ANNUAL REPORT

1994

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RESEARCH INSTITUTE FOR SOLID STATE PHYSICS

of the Hungarian Academy of Sciences, Budapest, Hungary

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of the Hungarian Academy of Sciences

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ANNUAL REPORT 1994

Edited by **L. Csillag, J. Kollár, G. Konczos**

Closed on 1st December, 1994

Preface

The Research Institute for Solid State Physics of the Hungarian Academy of Sciences was founded on 1st April, 1981 with research groups working in solid state physics, materials sciences and laser physics. Until 1st January, 1992 it was part of the Central Research Institute for Physics. Since this date it is an independent legal entity.

The institute consists of a strong theoretical and a number of experimental departments. „Nuclear" (neutron scattering, X-ray diffraction, Mössbauer spectroscopy, NMR, electron microscopy) and other (optical, microwave, magnetic, transport, calorimetric, dielectric) techniques are used for condensed matter studies, furthermore neutron, resonance and laser techniques are used for technological, metrological, environmental and medical applications. A small mechanical and electronics workshop and a few (metallurgical, chemical and thin film) service groups produce most of our samples for research and optical coatings for our laser research and development needs.

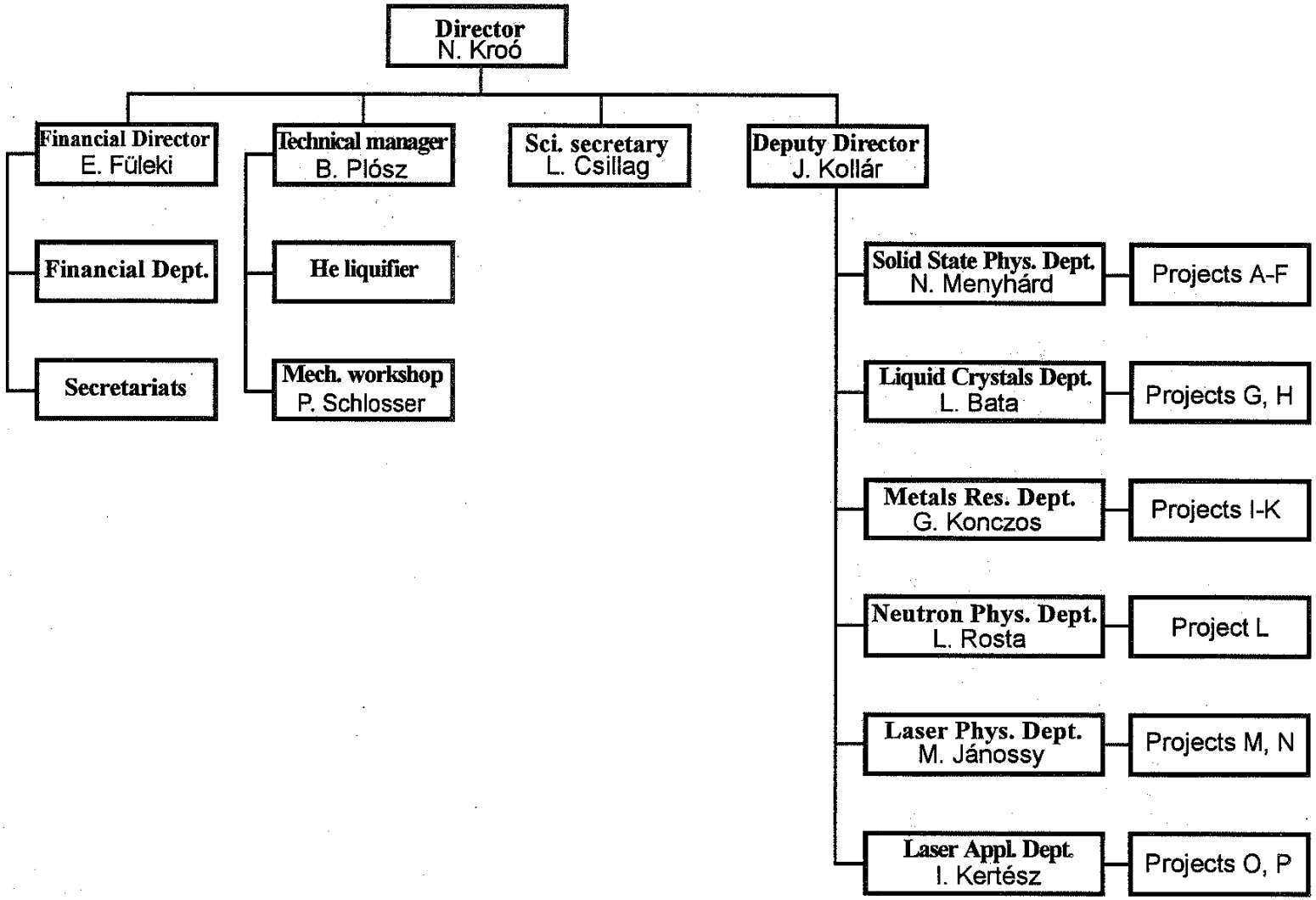
Our financial support comes mainly from the state budget through the Hungarian Academy of Sciences supplemented by domestic and foreign R & D contracts.

The institute has strong cooperation with numerous domestic, European and overseas laboratories and universities. We are strongly involved in the gradual and postgradual education in solid state and laser physics.

This is the first Yearbook of the independent Institute, which will hopefully be followed by similar booklets in the coming years.

1st December 1994

Norbert Kroó
director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A. STRONGLY CORRELATED SYSTEMS

J. Sólyom, P. Fazekas, G. Fáth, K. Penc, K. Vladár, F. Woynarovich, A. Zawadowski[+]

Low dimensional magnetic models. - Quantum fluctuations give rise to several new phases in spin-1 magnetic chains. It is known that the biquadratic coupling between the spins leads to a dimerized or trimerized phase, besides the usual ferro- or antiferromagnetic phases. Recently it has been suggested that a nondimerized quantum nematic phase might also exist. We have done a numerical study of the energy spectrum and have found no evidence for this phase.

One-dimensional fermionic models. - Three models are currently intensively used to describe strongly correlated one-dimensional electron systems, the Hubbard, t-J and Tomonaga-Luttinger models. We have studied the relationship among them using the Bethe-Ansatz results and large U expansion. We have shown that even in the large U limit the t-J model is equivalent to the Hubbard model if it is generalized to include three-site processes.

We have continued also the analysis of the Bethe-Ansatz solutions of the 1-d Hubbard and Heisenberg models. In particular we analyzed the correlation function exponents as a function of magnetization by solving the Bethe-Ansatz equations numerically.

Kondo lattice model. - The work on the variational approach to the ground state properties of strongly correlated systems has been continued. A correlated mean field Ansatz for the Kondo necklace model was evaluated. The variational method was used to discuss the ground state phase diagram of the Kondo lattice model.

Theory of dissipative motion of heavy particles. - We studied the dissipative motion of heavy particles (proton, muon, α-particle, ions) in condensed matter by theoretical methods. We examined the connection between the classical and quantum statistical solutions of a model containing harmonic oscillators. As it was known, the dissipative forces can be represented by an action formed as multiple integral on time, instead of single integral of a Lagrangian. We showed that the shape of the singularity in these time-integrals depends on, through the boundary conditions of the problem, whether the particle in question is in thermal equilibrium or it is a fast one. With the help of these we interpreted some of our former results for a more realistic model containing fermionic heat bath and we found connection between the friction coefficient and the localization of a particle.

Grants

OTKA[1] I/3 2979. Low dimensional magnetic systems and high temperature superconductivity
OTKA I/4 T4473. Low dimensional interacting electron systems and magnetic models.
OTKA T 014201. Theory of the phase diagram of heavy fermionic systems
OTKA T 014443. Completely integrable 1-d systems

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[1]OTKA = Hungarian Research Fund

Publications

A.1. P. Fazekas: Magnetic and non-magnetic states of heavy fermion systems. To be published in the Proceedings of the Amalfi Conference on Strongly Correlated Systems (World Scientific)

A.2. G. Fáth and J. Sólyom: Hidden domain walls as elementary excitations in the spin-1 valence-bond-solid model. Acta Physica Polonica A85, 37l (1994).

A.3. H.Y. Kee* and P. Fazekas: Correlated mean field Ansatz for the Kondo necklace. Int. J. Modern Phys. B8, 1355 (1994)

A.4. J. Sólyom and K. Penc: Relationship among the Hubbard, t-J and Tomonaga-Luttinger models. In Recent Progress in Many Body Theories, Vol. 4, edited by E. Schachinger, H. Mitter and M. Sormann (Plenum Press, 1994).

A.5. G. Fáth and J. Sólyom: Search for the nondimerized quantum nematic phase in the spin-1 chain. To be published in Phys. Rev. B

* The author is not a member of the Research Institute for Solid State Physics staff

B. COMPLEX SYSTEMS

N. Menyhárd, A. Csordás, F. Iglói, A. Sütõ, P. Szépfalusy[+] *, S. Varró*

Phase transitions and scaling - equilibrium and non-equilibrium. - Phase transitions on non-peroidic lattices have been studied. Quasi-periodic and, more generally, aperiodic systems can be considered as a state of matter which interpolates between the periodic (crystalline) and the random (disordered, glassy) states and the corresponding critical behaviour is very rich. The relevance or irrelevance of the aperiodicity is connected to the strength of the fluctuations in the couplings. For the two-dimensional Ising model different types of layered aperiodic modulation of the couplings have been considered. According to exact results obtained for thermodynamic quantities, the critical exponents are varying in the marginal case while for relevant modulations essential singularities show up at the critical point.

In the field of ordering kinetics kinetic Ising models offer a useful laboratory for exploring the different factors which influence scaling and (dynamic) universality classes. We have pointed out earlier that checkerboard updating of 2D Ising model with Metropolis-type kinetics leads to deterministicity at T=0 and a new universality class for quenches from T=∞ to T=0. The effect and significance of this determinicity all over the ordered phase and even at T_C in the time-dependences of the structure factor and autocorrelation function has been established via numerical simulation.

We have introduced a family of nonequilibrium kinetic Ising models which show a phase transition from Ising-type steady state to an active state reminiscent of that for directed percolation but with differing critical exponents. Phase boundary, scaling behaviour and critical exponents have been obtained via Monte-Carlo simulation. Connection with the problem of branching annihilating random walk has also been established.

Classical and quantum chaos. - Transient chaos has come into the focus of interest lately, both experimentally and theoretically. We have investigated several statistical properties of transient chaos, especially the extension of the intermittent state occurring in permanent chaos to transient chaos. It has been shown that in this state a phase transition-like phenomenon takes place, which is continuous, as opposed to the first-order transition occurring in the intermittent state of permanent chaos.

The investigation of energy-level statistics in describing the properties of various systems has been playing an increasingly important role. We have introduced a model system for studying the question how the level-statistics of some system is modified by varying a parameter of the system. By changing the curvature of a wall of a billiard, a new scaling law has been found for the transition from the Poisson-like to Gaussian- orthogonal-ensemble level-statistics, and its theoretical background could also be established.

