MSM25

Book of Abstracts

Edited by Lusine Tsarukyan and Harutyun Gyulasaryan

13th International Conference

Magnetic and Superconducting Materials (MSM25)

8-11 September 2025, Yerevan, Armenia

IPR

OPTICA
IPR Armenia Student Chapter

Yerevan 2025

https://ipr.sci.am/MSM2025

Book of Abstracts of the **13th International Conference on Magnetic and Superconducting Materials (MSM25)** (September 8-11, 2025, Armenia). – Yerevan, 2025 – 88 p. Edited by Lusine Tsarukyan (Institute for Physical Research, NAS of Armenia) and Harutyun Gyulasaryan (Institute for Physical Research, NAS of Armenia).

The book includes the abstracts of presentations submitted to the MSM25.

The MSM25 conference continued the series of meetings started in 1999 in Iran as an international platform for experts, researchers, and enthusiasts from around the world to converge and delve into the latest advancements, breakthroughs, and challenges in the field of magnetism and superconductivity. Our goal was that the MSM25 conference would spark new collaborations and inspire innovative ideas by bringing together international leading research groups.

Topics:

MAGNETISM:

- *Hard magnetic materials*
- *Magnetocalorics*
- *Magnetization dynamics*
- *Nanoscale magnetism*
- *Magnetic materials in biology and medicine*
- *Novel magnetic materials and emerging phenomena*
- *Multifunctional magnetic materials*
- *Frustration and topology in magnetism*
- *Unconventional processing for magnetic hysteresis design*
- *Experimental methods*

SUPERCONDUCTIVITY:

- *High-Tc superconductivity*
- *High-pressure hydrides*
- *2D superconductors*
- *Magnetic superconductors*
- *Topological superconductors*
- *Heavy fermions*
- *Superconductivity in confined geometries*
- *Tunneling and Josephson junctions*
- *Emerging superconducting materials*
- *Superconducting device*

Organizers:

- ✓ **Institute for Physical Research of National Academy of Sciences of Armenia**
- ✓ **IPR Armenia Optica Student Chapter**

Sponsors:

- ✓ **The International Union of Pure and Applied Physics (IUPAP)**
- ✓ **Higher Education and Science Committee of the RA MESCS**

Supporting Organizations:

- ✓ **National Academy of Sciences of Armenia, NAS RA**
- ✓ **Alikhanyan National Science Laboratory**
- ✓ **NAS RA Byurakan Astrophysical Observatory after V. Ambartsumian**

Conference Committees:

Chairs:

Prof. Alexander Mukasyan
University of Notre Dame, USA &
Institute for Physical Research, NAS of Armenia

Dr. Aram Manukyan
Institute for Physical Research, NAS of Armenia

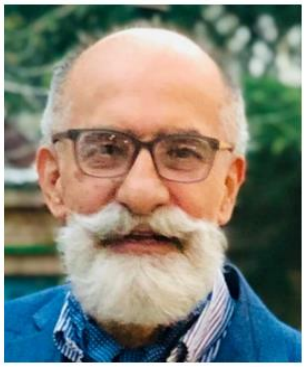
Scientific secretary:

Dr. Lusine Tsarukyan
Institute for Physical Research, NAS of Armenia

Executive Committee:

Prof. Michael Farle
University of Duisburg-Essen, Germany

Prof. Kee Hoon Kim
Seoul National University, South Korea



Prof. Mohammad Akhavan
Sharif University of Technology, Iran

Prof. Warren Pickett
University of California Davis, USA

LOCAL ORGANIZING COMMITTEE:

A. Manukyan, Armenia– chair
H. Gyulasaryan, Armenia
D. Hambardzumyan, Armenia
A. Ginoyan, Armenia
A. Sargsyan, Armenia
Kh. Kirakosyan, Armenia
A. Kuzanyan, Armenia
V. Balasanyan, Armenia
V. Avagyan, Armenia
G. Shmavonyan, Armenia
M. Hayrapetyan, Armenia

SCIENTIFIC PROGRAM COMMITTEE:

A. Manukyan, Armenia– chair
A. Mukasyan, USA
E. Antipov, Russia
S. Deemyad, USA
C. Draxl, Germany
S. Budko, United States
I. Eremin, Germany
S. Ovchinnikov, Russia
H. Ohldag, USA
M. Acet, Germany
A. Rogalev, France
M. Angelakeris, Greece
D. Kaczorowski, Poland
R. Morgunov, Russia
O. Volkova, Russia
M. Spasova, Germany

