglino, Ajasja Ljubetič, Tilen Koklič, Janez Štrancar, "Fluorescence microspectroscopy as a tool to study mechanism of nanoparticles delivery into living cancer cells", *Biomedical optics express*, vol. 2, no. 8, pp. 2083-2095, 2011.
3. Franci Bajd, Igor Serša, "Continuous monitoring of dough fermentation and bread baking by magnetic resonance microscopy", *Magn. reson. imag.*, vol. 29, issue 3, pp. 434-442, 2011.
4. J. Banys, J. Macutkevič, S. Lapinskas, Raša Pirc, Zdravko Kutnjak, Robert Blinc, "Low frequency dielectric investigation of $Rb_{0.5}(ND_4)_{0.5}D_2PO_4$ dipolar glass: comparison with nuclear magnetic resonance investigations", *J. appl. phys.*, vol. 109, no. 11, pp. 114101-1-114101-4, 2011.
5. Robert Blinc, Gojmir Lahajnar, Anton Potočnik, "The muon $F - \mu^+ - F$ hydrogen bond-like complex", *Acta chim. slov.*, vol. 58, no. 3, pp. 393-395, 2011.
6. Robert Blinc, Boštjan Zalar, Blaž Zupančič, Anna N. Morozovska, Maya Davydovna Glinchuk, "NMR study of size effects in relaxor PMN nanoparticles", *Phys. status solidi, b Basic res.*, vol. 248, no. 11, pp. 2653-2655, 2011.
7. Matej Bobnar, Stanislav Vrtnik, Zvonko Jagličić, Magdalena Wencka, Can Cui, An Pang Tsai, Janez Dolinšek, "Electrical, magnetic, and thermal properties of the single-grain $Ag_{42}In_{42}Yb_{16}$ icosahedral quasicrystal", *Phys. rev., B, Condens. matter mater. phys.*, vol. 84, no. 13, pp. 134205-1-134205-10, 2011.
8. Vid Bobnar, Andreja Eršte, X.-Z. Chen, C.-L. Jia, Q.-D. Shen, "Influence of dc bias electric field on Vogel-Fulcher dynamics in relaxor ferroelectrics", *Phys. rev., B, Condens. matter mater. phys.*, vol. 83, no. 13, pp. 132105-1-132105-4, 2011.
9. Vid Bobnar, Andreja Eršte, Xian-Zhong Chen, Qun-Dong Shen, "Glassy dielectric processes in reduced poly(vinylidene fluoride-trifluoroethylene) copolymer system", In: Proceedings of the ISAF ECAPD 2010, 19th International Symposium on the Applications of Ferroelectrics, Edinburgh, UK, *Ferroelectrics,* vol. 419, no. 1, pp. 59-65, 2011.
10. Vid Bobnar, Andreja Eršte, Urška Gradišar, Cene Filipič, Adrijan Levstik, Zdravko Kutnjak, "High-temperature dielectric response of ferroelectric relaxors", *IEEE trans. ultrason. ferroelectr. freq. control*, vol. 58, no. 11, pp. 2270-2275, 2011.
11. Vid Bobnar, Zdravko Kutnjak, "Does Burns temperature exist in ferroelectric relaxors?", In: The 10th Russia/CIS/Baltic/Japan Symposium on Ferroelectricity, RCBJSF-10, Yokohama, Japan, *Ferroelectrics,* vol. 415, no. 1, pp. 14-19, 2011.
12. Pierre Bouillot *et al.* (12 authors), "Statics and dynamics of weakly coupled antiferromagnetic spin-$\frac{1}{2}$ ladders in a magnetic field", *Phys. rev., B, Condens. matter mater. phys.*, vol. 83, no. 5, pp. 054407-1-054407-31, 2011.

13. Beate Boulgaropoulos, Zoran Arsov, Peter Laggner, Georg Pabst, "Stable and unstable lipid domains in ceramide-containing membranes", *Biophys. j.*, vol. 100, no. 9, pp. 2160-2168, 2011.
14. Zlatko Bradač, Samo Kralj, Slobodan Žumer, "Early stage domain coarsening of the isotropic-nematic phase transition", *J. chem. phys.*, vol. 135, no. 2, pp. 024506-1-024506-9, 2011.
15. Alexej Bubnov, Valentina Domenici, Vera Hamplová, Miroslav Kašpar, Boštjan Zalar, "First liquid single crystal elastomer containing lactic acid derivative as chiral co-monomer: synthesis and properties", *Polymer (Guildf.)*, vol. 52, no. 20, pp. 4490-4497, 2011.
16. Simon Čopar, Tine Porenta, Slobodan Žumer, "Nematic disclinations as twisted ribbons", *Phys. rev., E Stat. nonlinear soft matter phys. (Print)*, vol. 84, issue 5, pp. 051702-1-051702-7, 2011.
17. Simon Čopar, Slobodan Žumer, "Nematic braids: topological invariants and rewiring of disclinations", *Phys. rev. lett.*, vol. 106, pp. 177801-1-177801-4, 2011.
18. Janez Dolinšek, "Nobelovo nagrado za kemijo 2011 je prejel Danny Shechtman za odkritje kvasikristalov", *Obz. mat. fiz.*, vol. 58, no. 5, pp. 180-188, 2011.
19. Valentina Domenici, Marjetka Conradi, Maja Remškar, Marko Viršek, Blaž Zupančič, Aleš Mrzel, Martin Chambers, Boštjan Zalar, "New composite films based on MoO_{3-x} nanowires aligned in a liquid single crystal elastomer matrix", *J. Mater. Sci.*, vol. 46, no. 10, pp. 3639-3645, 2011.
20. E. A. Eliseev, Anna N. Morozovska, Maiia Davydovna Glinchuk, Robert Blinc, "Anion vacancy-driven magnetism in incipient ferroelectric $SrTiO_3$ and $KTaO_3$ nanoparticles", *J. appl. phys.*, vol. 109, no. 9, pp. 094105-1-094105-5, 2011.
21. Andreja Eršte, Brigita Kužnik, Barbara Malič, Marija Kosec, Vid Bobnar, "Dielectric properties of $CaCu_3Ti_4O_{12}$ ceramic thin films", In: Proceedings of the ISAF ECAPD 2010, 19th International Symposium on the Applications of Ferroelectrics, Edinburgh, UK, *Ferroelectrics,* vol. 419, no. 1, pp. 14-19, 2011.
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