Quantum systems. - Generation of higher harmonics by a metal surface irradiated by a powerful laser field has been treated theoretically. Especially, the spectral distribution of the radiation has been calculated with the aim to interpret recent experimental data by Farkas et al. who observed multiple-harmonic radiation from a gold surface induced by picosecond Nd:YAG laser pulses. We have used a nonperturbative method worked out by us earlier for solving the Schrödinger equation of surface electrons interacting with laser light. Using the laser and gold parameters of the above-mentioned experiment, our

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theoretical predictions of the relative harmonic-generation rates are in good agreement with the experimental data.

A comprehensive review of WKB theory for mesoscopic quantum tunneling in magnetism has been presented.The behaviour of a large quantum spin in an anisotropic surroundings and its penetration into a classically forbidden region is described. The key idea is to single out one of the anisotropy axes say z, work in a representation with S_z diagonal and to describe quantum tunneling as a hopping process on the spectrum of S_z.

A review of recent developments in the theory of one-dimensional tight-binding Schrödinger equation for a class of deterministic ergodic potentials has been given. In the typical examples the potentials are generated by substitutional sequences, like Fibonacci or Thue-Morse sequences.

GRANTS

OTKA F4472 Classical and quantum dynamics of non-linear systems
OTKA T12830 Critical behaviour of low-dimensional systems
OTKA T2090 Investigations of random processes and complex structures

PUBLICATIONS

B.1. F. Iglói and P. Lajkó: Polymer in gravitational field. Physica A209, 486 (1994)

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B.3. F. Iglói: Correlations in random Ising chains at zero temperature. J. Phys. A27, 2995 (1994).

B.4. F. Iglói and L. Turban*: Relevant aperiodic modulation in the two-dimensional Ising model. Europhys. Lett. 27, 91 (1994)

B.5. N. Menyhárd: Domain-growth properties of a two-dimensional kinetic Ising model. J. Phys. A:Math.Gen. 27, 663 (1994).

B.6. N. Menyhárd: One-dimensional non-equilibrium kinetic Ising model with branching annihilating random walk. J. Phys. A: Math.Gen. 27, 6139 (1994).

B.7. A. Csordás, R. Graham*, P. Szépfalusy and G. Vattay*: Transition from Poissonian to Gaussian orthogonal ensemble level statistics in a modified Artin's billiard. Phys. Rev. E49, 325 (1994)

B.8. S. Varró and F. Ehlotzky*: Higher-harmonic generation from a metal surface in a powerful laser field. Phys. Rev. A49, 3106 (1994).

B.9. S. Varró: On the unitary continuation of the exponential phase operator. In: Quantum Optics, Proc. of the II. Central European Workshop on Quantum Optics (Budapest, 1994), ed.: J. Janszky, p.36 (Research Lab. for Crystal Phys., Budapest, 1994)

B.10. S. Varró and F. Ehlotzky*: Potential scattering of electrons in a bichromatic laser field of frequencies ω and 2ω or ω and 3ω. In: Multiphoton processes, eds.: D.K. Evans and S.L. Chin, p. 93 (World Scientific Publ. Co., London, 1994)

B.11. S. Varró and F. Ehlotzky*: Higher-harmonic generation from a metal surface in a powerful laser field. In: ibid. p. 245 (1994)

B.12. J.L. van Hemmen* and A. Sütõ: Theory of mesoscopic quantum tunneling in magnetism: a WKB approach. To be published in: Quantum Tunneling of Magnetism, eds. L.Gunther and B. Barbara (Kluwer)

B.13. A. Sütõ: Schrödinger difference equation with deterministic ergodic potentials. To be published in: Proceedings of the Les Houches Winter School, March 1994, eds. F. Axel and D. Gratias (Springer).

B.14. A. Németh*, P. Szépfalusy: Properties of border states of transient chaos. To be published in Phys. Rev. E.

C. ELECTRONIC STATES IN SOLIDS

J. Kollár, I. Tüttõ, B. Ujfalussy, A. Virosztek and L. Vitos

The recent activities of the group cover the following main areas in the description of the electronic states in solids:

Effect of nonspherically symmetric charge distribution on the surface and bulk electronic structure. - In this approach we calculate the kinetic energy completely within the atomic sphere approximation, while the Coulomb and exchange-correlation contributions to the total energy are calculated by means of the complete, nonspherically symmetric charge density within nonoverlapping, space-filling Wigner-Seitz cells. We use a self-consistent Green's-function method in the surface energy calculation. The importance of these energy terms are demonstrated by applying our approach to the 4d elements and the light actinides. In the near future we plan to examine the effect of these terms on the structural stability of bulk f-electron metals with more complex structures (e.g. α-U, α-Pu).

Energy-dependent, screened KKR scheme for bulk metals and surfaces. - We have developed an efficient technique to calculate bulk and surface electronic properties based on the KKR scheme using κ-dependent, screened structure constants. The method was tested on Cu (111), (110) and (100) surfaces. The program has been generalized for the fully relativistic, and spin-polarized case as well and applied for the discription of the (111), (110) and (100) surfaces of Au and Pt.

We have continued our investigation of the effect of **long range Coulomb interaction in density wave systems**, and extended our earlier results on charge density waves to spin density waves as well. Some years ago we developed a theory of the electromechanical effect in density waves, this year we applied that theory in the case of transverse sound wave, which is of far more practical interest, than the longitudinal one.

In the field of **high temperature superconductors** we studied the effect of a superconducting gap on the microwave conductivity in the framework of the nested Fermi liquid theory. Comparison of our results with experiments supports a pairing mechanism of electronic origin in the cuprates. On the basis of a three-band Hubbard model we analysed the Raman scattering on phonons in the cuprates as well. Our results are consistent with a $d_{x^2-y^2}$ gap symmetry.

Continuing the investigation of the **role of the nonmagnetic impurities in the pinning of the spin-density waves**, its consequences on the Raman spectra was calculated. Furthermore, considering the high temperature superconductors, we started the calculation of a relatively simple model, where the superconducting state is formed on a spin ordered Fermi liquid. This model leads to the formation of a d-type superconducting state, which is in agreement with the recent Raman scattering and other experimental results.

GRANTS

OTKA 2950 Electronic structure and the calculation and measurement of optical spectra in solids

ERB-CIPA-CT-92-2096 (European Union Grant) Electronic structure of actinide surfaces

OTKA T4473 Low dimensional interacting electron systems and magnetic models

OTKA T7633 Appearance of the couplings between the superconducting and spin density wave fluctuations in the conductivity

PUBLICATIONS

C.1. J. Kollár, L. Vitos and H.L. Skriver*: Surface energy and work function of the light actinides. Phys. Rev. B 49, 11288, 1994

C.2. L. Vitos, J. Kollár and H.L. Skriver*: Full charge density calculation of the surface energy of metals. Ibid. B 49, 16694, 1994

C.3. L. Szunyogh*, B. Ujfalussy, P. Weinberger* and J. Kollár: Self-consistent localized KKR scheme for surfaces and Interfaces. Ibid. 49, 2721, (1994)

C.4. A. Virosztek and K. Maki*: Phason modes in a spin density wave in the presence of long range coulomb interaction. Ibid. 49, 6074 (1994)

C.5. J. Kollár and B. Ujfalussy: General formulas for the Slater-Koster tables. J. Comp. Phys. 110, 187 (1994)

C.6. B. Ujfalussy, L. Szunyogh*, P. Weinberger* and J. Kollár: A new KKR type equation for surfaces and interfaces: the "Tight-Binding KKR". In Metallic Alloys: Experimental and Theoretical Perspectives, Edited by J.S. Faulkner and R.G. Jordan, pp 301-311, Kluwer Academic Publisher, (1994)

C.7. L. Szunyogh*, B. Ujfalussy, P. Weinberger* and J. Kollár: The self-consistent fully relativistic screened KKR Green's-function method. Applications to the (100), (110) and (111) Surfaces of Au and Pt. J. Phys. Condensed Matter, 6, 3301 (1994)

C.8. C.T. Rieck*, W.A. Little*, J. Ruvalds* and A. Virosztek: Conductivity below T_c in high temperature superconductors. Physica B 195, 1465 (1994)

C.9. L. Vitos and J. Kollár: Optimized *l*-convergency in the solution of Poisson's equation with space-filling cells. To be published in Phys. Rev. B

C.10. T.P. Devereaux*, A. Virosztek and A. Zawadowski: Charge transfer fluctuation, d-wave superconductivity, and the B_{1g} Raman phonon in the cuprates: A Detailed Analysis. To be published in ibid.

C.11. A. Virosztek and K. Maki*: Electromechanical effect in charge- and spin-density waves. To be published in Synth. Metals

D. NON-EQUILIBRIUM ALLOYS

I. Vincze, J. Balogh, L. Bujdosó, L. Gránásy, D. Kaptás, T. Kemény, L.F. Kiss, Gy. Mészáros, E. Sváb

Spin-glasses - Our research in this field is aimed to establish a coherent physical picture of the magnetic structure of this class of materials. The Fe rich amorphous Fe-Zr alloys belong to this group. A detailed bulk magnetization and Mössbauer spectroscopy study of the composition, magnetic field and temperature dependence of the magnetic properties revealed surprising new features. In contrast to the traditional spin glass theories the collinear magnetic state is attained below 7 T at 4.2 K temperature and the observed high magnetic susceptibility can not be associated with canted magnetic moments. The magnetic freezing temperature and its magnetic field dependence is also established. It is verified in connection with the non-linear susceptibility as well as with the magnetic field and temperature dependence of the magnetization that the interacting magnetic clusters have an important influence to the magnetic behaviour traditionally described as spin glass.

Amorphous alloys by solid state reaction - The formation and properties of non-equilibrium phases have been studied by synchrotron radiation X-ray diffraction, cross sectional transmission electron microscopy and Mössbauer spectroscopy in the Fe-B system near to the 50 at% B composition. The multi layer structure and its modification with solid state reaction is established for 1.5 - 10 nm thick layers electron beam evaporated and heat treated in ultra high vacuum. The magnetic behaviour of the non-equilibrium alloy phases have also been investigated with the temperature and external magnetic field dependence of the Mössbauer spectra. Amorphous alloy formation is also detected in case of the mechanical alloying of the elemental components. It is verified, that in contrast to the solid state diffusion amorphization, in mechanical alloying the amorphous phase formation starts at low B concentration and proceeds with the gradual enhancement and homogenization of the B content, which can also be promoted by low temperature heat treatments.

Nucleation theory for diffuse interfaces - A diffuse interface theory of nucleation is proposed by relating the excess free energy of nuclei to macroscopic quantitities. The model is applied for vapour condensation, to crystal nucleation from liquids and from oxide and metallic glasses and to phase separation in a liquid miscibility gap. The results imply that for large deviation from equilibrium the proposed model is in better agreement with experiments than the classical theory, while for small deviations the two descriptions are equivalent.

Neutron diffraction - The short and medium range order have been studied in various amorphous systems. We have introduced a consistent new formalism to calculate the partial structure functions from the measured total diffraction intensities by taking into consideration the physically established features of both of the Faber-Ziman and Ashcroft-Langreth formalisms, generally used in the literature. It can be used for neutron diffraction data treatment of systems containing atoms with positive and negative scattering lengths: the weights exhibit no singularities even for zero-scattering samples. On the other hand, it takes into consideration the structure independent Laue monotonic scattering term.