INTERNATIONAL ADVISORY COMMITTEE:

M. Akhavan, Iran
W. Pickett, USA
D. Kaczorowski, Poland
L. Greene, USA
A. Ivanov, Russia
C. Draxl, Germany
H. Srikanth, USA
B. Gökce, Germany
K. Martirosyan, USA
A.Sokolov, Russia
A. Semisalova, Germany
J. Kuneš, Czechia
D. Peddis, Italy
A. Vasiliev, Russia
O.Volkova, Russia
V.Pudalov, Russia
A. Rogalev, France
I. Bozovic, United States

MSM25

Conference Venue:

National Academy of Sciences of Armenia, located in Yerevan, Armenia,

24 Marshal Baghramyan Ave, Yerevan 0019

Plenary Speakers & Abstracts of their Presentations

Konstantin Arutyunov

Konstantin Arutyunov, professor of HSE University Moscow Institute of Electronics and Mathematics https://www.hse.ru/en/org/persons/117711945/, Head of Quantum NanoElectronics Lab https://miem.hse.ru/en/quantum/, Leading Scientist at Kapitza Institute of RAS.

Konstantin Arutyunov graduated in 1985 from Physics Department of Moscow State University where he got his PhD degree in 1988 and later the degree of Doctor of Science in 2012.

At different periods of his professional activity Konstantin Arutyunov worked at Physics Department of Moscow State University (1988-1995), Lausanne University CH (1995-1996), Katholieke University Leuven BE (1996-1997), University of Jyvaskyla FI (1998-2014).

Konstantin Arutyunov is the (co)author of more than 100 research papers, more than 80 times has given invited talks at various scientific conferences, is the (co)author of 3 patents in nanotechnology. He is the member of editorial board of several international scientific journals. More that 10 times has been the PI of various national and international research projects.

The main scientific interests are related to nanotechnology, low temperature physics, quantum nanoelectronics and mesoscoipic superconductivity. Konstantin Arutyunov combines experimental research in the lab with teaching of basic and advanced courses to students.

Plenary Presentation

Fundamental limitations and perspectives of nanoelectronics development

K.Yu. Arutyunov[1,2]

[1] *National Research University Higher School of Economics, 101000, Moscow, Russia*
[2] *P. L. Kapitza Institute for Physical Problems RAS,119334, Moscow, Russia*

Email: karutyunov@hse.ru

A review of the main reasons limiting the miniaturization of nanoelectronic devices is presented: an increase in heat release per unit volume and various quantum size effects. Obviously, these limitations should not be ignored when designing new generation of subminiature nanoelectronic circuits. However, along with the negative impact of quantum effects on the operation of 'standard' devices, these phenomena can be used to build systems based on principles of information transmission, processing and storage that are different from the classical ones. Of particular interest are nanoscale superconducting elements offering zero energy dissipation combined with unique properties distinctive from the bulk objects.

Keywords: quantum nanoelectronics, quantum size phenomena, mesoscopic superconductivity.

Dariusz Kaczorowski

Dariusz Kaczorowski - Polish physicist, professor of physical sciences, corresponding member of the Polish Academy of Sciences, and member of the Academia Europaea. He is an ordinary professor at the Institute of Low Temperature and Structure Research of the Polish Academy of Sciences (INTiBS PAN) in Wrocław. His scientific work concerns experimental condensed matter physics, with particular emphasis on superconductivity and magnetism in systems with strong electronic correlations, and the physics of topological materials.

He is the author of three encyclopedic monographs published by Springer Verlag and more than 630 original scientific papers in leading journals, including Nature Communications, Proceedings of the National Academy of Sciences USA, Nano Letters, Physical Review X, Physical Review Letters, and Physical Review B. His publications have received over 7,800 citations, and his Hirsch index is 38 (Web of Science, as of 1 August 2025). According to the global ranking by Stanford University (2020, 2022, 2024, 2025), he belongs to the 2% of the most cited scientists in all scientific disciplines worldwide.

He has presented his research results at more than 150 international scientific conferences in Poland and abroad, delivering over 50 invited lectures, including numerous plenary talks. He has chaired seven international scientific conferences and co-organized fifteen others, including workshops and scientific schools. He serves on more than fifty advisory and program committees of major international conferences devoted to magnetism, superconductivity, and low-temperature physics.

Plenary Presentation

Unconventional superconductivity in Ce-based heavy-fermion compounds

D. Kaczorowski

Institute of Low Temperature and Structure Research, Polish Academy of Sciences, Okólna 2, 50-422 Wrocław, Poland

Email: d.kaczorowski@intibs.pl

Although it has been almost half a century since the discovery of this phenomenon, superconductivity in heavy-fermion systems remains incompletely understood and inadequately described theoretically. The reason is the richness of observed features, unconventional mechanisms of Cooper pairing and untrivial symmetry of wave functions that describe the superconducting condensate. In addition, new experimental findings in this field often lead to the identification of novel effects, which complicates efforts to create a coherent and universal theory of the heavy-fermion superconductivity.

In my lecture, I will recall our team's success more than a decade ago in discovering heavy-fermion superconductivity in the previously unknown Kondo lattice Ce_2PdIn_8, which emerges in the close vicinity of the magnetic field-induced quantum magnetic phase transition. I will also briefly present our results on the related compounds Ce_3PdIn_{11} and Ce_3PtIn_{11}, casting some doubt on the actual nature of the coexistence of the heavy-fermion superconductivity and long-range antiferromagnetic ordering, which was postulated for them in the literature.

Finally, I will discuss the results of our most recent studies on the unconventional superconductivity in the dense Kondo system $CeRh_2As_2$, which is currently attracting extraordinary attention due to the observed magnetic field induced transition between two different superconducting states, which has been tentatively attributed to the change of the superconducting gap function parity from even in the low-field phase to odd in the high-field phase. Despite intensive studies, the actual origin of this behavior remains elusive.

Karen Martirosyan

Dr. Martirosyan is Professor of Physics, Director of Advanced Nanoscience Laboratory, and former Associate Vice President for Research Enhancement and Houston Endowed Chair in Science, Math, and Technology at the University of Texas Rio Grande Valley (UTRGV). Prior to the AVP position, he served as the Associate Dean for Research and Educational Innovations at the College of Sciences and worked with faculty to create new undergraduate and graduate programs in STEM fields. Dr. Martirosyan's research is focused on experimental and theoretical condensed matter physics with a wide range of solid-state phenomena to design advanced multifunctional nano-tailored materials and devices for energy, environmental, and biomedical applications. The research area covers the development of a broad spectrum of advanced materials for imaging, targeted drug delivery, imaging-guided brachytherapy, and theranostics media, their design, fabrication, and characterization. He has been the Principal Investigator and Co-investigator for numerous federal funded research projects. His work has resulted in more than 190+ refereed papers, 21 patents, 12 book chapters, and over 170 presentations at national and international conferences. He has successfully mentored undergraduate, master, doctoral students as well as postdoctoral and Fulbright fellows and international scholars, exemplified by successful completion of their co-authorship in peer-reviewed publications. He was three times honored with prestigious AFRL Summer Faculty Fellowships and conducted research at the Eglin Air Force Base, Florida. Dr. Martirosyan is a reviewer for the NSF and NASA projects. He has chaired several major scientific conferences, annual college symposiums, interdisciplinary colloquiums, and hosted nationally and internationally recognized scholars.

Plenary Presentation

Magnetoelectric Materials: Structural Characterization and Multifunctional Applications

K.S. Martirosyan

Department of Physics and Astronomy, University of Texas Rio Grande Valley, Texas, 78539, USA
Email: karen.martirosyan@utrgv.edu

Magnetoelectric (ME) materials, which exhibit coupled magnetic and electric order parameters, have garnered significant interest for their potential in next-generation multifunctional devices [1]. These materials enable electric field control of magnetism and vice versa, making them highly desirable for applications in sensors, memory devices, energy-efficient electronics, and biomedical technologies such as controlled drug delivery. This talk explores the structural characterization and properties of various ME materials, including (i) single-phase magnetoelectric materials ($BiFeO_3$, $YMnO_3$), (ii) layered and noncentrosymmetric multiferroics (Cr_2Te_3, $MnWO_4$), (iii) rare-earth-based compounds ($Y_3Fe_5O_{12}$, $HoMnO_3$), and (iv) Janus-like ferroelectric–ferromagnetic composites ($BaTiO_3$–$CoFe_2O_4$) [2-5]. Emphasis is placed on phase purity, crystallographic symmetry, and microstructural features critical to their functional properties. Advanced characterization techniques, including X-ray diffraction, electron microscopy, and spectroscopy, provide insights into the correlation between structural attributes and ME coupling efficiency. Additionally, recent advancements in both composite and single-phase ME materials will be discussed, highlighting their role in tunable electromagnetic devices, biomedical applications, and spintronic systems. By integrating experimental findings with theoretical modeling, this work aims to optimize ME material design for enhanced performance and broader technological impact.