Inhomogeneities in amorphous Ni-Nb system prepared from various Ni-isotopes were investigated by neutron scattering. A strong increase in the structure factors was observed below 0.04 $Å^{-1}$. The partial Bhatia-Thornton density-concentration structure factors were

determined, and it was concluded that inhomogeneities originating from both density and chemical fluctuations with a characteristic correlation length about 180 Å are present.

Thermodynamical processes in various absorption type refrigerator systems have been investigated by dynamic neutron radiography method. Evaporation, condensation and flow of fluid (ammonia diluted in water) was visualized, and the reason of defective functioning was established for various constructions.

We have built out a new powder diffractometer based on position sensitive linear detector and a dynamic neutron and gamma radiography measuring working place at the refurbished 10 MW research reactor of the KFKI in cooperation with the KFKI Atomic Energy Research Institute.

Grants

OTKA I/3 2933 Atomic and electronic structure of non equilibrium alloys
OTKA I/3 2934 Structure study of amorphous alloys by neutron scattering
OTKA I/4 T 4464 The effect of the distribution of local magnetic properties to the magnetic order
OTKA I/4 T 4469 Atomic level alloying
OTKA A-267 Neutron diffraction
OMFB[2] SN1/1815 Neutron diffraction and neutron radiography

Publications

D.1. M. Balaskó*, E. Sváb, A. Nedelik*, I. Cserháti* and J. Oláh*: Development of household refrigerators by means of dynamic neutron radiography. Proc. 6th European Conference on Non Destructive Testing (ed. J.Ph. Berge, La Cofrend, France) 1, 1231-1233 (1994)

D.2. M. Balaskó*, E. Sváb and H. Nedelik*: Neutron radiography investigation of absorption and compression refrigerators. Nondestructive Testing and Evaluation 11, 69-76 (1994)

D.3. M. Balaskó* and E. Sváb: Neutron radiography in research and development. Nukleonika 39, 3-22 (1994)

D.4. L. Gránásy: Nucleation theory for diffuse interfaces. Mat. Sci. Eng. A178, 121-124 (1994)

D.5. L. Gránásy, I. Egry*, L. Ratke* and D.M. Herlach*: On the diffuse interface theory of nucleation. Scripta Met. Mater. 30, 621-626 (1994)

D.6. L. Gránásy, I. Egry*, L. Ratke* and D.M. Herlach*: Diffuse interface model of bulk heterogeneous nucleation. Ibid. 31, 601-606 (1994)

D.7. N. Hegman*, L.F. Kiss and T. Kemény: Broad peak of the non-linear susceptibility at the spin-glass temperature of amorphous $Fe_{93}Zr_7$. J. Phys: Condens. Matter 6, L427-430 (1994)

[2]OMFB = National Committee for Technical Development

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D.11. G. Petõ*, Zs. Horváth*, O. Gereben*, L. Pusztai*, F. Hajdu and E. Sváb: Implantation-induced structural changes in evaporated amorphous Ge. Phys. Rev. B50, 539-542 (1994)

D.12. G. Serfõzõ*, L.F. Kiss, É. Zsoldos*, J. Tóth, Sz. Sándor*, L. Papadimitrou* and L. Dózsa*: On the magnetic properties of cadmium doped Y-Ba-Cu-O high-temperature superconductors. J. Mat. Sci. Letters 13, 693-695 (1994)

D.13. E. Sváb and F. Hajdu: A consistent formalism for partial structure functions. J. Appl. Cryst. 27, 25-28 (1994)

D.14. I. Vincze, D. Kaptás, T. Kemény, L.F. Kiss and J. Balogh: Field induced magnetic moments in amorphous Fe-Zr Spin-Glass-Like Alloys. Phys. Rev. Letters 73, 496-499 (1994)

D.15. M. Balaskó*, E. Sváb, I. Cserháti*, F. Ozsvári* and J. Oláh*: Applications of dynamic neutron and gamma radiography at the Budapest Research Reactor. To be published in Acta Physica Hungarica

D.16. S.N. Ishmaev* and E. Sváb: Static and dynamic atomic correlations in amorphous systems. To be published in Acta Physica Hungarica

D.17. E. Sváb, S. Borbély, S.N. Ishmaev* and R. Glas*: Small-angle neutron scattering study of amorphous isotopic Ni-Nb system. To be published in ibid.

D.18. J. Balogh, L. Bujdosó, Gy. Faigel, T. Kemény and I. Vincze: Solid state amorphization in the Fe-B system. To be published in J. de Physique

D.19. A. Böhönyei*, L.F. Kiss and A. Lovas: Qualitative difference between the reversible relaxation spectra of Fe-Ni-P-B and Fe-Ni-B metallic glasses. To be published in J. Non-Cryst. Sol.

D.20. L. Gránásy and D.M. Herlach*: Diffuse interface approach to crystal nucleation in glasses, To be published ibid.

D.21. D. Kaptás, T. Kemény, J. Balogh, L.F. Kiss, L. Gránásy and I. Vincze: Temperature dependence of the iron hyperfine field distribution in amorphous Fe-rich Fe-Zr alloys. To be published in Hyperfine Interactions

D.22. L.F. Kiss and N. Hegman*: Frequency dependence of the ac susceptibility of amorphous $Fe_{93}Zr_7$ alloy. To be published in J.Magn.Magn.Mater.

D.23. I. Vincze, D. Kaptás, T. Kemény, L.F. Kiss and J. Balogh: Temperature and external magnetic field dependence of the spin freezing in amorphous $Fe_{93}Zr_7$. To be published ibid.

E. X-RAY DIFFRACTION

G. Faigel, G. Bortel, A. Jánossy[+], K. Kamarás, G. Oszlányi, S. Pekker, T. Pusztai, M. Tegze

Fullerene compounds. - The fullerenes are closed shell carbon cage molecules built up from 12 pentagons and an arbitrary number of hexagons. The most abundant among the fullerenes is the C_{60} molecule which is formed from 60 carbon atoms distributed on the surface of a sphere in a similar way as the corners of the pentagons and hexagons on a soccer ball. Fullerenes can form a large variety of compounds with elements or other molecules. We investigated the structure and physical properties of two families of compounds: C_{60}-clathrate and alkali-metal-C_{60} systems.

C_{60}-clathrates. Clathrates are the so called inclusion compounds in which the lattice of the host molecules (C_{60} in this case) is stabilized by the inclusion of the guest molecules situated in between the layers of the host molecules. The interaction between molecules is dominated by van der Waals forces. We concentrated our first efforts to the study of the structure and phase transitions of the C_{60} clathrates. As model material we choose the C_{60}-*n*-pentane since this C_{60} clathrate could be produced in good quality single crystal form and its behavior seemed to be typical of many similar clathrates. An interesting interplay between the molecular motion and crystal symmetry has been found. We showed that the orthorhombic symmetry of the room temperature phase can only be explained by the flip-flop motion of the *n*-pentane molecules. Further it was also shown that there is a symmetry change of the lattice from orthorhombic to monoclinic on cooling. This could be understood by supposing that all the guest molecules are frozen into one of the two possible orientations. Similar behavior was found in other clathrates.

Alkali-metal-C_{60} system. In the group of A_xC_{60} compounds (A=K,Rb,Cs x=1,3,4,6) there are materials with very interesting properties. Among them many superconducting materials (A_3C_{60}) with remarkably high critical temperature were found. Recently, the A_1C_{60} type compounds became the center of interest. In these samples several different phases were found as a function of temperature and thermal history. These phases show unexpected structural and transport properties. A typical example is the Rb_1C_{60}. This compound has a rock salt structure at high temperature (400K) and it is a conductor. Slowly cooling this sample to room temperature, it transforms to an orthorhombic phase via a first order phase transition. We determined the atomic structure of this phase, and found that a polymer state developed. This phase seems to be a one dimensional conductor. The K_1C_{60} compound shows a similar behavior. We have been able to grow small (few mm in length) single crystals of the K_1C_{60} polymer. Partial oxidation under toluene transformed these crystals into bundles of fibers. The degree of polymerization exceeded 100,000.

Nuclear Bragg scattering. - It was demonstrated in the early days of Mössbauer spectroscopy that coherent scattering of photons emitted by a Mössbauer source can be observed. In spite of the fact that scattering experiments could give information not accessible by the absorption method they are not widely used due to experimental difficulties. We have designed and built a diffractometer which makes feasible Mössbauer diffraction experiment on powder and polycrystalline samples on a time scale of few days with a moderately strong radioactive source. We have performed Mössbauer diffraction

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experiment on polycrystalline bcc iron. We have demonstrated that using the kinematical theory of gamma ray diffraction, useful information on the relative orientation of crystallographic axis to the hyperfine field directions can be subtracted.

Grants

OTKA 2943 and E-012313 X-ray and gamma spectroscopy of anisotropic and modulated systems

OTKA T4222 Preparation and physical properties of fullerene derivatives

OTKA T4226 Nuclear resonant scattering of gamma photons on periodic systems

OTKA T4474 Electrical properties of conductive fullerens.

PHARE ACCORD H9112-0522 Participation in the nuclear resonant scattering (Mössbauer) program of the European Synchrotron Radiation Facility at beamline No. 11

U.S.-Hungarian Joint Fund 225 Single crystal C_{60} spectroscopy

Publications

E.1. G. Oszlányi, G. Bortel, G. Faigel, S. Pekker, M. Tegze: Dynamic origin of the orthorhombic symmetry of C_{60}-*n*-pentane. Solid State Commun., 89, 417, (1994)

E.2. J. Hafner*, M. Tegze and Ch. Becker*: Amorphous magnetism in Fe-B alloys: First-principles spin-polarized electronic-structure calculations. Phys. Rev. B, 49, 285, (1994)

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E.4. S. Pekker, L. Forró*, L. Mihály* and A. Jánossy: Orthorhombic A_1C_{60}: A conducting linear alkali fulleride polymer? Solid State Commun. 90, 349 (1994)

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E.7. G. Faigel, G. Bortel, G. Oszlanyi, S. Pekker, M. Tegze and P. W. Stephens*: Phase transition in C_{60}-clathrates. To be published in the Proc. of the Int. Winterschool on Electronic Properties of Novel Materials,: Kirchberg, Tirol, March 5-12, 1994

E.8. M. Tegze, G. Bortel, G. Faigel, L. Forró*, G. Oszlányi, A. Jánossy and P. W. Stephens*: Structural study of Rb_1C_{60} and K_1C_{60} fullerides. To be published ibid.

E.9. G. Faigel, M. Tegze, G. Bortel, L. Forró*, G. Oszlányi and P. W. Stephens*: Parallel beam powder diffraction study on the A_1C_{60} system (A = K, Rb). To be

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E.10. P. W. Stephens*, G. Bortel, G. Faigel, M. Tegze, A. Jánossy, S. Pekker, G. Oszlányi and L. Forró*: Polymer chains in Rb_1C_{60} and K_1C_{60}. Nature, 370, 636, (1994)

E.11. A. Jánossy, O. Chauvet*, S. Pekker, J. R. Cooper*, L. Forró*, M. Tegze and G. Faigel: Reply. Phys. Rev. Lett., 72, 3131, (1994)

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E.14. M. Tegze and G. Faigel: Design of a new Mössbauer diffractometer. To be published in Hyperfine Int.

E.15. G. Faigel and M. Tegze: Mössbauer diffraction measurements on polycrystalline bcc iron. To be published ibid.

F. HIGHLY CORRELATED METALS

G. Kriza, A. Beleznay, T. Csiba, R. Gaál, O. Legeza, G. Mihály[+] and B. Sas

The principal interest of the team is the experimental investigation of the coherent electronic states - superconductor, charge- and spin-density wave - of highly correlated metals. The electronic transport and magnetic properties of these correlated states are studied as a function of a broad variety of experimental parameters such as temperature (down to 30 mK), magnetic field (up to 14 T), and frequency (up to microwave frequencies). The materials investigated include inorganic and organic quasi-one-dimensional metals (e.g., $K_{0.3}MoO_3$ and $(TMTSF)_2PF_6$), quasi-two-dimensional superconductors (Cu-O based high-temperature superconductors and organic superconductors such as $(BEDT\text{-}TTF)_2Cu[N(CN)_2]Br$), and C_{60}-based solids.

The main effort of the team in the year of 1994 has been the development of a new low-temperature laboratory in collaboration with the Department of Physics of the Technical University of Budapest. This laboratory features:

— Three different low-temperature probes for transport and magnetic measurements covering the temperature range of 0.03 to 500 K.

— A 14-tesla superconducting magnet.

— Instrumentation for transport measurements (conductivity, magnetoresistance, Hall effect, thermoelectric effects, conduction noise) and magnetic measurements (dc and ac magnetization with rf SQUID detection, ac susceptibility).

Preliminary results have been obtained on the phase diagram and magnetic relaxation properties of the vortex state of layered organic superconductors and on the magnetic susceptibility of various alkaline-doped fullerenes. The anomalous Hall effect in the vortex liquid state of Cu-O-based high-temperature superconductors and the dc and microwave conductivity of fullerene superconductors have also been studied.

Grants

OTKA 2944 Charge- and Spin-Density Waves
OTKA 7277 Dielectric Properties of Coherent Density Waves
PHARE "ACCORD" Program: Vortex State of Organic Superconductors

Publications

F.1 A. Jánossy, O. Legeza, A. Beleznay, R. Gaál, G. Mihály, O. Chauvet,[*] and L. Forró[*]: Microwave conductivity and conduction electron spin relaxation of Rb_3C_{60}. In: Electronic Properties of Novel Materials, edited by H. Kuzmany, J. Fink, M. Mehring, and S. Roth (World Scientific, Singapoore, 1994).

F.2 S. Mészáros,[*] K. Vad,[*] G. Halász,[*] N. Hegman,[*] B. Keszei[*] and B. Sas: Temporal and spatial correlations in voltages generated by transport currents in HTSC materials. To be published in Physica C.

[+] Permanent position: Technical University Budapest

F.3 A. Jánossy, O. Legeza, G. Oszlányi, and L. Forró*: Electric conductivity of the fullerene superconductors Rb_3C_{60} and K_3C_{60}. To be published in Europhys. Lett.

G. LIQUID CRYSTAL RESEARCH

L. Bata, N. Éber, K. Fodor-Csorba, A. Jákli, A. Vajda

Ferroelectric liquid crystals. - The homologeous series of (R)-(2-chloropropyl)-4-[4'-(n-alkoxy)benxoyloxy] benzoates was synthetized by a new synthetic pathway with high optical purity. The liquid crystalline members of the series exhibited smectic A phase, but they could be used as chiral dopants to produce ferroelectric liquid crystalline mixtures in broad temperature region eg. the member n=8 was used for mixtures exhibiting monotropic smectic C phase around room temperature. The compounds and intermediates were studied by IR, thin layer chromatography and NMR methods.

Liquid crystal polymer composite systems can be divided into two main subgroups. The first consists of the polymer dispersed liquid crystals (PDLC), where the liquid crystal is dispersed in the continuous polymer matrix. The second contains the liquid crystal dispersed polymer (LCDP) systems (sometimes called as liquid crystal/gel dispersions), where only a small amount of polymer is dispersed in a continuous liquid crystal matrix.

Neutron scattering and optical studies on various LCDP systems were made to investigate the structure of polymers dispersed in nematic and smectic liquid crystals. Our study showed that 1 wt% of polymer can induce phase separation in the form of fibres. We have found that the cross-sectional radius of such fibres is tipically 300 Å and they have rough surfaces. The spatial distribution on the fibres does not change during the phase transitions of the liquid crystal. We have found that there is a correlation between the size of the separated polymer particles and the roughness of their surfaces: larger objects have less smooth surfaces. The results indicate that small (<100 Å size) fuzzes on the surface of the polymer fibers may play the essential role in the alignment of the liquid crystal molecules. These fuzzes can be realigned by the combination of external fields and heat treatments yielding a fading memory effect.

Other activity. - The 15th International Liquid Crystal Conference (Budapest, 3-8 July, 1994) was organized by the group working on liquid crystals (themes G and H). This conference with over 900 submitted papers and 700 activ participiants proved again that this topic is up to date and covers broad international interest. Two members of this group edit the Proceedings to be published in Molecular Crystal and Liquid Crystal.

Grants

OTKA I/3 2946 Physical investigation of ferroelectric liquid crystals
OTKA T 7409 Physical investigation of liquid crystal - polymer composites

Publications

G.1. A. Jákli, L. Bata, K. Fodor-Csorba, L. Rosta, L. Noirez* : Structure of polymer networks dispersed in liquid crystals: small angle neutron scattering study. Liquid Crystals, 17, 227 (1994)

G.2. I. Jánossy, A. Jákli: Azimuthal reorientation of homeotropic nematic films. Mol. Cryst. Liq. Cryst. 251, 289-301 (1994)

G.3. A. Jákli: Structure and optical properties of liquid crystal dispersed polymers nematic films. Ibid. 251, 289-301 (1994)

G.4. K. Fodor-Csorba, A. Vajda, L. Bata: Synthesis of LC containing chlorine on the chiral center. To be published ibid.

G.5. A.Jákli, A. Saupe* : Mechanical vibration of smectic cells under fast field reversal. To be published ibid.

G.6. A. Jákli, A. Saupe*: Electrically induced uniform planar alignment of SmC liquid crystals on homeotropically treated plates. To be published in Appl. Phys. Lett. 65 (1994)

H. INSTABILITIES AND NONLINEAR PHENOMENA IN LIQUID CRYSTALS

Á. Buka, I. Jánossy, T. Kósa, J. Szabon, T. Tóth Katona

Activities in 1994 have been concentrated around three main subjects:

Pattern forming instabilities:

1. The *interface of a smectic B* phase growing into a supercooled nematic has been studied on one-component thermotropic liquid crystals. Observations were carried out for both planar and homeotropic initial director alignment of the nematic phase. Two types of *equilibrium shapes* have been found, one had a rectanglelike, alongeted form with two long facetted sides, the other one is circular with a small hexagonal modulation, reflecting the symmetry of the smectic B structure. Four growth *morphologies*, dendritic, petal shape, dense branching and facetted have been found and studied. For all growth regimes the time dependence of the growth velocity has been measured.
2. A homeotropically aligned nematic with negative dielectric anisotropy subjected simultaneously to electric and magnetic fields has been studied. If an electric field perpendicular to the nematic layer is applied, the first instability to take place is the bend Fréedericksz transition, spontaneously breaking the rotational symmetry. Subsequently the *electrohydrodynamic convection* sets in. An additional magnetic field in the plane of the layer induces a preferred director orientation. The effect of the magnetic field on the EHC threshold voltage, on the critical wave vector and on the roll angle were exemined as a function of the applied frequency. Accompanying domain walls were characterised.
3. The influence of *different wave forms*, superposed on a harmonic electric excitation inducing EHC on a planarly oriented nematic was also investigated. A 60 Hz sine wave was used as the carrier signal and another sine or a square wave of variable frequency in the deterministic case were superposed. To study the effect of stochastic signals, a binomial noise was also added of variable bandwidth. The influence of the wave form and frequency on the threshold voltage was measured.

Nonlinear optics. - Studies of the optical reorientation of liquid crystals have been continued. The effect of azo dyes has been studied, which similar to the antrachinon based ones studied before, amplify the orienting effect of the laser. The dye induced torque was found negative in most substances. In the case of one dye a positive sign was found, though changing the frequency a change of sign occured. A model was proposed to explane this behaviour. A new method was proposed to measure the director tilt angle at the surface of the liquid crystal cells. The method is based on using dichroic dyes and anables us to measure the tilt angle with high accuracy.

Physico-chemical qualifying measurements. - Thermoanalitic, calorimetric and microscopic measurements of liquid crystals have been carried out with technological purposes. Glassy liquid crystal states with different polymer content have been measured after UV radiation with varied duration.

Grants

OTKA 2976 Spatio-temporal patterns
Volkswagen Foundation: Pattern formation
OTKA 2948 Nonlinear optics

OTKA F4225 Optical orientation of polymers
OTKA W015056 travel grant

Publications

H.1. Á. Buka, T. Tóth Katona and L. Kramer*: Equilibrium shapes of a nematic-smectic B interface. Phys.Rev.E. 49, 5271 (1994)

H.2. I. Jánossy: Molecular interpretation of the absorption induced optical reorient-ation of nematic liquid crystals. Ibid. 49, 2957 (1994)

H.3. I. Jánossy (editor): Proceedings of the 5th International Topical Meeting on the Optics of Liquid Crystals. Gordon and Breach, Mol. Cryst. Liq. Cryst. 251 (1994)

H.4. H.Richter*, Á. Buka and I. Rehberg*: On the optical characterization of convection patterns in homeotropically aligned nematics. Ibid. 251, 181 (1994)

H.5. D. Paparo*, P. Maddalena*, G. Abbate*, E. Santamato* and I. Jánossy: Wave-length dependence of optical reorientation in dye-doped nematics. Ibid. 251, 73 (1994)

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H.7. T. Kósa, T. Wagner*, P.J.S. Ewen* and A.E. Owen*: Optical properties of silver-doped As_{33} S_{67}. Int. J. Electronics, 76, 845 (1994)

H.8. H. Richter*, Á. Buka and I. Rehberg*: The electrohydrodynamic instability in a homeotropically aligned nematic. In: Spatio-temporal Patterns in Nonequilibrium Complex Systems, Addison-Wesley (1994)

H.9. Á. Buka, T. Tóth Katona and L. Kramer*: Free growth properties of a nematic-smectic B interface. To be published in Phys.Rev.E.

H.10. T. Tóth Katona and Á. Buka: Nematic-smectic B interface, Equilibrium and growth properties. To be published in Mol.Cryst.Liq.Cryst.

H.11. D.Z. Obadovic*, A. Vajda*, T. Tóth Katona and R. Marinkovic*: The structure of mesophases of binary and multicomponent mixtures of some cholesteric liquid crystals. To be published ibid.

H.12. H. Richter*, N.Kloepper*, A. Hertrich* and Á. Buka: Electroconvection in a homeotropic nematic under the influence of a magnetic field. To be published in Europhys.Letters

H.13. T. Kósa, T. Wagner*, P.J.S. Ewen* and A.E. Owen*: Index of refraction measurement in Ag-As_{33} S_{67} films. To be published in Phil. Mag. B.