References

[1] H. Schmid, *Ferroelectrics*, 162, 317-338 (1994).
[2] E. Galstyan, B. Lorenz, K.S. Martirosyan *et al.*, *J. Phys.: Condens. Matter*, 20, 325241 (2008).
[3] D. Karthickraja, S. Karthi, A. Gangadharan *et al.*, *New Journal of Chemistry*, 34, 43, 13584-13593 (2019).
[4] C. Trevino De Leo, G.C. Dannangoda *et al.*, *Ceramic International*, 47, 4, 5415-5422 (2021).
[5] F.S. Samghabadi, L. Chang, M. Khodadadi *et al.*, *APL Materials*, 9, 021104 (2021).

Ulf Wiedwald

Ulf Wiedwald is a Professor of Experimental Physics at the University of Duisburg-Essen (UDE), Germany.

He studied physics at the Technical University of Braunschweig, where he received his diploma in 2001 and completed his PhD at UDE in 2004. He then moved to Ulm University, where he continued his research on the magnetism of nanoparticles, epitaxial layers, and the interaction of periodic nanostructures with thin films. In 2011, he obtained his habilitation in Experimental Physics. Since returning to the Faculty of Physics at UDE in 2013, he has been working on the biomedical applications of magnetic nanoparticles and multifunctional hybrid structures, and since 2015 also on MAX phases and MXenes. In 2018, he held a guest professorship at the National University of Science and Technology MISiS in Moscow.

Ulf Wiedwald has published more than 140 papers in international peer-reviewed journals and 6 book chapters. The team's scientific interests include magnetic properties of novel low-dimensional structures and the preparation and characterization of nanostructured materials ranging from magnetic mono/multilayer deposition in ultrahigh vacuum, to the forming of self-organized assembly of superparamagnetic nanoparticles. Currently, he is the principal investigator in the CRC/TRR 270 and a joint ANR-DFG research project funded by the German Research Foundation.

Recent publications:

• N. Josten et al., Temperature-dependent magnetocrystalline anisotropy of Fe2AlB2 single crystals, Physical Review Materials 9, 054405 (2025).

• M. V. Efremova et al., Genetically controlled iron oxide biomineralization in encapsulin nanocompartments for magnetic manipulation of a mammalian cell line, Advanced Functional Materials 2418013 (2025).

• A. Neusch et al., Semisynthetic Ferritin-based Nanoparticles with High Magnetic Anisotropy for Spatial Magnetic Manipulation and Inductive Heating, Nanoscale 16, 15113 (2024).

• T. Feggeler, An ultrasensitive molecular detector for direct sensing of spin currents at room temperature, ACS Applied Materials & Interfaces 16, 54139 (2024).

Plenary Presentation

Harnessing Bioengineered Magnetic Nanoparticles for Advanced Theranostics

U. Wiedwald
University of Duisburg-Essen, Faculty of Physics, 47057 Duisburg, Germany
Email: ulf.wiedwald@uni-due.de

Magnetic nanoparticles (MNPs) are invaluable for theranostics, integrating multiple diagnostic and therapeutic applications, such as targeted drug delivery, magnetic hyperthermia, and imaging. Mostly prepared ex vivo via wet chemical methods, their biocompatibility and solubility under physiological conditions require critical evaluation. A promising alternative is the use of biological nanocompartments for synthesis, enabling MNPs tailored for in vitro and in vivo applications while minimizing adverse effects. Naturally occurring nanocompartments like ferritin (diameter 8 nm) and encapsulin (diameter 30 nm) facilitate biomineralization of Fe and other 3d metal ions, forming Fe oxides, hydroxides, and ferrites [1,2]. Their size and anisotropy can be tuned, though some exhibit reduced performance due to defects.