H.14. J. Hajtó*, A.J. Snell*, M.J. Rose*, A.E. Owen*, I.S. Osborne*, T. Kósa, A. Holmes* and R.A.G. Gibson*: Step-like current-voltage characteristics in metal/a-Si:H/metal structures. In: Proceedings of '92 MRS, San Francisco.

See also G.2

I. METAL PHYSICS

K. Tompa, I. Bakonyi, Cs. Hargitai, Gy. Lasanda, A. Lovas, J. Tóth, E. Tóth-Kádár

Amorphous alloy - hydrogen systems. — The research work made on metal-hydrogen systems has two coherent aspects:

1. The first one is the selection of the proper amorphous alloy, in which the contribution of host nuclear magnetization can be varied within a given range. The Zr-Ni family of different composition and Zr-Ni-Cu ternary system were selected. The contributions of Zr and Ni nuclei to the local dipole - dipole fields at proton sites are negligible comparing to that originating from other protons. The addition of Cu can modify the situation, because the abundance probability of Cu nuclei with non zero magnetic moment, the values of gyromagnetic ratios and the spin values, fix the Cu contribution to the local field. Because of the strong distance dependence of the dipole field there exists a hope to get some conclusions as far as the hydrogen locations are concerned in the tetrahedral sites of different compositions. Energetically these distorted tetrahedral sites are different and the occupation of the sites depends on the hydrogen content of the sample. Near the low temperature more or less static atomic arrangements the high temperature NMR characteristics, namely the relaxation times and the diffusion parameters can also be influenced by both the hydrogen and Cu content.
2. The second aspect is methodical, that is the measurements of the wanted NMR quantity together with the hydrogen content as precisely as possible. Hydrogen content, spin-spin relaxation time, PMR spectrum width, second moment, *Knight shift* and spin lattice relaxation time, and additionally electric transport parameters, electrochemical P-C isotherms and susceptibility were measured on the amorphous alloys at different H concentrations.

The main goals of this investigation are:

— first, to measure the hydrogen content as precisely as possible by an NMR method not used before in this field;

— second, to monitor the effects of increasing nuclear magnetization on certain NMR parameters by adding Cu nuclear spins to protons;

— third, to study the static and kinetic neighbourhood of hydrogen including the electronic structure at substantially different hydrogen content;

— and finally the electrochemical investigations are also motivated by practical purposes.

Nanophase materials. — Porosity-free nanocrystalline Ni foils typically 1 to 10 μm thick were produced by DC-plating and by pulse-plating. After removing the substrates, their surface morphology (SEM), microstructure (TEM and/or XRD), electrical transport properties, Curie temperature and thermal stability (DSC) were investigated as a function of the deposition conditions (bath composition, Cu or Ti substrate, deposition current density). In *DC-plating*, deposits with an average grain size as low as about 30 nm could be produced for the lowest current densities applied (5 A/dm^2). In preparing *pulse-plated* nanocrystalline Ni electrodeposits, systematic variations of the electrical transport parameters with the pulse length and the separation between pulses both varied from 0.001 s to 10 s were observed as a consequence of a corresponding variation of the deposit grain size. In a detailed low-temperature study of nanocrystalline Ni foils, a large residual resistivity was observed and the temperature variation of resistivity was also different from that of well-annealed, defect-free Ni with large crystallite size. It was concluded

that the large residual resistivity cannot be completely ascribed to crystallite boundaries only but the presence of a high density of other types of lattice imperfections due to the nanocrystalline structure must also be assumed in the electrodeposited Ni foils. The different temperature behavior can be explained by considering that the electronic mean free path of the matrix is higher than the average crystallite size at low temperatures and the situation is reversed at room temperature.

Information desk. - As a part of an information desk for materials and materials engineering (ANTINFO), data have been compiled on Hungarian institutes, facilities, methods, experts, and qualifications in the field of solids with special references to metals. On-line contacts have been established to data banks in Hungary and abroad.

Grants

OTKA I/3 2949 Hydrogen in metals

OTKA I/4 4228 Mechanism of absorption and desorption of hydrogen

OTKA I/3 2942 Compositionally modulated alloys

OTKA I/4 T4218 Study of pulse-plated electrodeposits

CEC[3] DG XII. CI1*CT 91-0926 Pilot activities in support of Hungarian industry in the field of materials engineering. Project C: Development of an information desk for materials and materials engineering.

Publications

I.1. I. Bakonyi, E. Tóth-Kádár, I. Nagy, J. Tóth, K. Tompa, A. Lovas, Á. Cziráki*, B. Fogarassy*, G. Wiesinger*: Hydrogen absorption and hydrogen-induced phase-separation in amorphous $Zr_{50}Ni_{50-x}Cu_x$ alloys. Z. für Phys. Chem. 183, 87-91 (1994)

I.2. K. Tompa, I. Bakonyi P. Bánki, G. Lasanda, A. Lovas: PMR spectrum, proton spin relaxation and diffusion in $Zr_{0.5}(Cu_xNi_{1-x})_{0.5}H_1$ metallic glasses. Ibid. 183, 93-98 (1994)

I.3. L.K. Varga, A. Lovas, I. Bakonyi, E. Tóth-Kádár, K. Tompa: Time evolution of H-absorption in Ni-Zr metallic glasses. Ibid. 183, 73-77 (1994)

I.4. I. Bakonyi, E. Tóth-Kádár, J. Tóth, Á. Cziráki*, B. Fogarassy*: Electronic transport in nanocrystalline metals: a study of electrodeposited nickel foils. In: G. C. Hadjipanayis, R.W. Siegel (eds.): Nanophase Materials, Kluwer Academic Publishers, Dodrecht, The Netherlands, pp. 423-432 (1994)

I.5. Á. Cziráki*, B. Fogarassy*, G. Van Tendeloo*, P. Lamparter*, M. Tegze, I. Bakonyi: Electron microscopy and X-ray diffraction studies of rapidly quenched Zr-Ni and Hf-Ni ribbons with about 90 at.% Ni. J. Alloys and Compounds 210, 135-141 (1994)

[3]CEC DG XII: Commission of the European Communities, Directorate General for Science, Research and Development

I.6. Á. Cziráki*, B. Fogarassy*, I. Geröcs*, E. Tóth-Kádár, I. Bakonyi: Mirostructure and growth of electrodeposited nanocrystalline nickel foils. J. Mater. Sci. 29, 4771-4777 (1994)

I.7. Á. Cziráki*, Zs. Tonkovics*, L. Geröcs*, B. Fogarassy*, I. Groma*, E. Tóth Kádár, T. Tarnóczi, I. Bakonyi: Thermal stability of nanocrystalline nickel electrodeposits: differential scanning calorimetry, transmission electron microscopy and magnetic studies. Mat. Sci. Engr., A179/A180 531-535 (1994)

I.8. G. Lasanda, K. Tompa, C. Hargitai, P. Bánki, I. Bakonyi: PMR lineshapes on $Zr_{50}Ni_{(50-x)}Cu_x$-H amorphous alloys. In: K.M. Salikhov (ed.): Magnetic Resonance and Related Phenomena. Extended abstracts of the XXVIIth Congress Ampere, Kazan, Russia, Aug. 21-28, 1994, vol.2, p. 569

I.9. G. Lasanda, K. Tompa, C. Hargitai, P. Bánki, I. Bakonyi: PMR spectra and H-site occupancy in $Zr_{0.5}Ni_{0.5-y}Cu_yH_x$ metallic glasses. To be published in J. Alloys and Compounds

I.10. K. Tompa, P. Bánki, C. Hargitai, G. Lasanda, A. Lovas, L.K. Varga: PMR measurements on $(Ni_{1-x}Cu_x)_{0.5}Zr_{0.5}$-$H_y$ amorphous alloys. To be published ibid.

I.11. K. Tompa, P. Bánki, G. Lasanda, L.K. Varga: Susceptibility and proton line shift on $Zr_{0.33}Ni_{0.67}$-H_x amorphous Alloy. To be published ibid.

I.12. J. Tóth, K. Tompa, A. Lovas, P. Bánki: High temperature hydrogen diffusion in $Zr_{0.33}Ni_{0.67}$-H_x amorphous alloys. To be published ibid.

I.13. L.K. Varga, A. Lovas, K. Tompa, M. Latroche*, A. Percheron-Guegan*: Electrochemical P-C isotherms for amorphous $Ni_{1-x}Zr_x$ alloys. To be published ibid.

See also D.10, J.8

J. RAPIDLY SOLIDIFIED AMORPHOUS AND NANOCRYSTALLINE ALLOYS

A. Lovas, G. Konczos, L. Pogány, T. Tarnóczi, L.K. Varga

Thermal and mechanical properties of iron-metalloid glasses. - The investigation of thermal stability of transition metal-metalloid glasses has began already in the early eighties (1978-84). The concentration dependence of thermal stability (expressed by the temperature of crystallization, T_{cr}) was interpreted on the basis of outer electron concentration of the metallic atoms and the size-difference between the metallic constituents. It was also found, that the hardness of glassy state is increased with the temperature of crystallization. The cited results were obtained on systems containing two types of metalloids. The electron concentration was changed by the replacement of host metal with other transition element.

This experimental finding and interpretation has been critically re-investigated on ternary systems at different metalloid concentrations (Fe_x-Cr_y-B_z, Fe_x-W_y-B_z). It was found, that T_{cr} and ΔH_{cr} as well as the hardness depend not only on the electron-concentration but an additional structural stabilizing factor have to take into consideration. The onset of the first DSC crystallization peak, and the appropriate heat evolution depend primarily on the relative number of bcc and fcc-like Fe-environments (α-Fe or γ-Fe regions) which is influenced by the boron content and by the quenching conditions as well. Formation of the α-Fe like environments can be also suppressed or enhanced by the third metal addition.

The solution hardening caused by the chromium and tungsten addition shows a saturation value versus the concentration of the third element (instead of a monotonic increase, like in the binary Fe-B) which also indicates the structural origin of the hardening mechanism in the investigated metallic glasses.

Study of the nanocrystalline soft-magnetic alloys. - We have started a systematic study in order to understand the development of nanocrystalline structure from amorphous precursors and the structural aspects of the magnetic softness in these alloys. An ideal soft magnetic material would have not only zero magneto-crystalline anisotropy (k) and zero magnetostriction (λ), but also high saturation magnetization (M_S) as high as possible. While $\langle k \rangle \cong 0$ results inherently from the nanostructural state, the $\langle \lambda \rangle \cong 0$ and the high M_S are competitive demands.

The temperature and time-dependence of the development of nano-structure and the simultaneous evolution of the soft-magnetic properties have been studied in a Finemet-type amorphous alloy ($Fe_{73.5}Cu_1Nb_3Si_{13.5}B_9$).

We have shown by detailed DSC, X-ray and by magnetic measurements, that the magnetic softness saturates as a function of time during the heat treatments at 550 °C. This state can be characterized structurally by the saturation value of Si-content of the α-Fe nanocrystalline grains. The deterioration of the magnetic softness at higher temperatures can be attributed to the segregation of Fe_3Si compound (enhancing the magnetostriction) and to the segregation of Fe_2B compound above 600 °C, destroying the intergranular magnetic coupling.

Miscellaneous. - Special alloys have been prepared by rapid solidification processing for other domestic laboratories e.g. copper based amorphous ribbons to study the catalytic

activity, microcrystalline aluminium flakes to produce conductive metal-polymer composites for electro-magnetic shielding, quasicrystalline aluminium based alloy powders for plasma spraying.

Grants

OTKA T4219 Role of exchange interaction in the relaxation of metallic glasses

OTKA I/3 2656 Mechanism of high energy density technological processes (cooperation with the Technical University Budapest)

OTKA 1975 Formation of disordered, non-equilibrium structures (cooperation with the József Attila University, Szeged)

OTKA T7506 Study of new phenomena and properties in the plasma spraying of Al_2O_3 and Al base powders made by mechanical alloying (cooperation with the Technical University Budapest)

OMFB 94-97-69-0660 Development of conductive polymer composites (cooperation with the Plastic Research and Development Ltd., Budapest).

Publications

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J.5. A. Lovas, L.K. Varga, É. Kisdi-Koszó*, J. Kovác*: Inhomogenities and basic magnetic properties in Fe-B glassy alloys. Ibid. 30, 467-469 (1994)

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J.7. K. Russev*, L. Stojanova*, A. Lovas: Effect of processing conditions on the ribbon geometry and viscous flow behaviour of $Fe_{40}Ni_{40}Si_6B_{14}$ amorphous alloy. Int. J. Rapid Solidification 8, 147-159 (1994)

J.8. L.K. Varga, É. Bakos*, L.F. Kiss, I. Bakonyi: The kinetics of amorphous-nanocrystalline transformation for FINEMET alloy. Mat. Sci. Engr., A179/A180, 567-571 (1994)

See also D.10

K. NON-DESTRUCTIVE EVALUATION

F. Tóth, P. Kamasa

Micromagnetic equipment for the non-destructive investigation of internal stresses and fatigue. - An automated magnetic testing instrument has been developed to measure the main magnetic parameters of ferromagnetic materials and components in situ.

The magnetic properties are sensitive to the mechanical and microstructural state of iron and its alloys. The residual and applied stress, creep and fatigue damage, plastic deformation and corrosion affect the magnetic hysteresis loop; due to the quantitative correlation between materials properties and magnetic parameters, the state of ferromagnetic materials can be monitored non-destructively during service. Magnetic inspection is capable of detecting anomalous failure prematurely and of giving prior warning of impending damage.

The portable magnetic testing instrument includes an inspection head for generating a magnetic excitation field and for measuring different induction signals, an instrumentation for data analysis, a standard IBM PC with the proper control and data evaluation software.

The measurements and analysis are accomplished in one program, so they can be performed easily, rapidly and reproducibly. For performing a measurement, the instrument determines the hysteresis loop and Barkhausen noise spectrum after demagnetisation. Using various routines, the computer determines from the hysteresis loop different magnetic parameters such as remanence, coercivity, initial and maximum differential permeability, hysteresis loss and magnetic anisotropy. The measured and calculated parameters are stored in the computer memory for making meaningful evaluation of the mechanical state of the test piece, e.g. actual hardness, detected stress or fatigue.

Beside of the standard measurement and control software, a novel computer algorithms have been developed and applied to the Barkhausen effect analysis. The joint time-frequency analysis (JTFA), which shows simultaneously the time and frequency content of the detected signal, gives direct energy distribution of the Barkhausen noise over frequency range up to 1 MHz. The obtained time-frequency spectrogram is in relation to the hysteresis curve. and can be correlated with micromagnetic structure.

Publications

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L. NEUTRON SPECTROSCOPY

L. Rosta, S. Borbély, L. Cser, B. Faragó[+] , T. Grósz, J. Jani, L. Kõszegi, L. Riecsánszky, Gy. Török

The neutron scattering activity of our Institute is strongly related to the Budapest Research Reactor (BRR) at KFKI.

Instrument development. - The Budapest Research Reactor was restarted after a major reconstruction and upgrading and operates at 10 MW nominal power from November, 1993. This unique important neutron source in Central Europe serves various purposes, such as basic and applied research in physics, chemistry, biology, materials science as well as commercial utilisation. Our department operates and uses several instruments at the horizontal neutron beams of BRR.

This year 2 *curved guides* were set-up to provide neutrons to the new guide hall extending from the reactor hall and housing the guide instruments. Two instruments were started for routine operation:

On the *three-axis spectrometer* the monochromatic beam from guide No 1 is provided by a focusing assembly of pyrolytic graphite blades. The incident wavelength is continuously variable due to the chain type monochromator shielding. For higher order filtering a multidisk neutron velocity selector was installed in the incident beam. Pyrolytic graphite analyser serves for dynamical studies of condensed matter samples. The main parameters of the spectrometer, according to the test measurements are: monochromatisation (FWHM) 100 μeV, momentum transfer range 0,02-2.7 Å, flux at the specimen ~10^5 $n \cdot cm^{-2} s^{-1}$.

The *small-angle neutron scattering* device was installed at the end of guide No 2 equipped with a tuneable velocity selector for broad band monochromatisation. The main component of the instrument is a movable 64×64 cm^2 BF_3 XY-detector in an evacuated flight path chamber. Test measurements yielded 0.002-0.3 Å momentum transfer range with $3 \cdot 10^4$ $n \cdot cm^{-2} s^{-1}$ flux at the sample (λ=4.4 Å wavelength).

The activity for installation of a *liquid hydrogen moderator* for enhancement of the cold neutron flux was continued. After that the feasibility study was approved last year, we set up a proper scheme for designing and manufacturing the cold source assembly and applied for financing support to different agencies. Important progress in the cold source project is the granting of $240,000 for technical assistance in 1995-96 years by IAEA.

Scientific activity. - Besides the very intense and time-consuming instrument development programme, our staff members provided wide scientific activity mostly in international collaborations. The structure and dynamics of various kind of materials were studied, the main fields are shortly listed below:

Early stage of *crystallisation* in heat treated Ti-Si and Al-Ni-Y metallic glasses has been investigated by neutron small-angle scattering and modelled by polidisperse spherical shape model.

Decomposition phenomena were studied in different materials. The evolution of the structure was followed in binary systems, when starting from a homogeneous phase, decomposition was induced under different circumstances. Thermal treatment was applied

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in the case of Au-Pt and Au-Ni alloys, while polymerisation by UV-light was the driving force of decomposition in liquid crystal (LC)-monomer mixtures. Small angle neutron scattering revealed the pattern formation and development of medium range correlations. Modulated structures in the form of platelets in the (002) crystallographic direction with 4-20 nm typical correlation length were observed for the Au-based system. In the case of the LC-based mixture a few percent of reactive monomer was enough to form a polymer network with fibril diameter of ~60 nm and rough LC-polymer interface, well described in a surface fractal model.

Excess *internal stress* was measured on the copper grain boundaries in the V-7.5at%Cu alloy as a function of external stress using a special stress rig developed earlier in our laboratory for in-situ high resolution diffraction experiment completed with light and scanning electron microscope investigations - including EDS microanalysis. The line broadening of the Cu (111) Bragg peak on the as casted alloy corresponds to microstresses.

Small-angle scattering and spin-echo experiments were carried out on *ferrofluids* consisting of $Zn_{0.3}Mn_{0.7}Fe_2O_4$ particles in order to study the anomalous cross-over in ferrofluid dynamics described by a dynamic fractal model.

The dimer formation of tetramethyl molecules due to the *hydrofobic interactions* was investigated by small-angle neutron scattering both in aqueous and CS_2 solutions.

Neutron tomography, a new experimental development of the neutron spin-echo method was used for studying of trapped magnetic flux distribution in high-T_c superconducting ceramics as well as on special model samples in collaboration with PNPI, Gatchina (Russia).

On the triple-axis spectrometer, the first experiments involved quasi-elastic measurement of EBBA liquid crystal, diffraction experiment on $K_3Fe(CN)_6$ as well as phonon measurements on a 40 mg pyrolytic graphite (PG) single crystal sample. This later serves for future high pressure chamber experiments.

Other activity. - Our department was the principal organiser of the successful International Workshop on Neutron Research and Applications in March with 80 participants from abroad and 50 ones from Hungary promoting the neutron research possibilities at BNC.

Grants

OTKA T 4490 Complex investigation of hydrofob effects in aqueous solutions
OTKA 2951 Neutron scattering in materials research
EU Network project WENNET: Neutron scattering in molecular systems

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L.11. L. Rosta: Neutron scattering for condensed matter research and materials science at the Budapest Research Reactor. To be published ibid.

L.12. L. Rosta, O. Blaschko*, S. Borbély, A. Jákli, L. Noirez*: Medium range correlation in decomposing binary systems. To be published ibid.

L.13. Gy. Török, L. Rosta, R. M. Ibberson*, G. Pépy*: Model of MBBA solid phase structures using X-ray and neutron diffraction. To be published in Mol. Cryst. Liq. Cryst.

See also G.1

M. INTERACTIONS OF INTENSE LASER FIELDS WITH MATTER

Gy. Farkas, A. Kõházi-Kis, Cs. Tóth

Generation of high order multiple harmonic coherent light beams using ultrashort laser pulses. - By conferring our former experimental results realized by long (1 μm) wavelength Nd laser and the recently performed ones using short (248 nm) wavelength excimer laser, we gave the proof for the validity of the QED predicted cut-off value of the high harmonic spectrum for solids. Accordingly, it was proven that in contrast with the long wavelength case where many harmonics were observed, at short wavelengths only the second harmonics appeared. The cut-off value was at the work function value (for a gold surface ~5 eV) corresponding 250 nm in wavelength.

In the subsequent step we measured and analyzed the duration and shape of the obtained harmonic light pulses on the psec and fsec time scales by two methods:

— in the first one we produced the 2nd and 3rd harmonics of ~100 psec duration of a Nd:YAG laser from a gold surface and analyzed them by a repetitive mode syncroscan streak camera of 15 psec resolution. The cut-off value, the pulse shape and the polarization of the harmonic light coincided with the QED predictions.

— in another work, using Nd:glass laser and Au surfaces, we produced harmonics after transmitting the laser light through a Michelson interferometer type autocorrelator. We obtained autocorrelation curves with contrast values corresponding to the harmonic orders. This method revealed even the slightest phase changes of femtosecond duration in the ultrashort pulses.

By tuning the wavelegth of the inducing laser, all harmonics are tuned.

At last, considering the extreme high sensitivity of the high order multiphoton photoelectron emission induced by laser pulses from metals, we performed a preliminary experiment aiming on the observation of the influence of squeezing of the laser light on the multiphoton interaction. According to the experimental results, the fluctuations of the multiphoton electron counts were very strongly changed when a (two-photon absorbing) KDP crystal was inserted into the inducing Nd laser beam.