We investigated ferritin-based and encapsulin-derived MNPs offering innovative strategies for precise magnetic control in biological systems. Ferritin MNPs enable controlled biomineralization. Doping of 7% Co for Fe enhances their magnetic blocking temperature from 35 K to 137 K and thus, improve inductive heating and enabling rapid, reversible spatial manipulation within cellular environments at high intracellular stability and traceability. Similarly, encapsulins enable fully genetically controlled biomineralization of 30 nm iron oxide cores (Fig. 1), forming quasicrystalline structures with mixed para- and ferrimagnetic behavior. These nanoparticles generate magnetic moments (10^{-15} A·m² per cell), comparable to conventional exogenous labels, facilitating magnetic-activated cell sorting (MACS) and precise cell manipulation. Their ability to enable magnetic control without external agents makes them valuable for advanced biomedical applications.

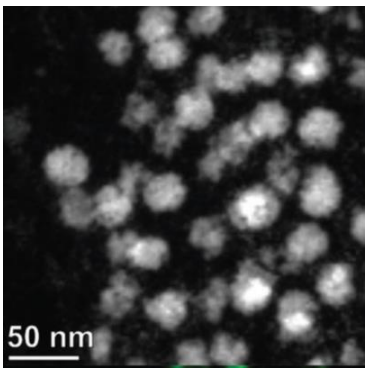


Fig. 1. HAADF scanning transmission electron microscopy image of encapsulin-derived 30 nm Fe oxide MNPs [2].

The presented works are highly interdisciplinary with contributions from M.A. Abakumov, I.B. Alieva, I. Beer, S.-V. Bodea, F. Curdt, M.V. Efremova, M. Farle, T. Feggeler, J. Franke, A.S. Garanina, P. Hagemann, N.P. Ivleva, N. Josten, D.A. Kuckla, R. Lavrijsen, R. Meckenstock, A. Neusch, C. Monzel, I.P. Novoselova, H. Ohldag, L.N. Panzl, S. Sadik, A.S. Semkina, F. Sigmund, N. Tetos, G.G. Westmeyer, M. Winklhofer, S. Wintz.

References

[1] A. Neusch, U. Wiedwald, I.P. Novoselova *et al.*, *Nanoscale* 16, 15113 (2024).
[2] M. V. Efremova, U. Wiedwald, F. Sigmund *et al.*, *Adv. Funct. Mater*. 2418013 (2025).

Abstracts of Invited & Special Presentations

Invited Presentation

Dr. Maxim Abakumov

National University of Science and Technology "MISIS"

Russia

Magnetic nanoparticles in biomedicine: effects of shape, size and structure on biomedical applications

M.A Abakumov[1,2], N.A. Nikitin[1,2], A.G. Savchenko[2], A.G. Majouga[2], V.P. Chekhonin[1]

[1] *Pirogov Russian National Research Medical University, Russia, Moscow, Ostrovityanova st. 1*
[2] *NUST MISIS, Russia, Moscow, Leninskiy prospect, 4*

Email: abakumov_ma@rsmu.ru

Nowadays magnetic nanoparticles bring a lot of attention as a theranostic platform by combining unique MRI contrast properties, ability to delivery drugs to tumors by magnetic field, ability to generate heat, being irradiated by high frequency alternating magnetic field and many others. However, each of the applications requires special design of nanoparticle shape, size, structure and surface chemistry.

This work is a brief introduction of factors affecting magnetic nanoparticles applications in listed above fields, based on results previously obtained in our group.

With change of nanoparticles shape their biodistribution and efficiency as a tumor specific MRI contrast agents change dramatically. Shperes demonstrate the highest accumulation in tumors, whereas rods are mainly accumulated in lungs, and clusters are excreted through the kidneys. We have shown that serum albumin coating is one of the best coating strategies for combination of drug delivery and MRI imaging, allowing to visualize tumor by MRI and delivery anticancer drugs, such as doxorubicin [1]. Moreover it was shown that combination of MRI imaging modality and photosensitizer molecules can provide a new tool for real time monitoring and therapy scheduling for deeply located tumors [2]. On the other hand such nanoparticles are not capable to provide any sufficient heating under influence of high frequency alternating magnetic field, whereas 8-12 nm cobalt ferrite nanoparticles are one of the best candidates for magnetic hyperthermia treatment allowing not only heat tumor locally, but also control the temperature for precise tumor therapy [3].