Application of the strong field induced multiphoton effects at metal surfaces. -Laser produced plasma on a metallic target surface was used to create a new class of excimer molecules, the alkali halide ionic excimers, which are promising laser sources in the VUV wavelength region. The soft x-rays emitted from the laser produced plasma on a stainless steel target were used to produce excited state $Cs^{2+}F^{-}$ molecules. By using the plasma creating source of a Nd:YAG based mode-locked oscillator/regenerative amplifier system, we achieved an average gain coefficient of 0.30 cm^{-1} at 185.4 nm using 6 cm length and 10 mbar CsF vapor pressure. The measured gain values are consistent with the theoretical predictions and this result constitutes the first example of gain in this new class of ionic excimer molecules that have strong emission covering the whole VUV range from about 50 nm to 200 nm.

Grants

OTKA I/3 2936 Experimental investigation of interactions predicted by high intensity QED

OTKA I/4 4471 Electron emission processes induced by the simultaneous presence of two intense laser fields of various frequencies

BALATON 25/94 (French-Hungarian Bilateral Cooperation): Picosecond time scale characterisation of light beams of higher order harmonics generated by intense laser beams at metal surfaces

NATO Linkage Grant #930179 (USA-Hungary): Interaction studies of ultra intense laser fields with matters

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See also P.9.I

N. LASER PHYSICS

M. Jánossy, P. Apai, L. Csillag, Z. Donkó, Z. Horváth, Zs. Lenkefi, P. Mezei, K. Rózsa, Zs. Szentirmay

Gas discharge experiment and modelling. — The obstructed operation mode of glow discharges was studied in helium and hydrogen gas by measuring electrical characteristics of the discharge and the spatial distribution of the electric field (using Stark spectroscopy). The calculated self-consistent electric field distribution showed a good agreement with

experimental data. Electron multiplication data, energy distribution of electrons absorbed by the anode, energy distribution of ionizing electrons, share of high-energy electrons in ion production and spatial distribution of ion production were obtained from the modelling calculations to provide detailed insight into the discharge operation. The effect of electron reflection of the anode on the discharge characteristics was also investigated and was found to affect significantly the characteristics of the discharge. We have carried out spectroscopic investigations of an argon glow discharge over a cold cathode surface in order to study the different excitation mechanisms (fast neutral, fast ion, electron collisions) of the cathode glow and the negative glow parts of the discharge. In subnormal glow discharges we measured self-generated oscillations. The coupling of two subnormal glow discharge cells resulted in the appearance of nonlinear oscillations of various waveforms.

Lasers in segmented hollow cathode discharges. — In order to improve the hollow cathode laser performances we have worked out a novel discharge geometry which combines the advantages of the conventional and the high voltage hollow cathode discharges. The fast electrons accelerated by the cathode fall are focused into the axis of the hollow cathode. These electrons can oscillate between the opposing cathode surfaces ensuring the optimal energy transfer into the highly excited states. The cylindrical cathode cavity matches the TEM_{00} beam. The sputtered metal has an easy access into the hollow cathode. The discharge is highly stable against arcing and the operating voltage can be increased (independently from the gas pressure) to obtain higher density of fast electrons necessary for laser excitation. High gain and low threshold current were found even in the ultraviolet range. On the Au 282 nm transition we obtained over 55%/m gain which can further be increased by reducing the hollow cathode diameter. The threshold current was below 300 mA. We determined optimal current density for gain and for output power. These results indicate the continuous VUV laser oscillations (CuII lines around 160nm) might be possible using these type of discharges.

Cathode sputtered He-Zn laser. — Experiments have been carried out on a quasi-cw slotted hollow cathode He-Zn laser, where the Zn vapour was produced by cathode sputtering. Due to the efficient operation of the hollow cathode discharge relatively low threshold currents and high output powers could be obtained. The minimum threshold currents were 0.3 A (758.8 nm), 1.3 A (747.9 nm), 0.7 A (492.4 nm) and 1.1 A (491.2 nm). The maximum peak output power obtained was 70 mW at the blue lines and 78 mW at the infared ones. Addition of a small amount of Ne completely quenched the blue laser oscillation, due to Ne ions strongly populating the lower levels. The cross-section for the Ne ion-Zn atom charge transfer process was estimated to be in the order of 10^{-14} cm^2. This high cross-section points to the possibility to obtain laser oscillation at the 210 nm Zn II transition.

Research on multidimensional lasers. — An efficient laser resonator construction was developed for thin, disc shaped laser-active materials. In our model experiment a laser excited "flying saucer" dye cuvette emitted the expected, rather unusual, but easily focusable conical-wall laser radiation. This off-plane halo resonator can generally be used for all laser materials.

Atmospheric pressure discharge. — A serious problem of environmental protection is continuous determination of the heavy metal content of waters. For this aim a new glow discharge atomic emission source was developed: a stable glow discharge was produced in atmospheric air using water as a cathode. Spectral lines of elements dissolved in water

appeared due to cathode sputtering in the discharge. This phenomenon can be used for the continuous analysis of water.

Surface plasmon decay length measurements. — A novel method was used for the determination of surface plasmon decay length L (x) on thin silver and gold films in the visible and near infrared spectral region. In this method the distribution of light, emitted by surface plasmons which were excited on metal/air interfaces by an ATR (attenuated total reflection) technique, was determined with a CCD detector array and subsequent mathematical analysis.

The obtained optical L(x) data were in good agreement with values measured by using a scanning tunnelling microscope (STM). Theoretical calculations allowed to determine the specific optical constants of the metal films.

Grants:

OTKA F/1 4475 Studies of the cathode region of glow discharges
OTKA F/2 7475 Chaotic phenomena in gas discharges
OTKA T-2935 Cathode sputtered hollow cathode lasers
OTKA T-4220 Multidimensional lasers
OTKA T-4221 High voltage discharges
OTKA T-4227 Excitation mechanisms in hollow cathode lasers
OTKA T-2940 Surface plasmon studies

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N.13. K. Szõcs*, Z.Gy. Horváth: Throw away that film, use a leaf! To be published in American Journal of Physics

N.14. N. Kroó, W. Krieger*, Zs. Lenkefi, Zs. Szentirmay, J.P. Thost* and H. Walther* A new optical method for investigation of thin metal films. To be published in Surface Science

Patent

P. Csonka*, Z. Gy. Horváth, N. Kroó:

Method and apparatus for reduction of scattered light of Fresnel lenses and to change the spatial distribution. OTH P '94 01602 (pending)

O. LASER APPLICATION

I. Kertész, A. Czitrovszky, P. Jani, Á. Kiss, M. Koós, Gy. Messing, Said H.S. Moustafa, B. Plósz, I. Pócsik, L. Tóth

Solid state laser development. - In the frame of the „High power solid state laser" EUREKA Project we dealt with special laser pumping lamps, with new Q-switch types for high average powers, and developed a multi-hundred watt Nd:YAG laser.

The AC or DC driven potassium lamps with short pulses superposed at 50 Hz repetition rate enabled us to achieve medium laser powers at very low - several hundred watt - pumping rates.

Developing a two head Nd:YAG laser 400-500 W average power - continuous wave or pulsed - enabled us to investigate new: FTIR (Frustrated Total Internal Reflection) and VBFP (Varied Base Fabry-Perot) Q-switches. Both Q-switches proved to be useful up to kilowatt range with 0-100 kHz repetition rates and the switching speed was adjustable to the damage thresholds and application requests. Besides, the Q-switches with adequate parameter choices improved the beam quality by a factor of 3 making 9-times higher power density possible in the focal spot of a lens.

Optical measuring techniques based on light scattering and interference. - On the basis of previously developed airborne particle counters we have designed and developed a PC controlled *liquidborne particle counter* (LPC 1-200) to measure the size distribution and concentration of particles suspended in various liquids whose viscosity is between near 0 and 100 poise. The size range of the device is 1 - 200 μm, size resolution 6 bit, logarithmic, max. particle concentration 10 000 particle/ml, flow rate 20 - 80 ml/min, variable, measurement cycle time 1 sec - 3 600 sec, detectable in 1 sec, number of preset cycles 1 - 100, maximum level difference between the device and liquid to be tested - 1 m.

Sampling efficiency of previously developed APC-03-2 and APC-03-2A *airborne particle counters* was studied in dependence of the length and diameter of the sampling tube. The testing aerosol was produced by means of a PG-100 aerosol generator with a polydisperse calibration latex from Dow Chemical Inc. The diameter of sampling tubes was between 3 and 8 mm the length between 1 and 10 m.

The aerosol released from heated *LWR fuel rods* were investigated when an LWR core damage accident was simulated by heating the fuel rod samples in a special furnace in Ar flow. The size distribution, the concentration of the released ingradients and the chemical content was measured in the temperature region from 20 to 1500^{o}C.

The monitoring of environment polution of air in Budapest was carried out by measuring the size distribution and concentration of the suspended contamination in the respirable region in 10 different locations and in several industrial plants.

By parametric down-conversion of the 488, 351 and 352 nm lines of an Ar-ion laser in various non-linear crystals *CW squeezed light* was generated. A high time resolution (300 ps) system was developed for the study of the statistical properties of the squeezing.

The development of a 1 nm resolution *interferometric motion analyzer system* **(LIMAS)** has been finished this year. The outstanding feature of the system is that it reconstructs all the time dependent functions of motion such as displacement, velocity, acceleration and the fast Fourier transform of these from sample displacement of 1 nm precision taken at

50 kHz rate. Accelerations up to 10 000 m/sec^2 are readily measured which can be of interest for the measurement of start-stop dynamics of machine tools, or the study of elastic - unelastic deformation of materials.

Hydrogenated amorphous carbon (a-C:H). - The scope of this research is how the nanostructure and bonding properties of these a-C:H films are related to their „diamond-like" behaviour.

Amorphous carbon films of different π bonding concentrations and nanoscale ordering were grown by tuning plasma parameters of the deposition process and their structural properties were analysed by ERD method, proton NMR measurements and Raman scattering. Results concerning absolute hydrogen content, H bonding entities and graphit-like clusters were correlated with dc electrical and photoluminescence properties. Main results are the following:

Resonance Raman scattering was found by using 1,06 μ probe wavelength. This resonant effect allows a size-specific investigation of π bonded clusters.

Temperature independent NMR spin-lattice relaxation time was measured in a broad range (10-300 K), the value obtained was found to be surprisingly short, which is hard to explain by usual relaxation process. Different behaviour was observed below 10 K and its variation with film structure will be helpful to understand general relaxation dynamics of the amorphous carbon.

Close correlation between luminescence efficiency and size distribution of π bonded carbon clusters was proven by laser soaking the carbon films.

Grants

ACCORD N^0 9112-0167: Beam quality control and improvement of high power solid state lasers
OTKA 1444: Generation of squeezed light and studying of their properties
OTKA 1/4 4223: Cluster size-distribution in amorphous carbon films & their effect on the physical properties of the film.

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O.11. I. Pócsik, M. Koós: Low frequency vibrational properties of amorphous matter. To be published in J. Vibr. Spectr.

Patent

I. Kertész, N. Kroó, B. Plósz, Z. Horváth, J. Danileiko*, B. Denker*, A. Korcsagin*, V. Osiko*, A. Prohorov*: Optical elements combined with laser for the control of the spatial-, time- and power behaviour of the laser beam. Patent 1994.

P. OPTICAL THIN FILMS

K. Ferencz, R. Szipöcs

Optical thin film structures in femtosecond lasers. The research work made on optical thin film structures has had several aspects:

1. **Understanding general problems in femtosecond pulse generation and in their applications.** One of the main trends in laser physics today is the development of femtosecond laser sources. The ultimate pulse duration of recent systems is strongly connected with the overall dispersive properties of different intra- and extracavity optical elements. For example, operation of femtosecond pulse solid state lasers relies on a net negative, i.e. anomalous dispersion in the resonator. Until recently, prism pairs built in the laser cavity were the only low loss sources of broadband negative dispersion. In practical prism-pair-controlled broadband laser systems a major limitation to ultrashort pulse generation originates from the variation of the intracavity dispersion with wavelength. The principal source of this high-order dispersion, however, was found to be the prism pair. As a consequence, the spectra of sub-20-fs pulses from prism-pair-controlled oscillators are inherently asymmetric, which result in a pedestal of the pulse in the time domain. An additional problem in these systems is the increased sensitivity of the pulse width (and the corresponding spectrum) to cavity and prism alignment. Furthermore, the minimum prism separation sets a constraint on the resonator length, and thus the repetition rate of femtosecond pulse solid-state laser oscillators.
2. **Design of dielectric mirrors with pre-set phase and amplitude properties**. In order to solve the inherent problems of prism-pair-controlled femtosecond systems listed above, we initiated a new technology for dispersion control: optical thin film structures exhibiting well defined dispersion properties have been developed at our optical thin Film laboratory. For the first time, we have shown that chirped dielectric mirrors may exhibit high reflectivity and nearly constant negative dispersion over frequency ranges as broad as 80 THz. We have shown that dispersion in chirped multilayer structures arises from the wavelength dependence of the penetration depth of the incident optical field. The dispersive mirrors have been designed by the use of our computer software comprising a simple computer refinement algorithm, which minimises the quadratic deviation of the complex reflectivity vs. frequency function of the actual mirror design from the required specification by automatically modifying layer thicknesses. Specific dispersive mirrors have been developed for a femtosecond Ti:sapphire laser and its amplifier operating at 800 nm, and for a femtosecond pulse parametric oscillator operating at 1.2-1.3 microns.

   From the theoretical point of view, we have demonstrated that dielectric rugate mirrors with pre-set phase and amplitude characteristics can be synthesised by the use of Fourier transform, which may lead to the development of more sophisticated practical designs.
3. **Measuring dispersive properties of dielectric mirrors**. A fully automated inexpensive method has been developed for fast, accurate determination of the frequency dependent group delay of dispersion engineered mirrors, in cooperation with JATE University, Szeged, Hungary. The method is based on spectrally resolved white-light interferometry.

4. **Testing mirrors in femtosecond laser oscillators, amplifiers and optical parametric oscillators**. Using chirped dielectric and other dispersion engineered mirrors, a self-mode-locked Ti:sapphire laser oscillator generating nearly bandwidth limited 8-fs optical pulses around 800 nm has been built at the Technical University of Vienna, which represents the best result reported to date. Our experiments indicate that the performance of mirror-dispersion-controlled laser oscillators are likely to surpass their prism-pair controlled predecessors with some fundamental benefits, such as pulse quality (in terms of spectral symmetry and fitting the sech envelope), stability and compactness.

   Chirped mirrors have been developed for a broadband third-order dispersion control in a femtosecond Ti:sapphire amplifier system as well.

   Recently, chirped mirrors have been successfully tested in a femtosecond optical parametric oscillator at MPI Stuttgart.

5. **Femtosecond pulse propagation in layered dielectrics**. Propagation of electromagnetic wave packets through 1D photonic band gap materials (quarter-wave mirrors) has been studied using 12 fs optical pulses. The calculated and measured transit time has been found to be paradoxically short (implying superluminal tunnelling) and independent of the barrier thickness for opaque barriers, in analogy to the behaviour of electrons tunnelling through potential barriers. Shortening of Fourier-limited incident wave packets has also been observed upon transmission through these linear systems. Although in apparent conflict with causality and the uncertainty principle, neither of these general principles have been found to be violated because of the strong attenuation suffered by the transmitted signals.

Grants

OTKA T-007376 Optical thin film structures in femtosecond laser systems
WTZ-Ö-U Project A 17 Optical thin film structures in femtosecond laser systems (Austro-Hungarian joint project)

Publications

P.1. R. Szipöcs, K. Ferencz, Ch. Spielmann*, and F. Krausz*: Chirped multilayer coatings for broadband dispersion control in femtosecond lasers. Opt. Lett. 19, 201 (1994)

P.2. A. Stingl*, Ch. Spielmann*, F. Krausz*, and R. Szipöcs: Generation of 11-fs pulses from a Ti:sapphire laser without the use of prisms. Opt. Lett. 19, 204 (1994)

P.3. Ch. Spielmann*, R. Szipöcs, A. Stingl*, and F. Krausz*: Tunneling of optical pulses through photonic band gaps. Phys. Rev. Lett. 73, 2308 (1994)

P.4. A. P. Kovács*, R. Szipöcs, K. Osvay*, and Zs. Bor*: Group-delay measurement on laser mirrors by spectrally resolved white-light interferometry. Ultrafast Phenomena IX, Springer, Heidelberg (1994)

P.5. F. Krausz*, Ch. Spielmann*, P.F. Curley*, T. Brabec*, S. M. J. Kelly*, A. Stingl*, R.Szipöcs, E. Wintner*, and A. J. Schmidt*: Ultrafast solid state lasers: status and prospects. (invited). Ibid. (1994)

P.6. R. Szipöcs, K. Ferencz, Ch. Spielmann*, and F. Krausz*: Chirped multilayer coatings for broadband dispersion control in femtosecond lasers. Optics&Photonics News, p. 54, February 1994.

P.7. R. Szipöcs, and A. Köházi-Kis: Design of dielectric high reflectors for dispersion control in femtosecond lasers. In: Optical Interference Coatings, Ed. Florin Abeles, Proc. SPIE 2253, Paper 17 (1994)

P.8. A. P. Kovács*, K. Osvay*, Zs. Bor*, and R. Szipöcs: Group-delay measurement on laser mirrors by spectrally resolved white-light interferometry. To be published in Opt. Lett.

P.9. A. Stingl*, M. Lenzner*, Ch. Spielmann*, F. Krausz* and R. Szipöcs: Sub-10-fs, mirror-dispersion-controlled Ti:sapphire laser. To be published ibid.

Patent

R. Szipöcs, F. Krausz*: Dispersive dielectric mirror. Filed by Research Institute for Solid State Physics in US, based on Hungarian Patent serial No. P 93 02398

EDUCATION

Graduate and postgraduate courses, 1994

— Collective phenomena in electron systems (P. Fazekas, ELTE[4])
— Magnetism I. (P. Fazekas, ELTE)
— Magnetism II. (P. Fazekas, ELTE)
— Electronic states in solids (J. Kollár, ELTE)
— Solid state research (I. Vincze, ELTE)
— Selected experimental methods in materials science (K. Tompa, ELTE)
— Advanced materials and processes (G. Konczos, ELTE)
— Special metals and alloys (A. Lovas, BME[5])
— Statistical physics (F. Iglói, JATE[6])
— Electrodynamics II. (F. Iglói, JATE)
— Many body problem (I. Tüttõ, ELTE)
— Weak localisation (I. Tüttõ, ELTE-BME)
— Solid state physics III. (A. Virosztek, BME)
— Medical application of lasers (Z.Gy. Horváth, L. Csillag, SOTE[7])
— Modern experimental methods in solid state physics (Gy. Faigel, ELTE)
— Physics of liquid crystals and polymers (Á. Buka, ELTE)
— Condensed matter and light interaction (I. Jánossy, ELTE)
— Advanced solid state physics I. (J. Sólyom, ELTE)
— Advanced solid state physics II. (J. Sólyom, ELTE)
— Theoretical physics (S. Varró, JPTE[8])

Laboratory practice and seminars

— Preparation and crystallization of metallic glasses (I. Vincze)
— NMR spectroscopy (K. Tompa)
— Selected modern optical laboratory measurements (Zs. Szentirmay, Z. Donkó, P. Apai, P. Mezei)
— Advanced solid state physics laboratory for majors in physics (Gy. Kriza, Gy. Mihály)
— Wishful thinking in solid state physics (I. Vincze)
— Solid state physics and materials science (I.Vincze)

[4]ELTE: Loránd Eötvös University, Budapest,
[5]BME: Technical University, Budapest
[6]JATE: Attila József University, Szeged
[7]SOTE: Semmelweis Medical University, Budapest
[8]JPTE: Jannus Pannonius University, Pécs

— Experimental neutron physics (L. Cser, F. Mezei)

Diploma works

— Do Than Son (BME) : Back scattered electron signal control by computer (Consultant: L. Pogány)

— I. Varga (BME): Computer control for the scanning electron microscope (Consultant: L. Pogány)

— L. Szalai (JATE): Dependence of laser power and gain on diameter in a segmented hollow cathod Cu ion laser (Consultant: M. Jánossy)

— K. Szõcs (Babes-Bolyai Univ. Cluj, Rumania): Investigation on the fluorescence of clorofill using CCD detector (Consultant: Z.Gy. Horváth)

— T. Bereczky (Babes-Bolyai Univ. Cluj, Rumania): Investigation of the fluctuations of "Laser speckle" in living tissues (Consultant: Z.Gy. Horváth)

— L. Szabados: Measurements of pretilt in liquid crystal cells (Consultant: I. Jánossy)

— T. Börzsönyi: Study of liquid crystal interfaces at phase transitions (Consultant: Á. Buka)

Ph. D. students

L. Vitos: Electronic structure of solids (Supervisor: J. Kollár)

B. Ujfalussy: Application of the generalized KKR scheme. (Supervisor: J. Kollár, defended in 1994)

A. Beleznay: Relaxation phenomena of charge density waves. (Supervisor: Gy.Mihály, defended in 1994)

Z. Donkó: Gas discharge experiments and modelling. (Supervisor: M. Jánossy)

Á. Hofmann: Apparatus for measurement of surface reflection. (Supervisor: Zs. Szentirmay)

A. Kõházi-Kiss: Multiphoton photoelectron emission from metals induced by intense laser fields. (Supervisor: Gy. Farkas)

T. Tóth Katona: Pattern formation at the interfaces of liquid crystal phases. (Supervisor: Á. Buka)

T. Börzsönyi: Instabilities in liquid crystals due to external excitations. (Supervisor: Á. Buka)

DISSERTATIONS

A. Virosztek: Low dimensional electron systems (in Hungarian) (Doctor of Physical Science)

Z.Gy. Horváth: Special time and spatial properties of pulsed lasers (in Hungarian) (Candidate of Physical Science)

A. Csordás: Phase transition-like behaviour of chaotic systems in the thermodynamic description (in Hungarian) (Candidate of Physical Science)

A. Sütõ: Investigation of magnetic and conducting properties of electronic systems with mathematical methods (in Hungarian) (Doctor of Physical Science)

J. Bergou: Quantum fluctuations of photon fields in lasers and masers (in Hungarian) (Doctor of Physical Science)

I. Pócsik: In vitro proton NMR investigations of water content of biological tissues. For the degree of "Candidate of physical sciences"

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