References

[1] S. Semkina *et al.*, *Nanomedicine Nanotechnology, Biol. Med.* 14, 1733 (2018).
[2] P. Ostroverkhov *et al.*, *Pharmaceutics* 10, 284 (2018).
[3] A. S. Garanina *et al.*, *Nanomedicine Nanotechnology, Biol. Med.* 25, (2020).

Invited Presentation

Dr. Mojtaba Alaei

Isfahan University of Technology

Iran

&

Skolkovo Institute of Science and Technology

Russia

Accurate Derivation of Exchange Interactions from DFT: Mapping Methods, Supercell Optimization, and Functional Benchmarking

M. Alaei[1,2]

[1] *Skolkovo Institute of Science and Technology, 121205, Bolshoy Boulevard 30, bld. 1, Moscow, Russia*
[2] *A Department of Physics, Isfahan University of Technology, Isfahan 84156-83111, Iran*
Email: m.alaei@skoltech.ru

In this talk, I will first explain how exchange interactions can be derived from DFT calculations using the mapping method [1]. This approach involves computing the total energies of different magnetic configurations and fitting them to a Heisenberg Hamiltonian to extract the exchange parameters. I will then introduce a method we developed for identifying optimal supercells for calculating exchange interactions [2]. By systematically generating supercells and analyzing the null space of the mapping equations, we can select supercells that maximize the number of independent exchange parameters while minimizing computational costs. Following this, I will explore the accuracy of exchange interactions calculated using different DFT methods, such as DFT+U and meta-GGA functionals [1,3]. Their predictive capabilities are evaluated by comparing the calculated transition temperatures with experimental values, highlighting the limitations of traditional GGA+U approaches and the significant improvements offered by newer meta-GGA functionals [3].

References

[1] Z. Mosleh, M. Alaei, *Physical Review B* 108 (14), 144413 (2023).
[2] M. Alaei, A.R. Oganov, *Physical Review B* 111 (14), 144419 (2025).
[3] N. Rezaei, M. Alaei, A.R. Oganov, *Physical Review B* 111 (14), 144406 (2025).

Invited Presentation

Prof. Makis Angelakeris

Aristotle University of Thessaloniki

Greece

Magnetic nanoparticle tuning for active biosensing performance

A. Makridis[1], K. Kazeli[1], G. Katsipis[2], E. Tzekaki[2], A. Pantazaki[2], M. Angelakeris[1]

[1] *Magnetic Nanostructure Characterization: Technology & Applications, Centre for Interdisciplinary Research and Innovation, Aristotle University, 57001, Thessaloniki, Greece*

[2] *Laboratory of Neurodegenerative Diseases, Centre for Interdisciplinary Research and Innovation, Aristotle University, 57001, Thessaloniki, Greece*

Email: agelaker@auth.gr

Magnetic nanoparticles (MNPs) typically range in size from 1 to 100 nanometers and have unique magnetic properties due to their small size and high surface-to-volume ratio. They are widely exploited as biomedical probes in Magnetic Resonance Imaging (MRI) as contrast agents to enhance imaging, in Drug Delivery where they are guided to specific sites using external magnets, in Hyperthermia Treatment to deliver specific localized heating to kill cancer cells and in Biosensors and Diagnostics to detect biomolecules via magnetic labelling or to magnetically sort of cells or biomolecules. Their facile remote manipulation via magnetic fields together the non-invasive guidance and retrieval and the easily modified surfaces for targeting are key aspects of their exploitation. Yet, challenges to be addressed are aggregation in solution, potential cytotoxicity depending on composition and long-term biocompatibility and clearance from the body. To perform as active biosensing elements, MNPs, should be incorporated to bio-platforms whereby functionalized surfaces and interfaces on them, provide biorecognition support assist by selective binding of DNA, proteins, or cells.

Alzheimer’s disease (AD) ranks among the leading causes of adult death standing as the most debilitating form of dementia. Although, its precise onset remains uncertain, underlying pathological changes may appear at preliminary stages many years before clinical cognitive symptoms. Thus, the facile, reliable, specific and sensitive detection of diverse AD biomarkers. Such a multifunctional nanoplatform holds promise for next-generation point-of-care diagnostics and magnetically modulated therapeutic strategies.) is of the essence. In this framework, we evaluate the immobilization of Alzheimer's-specific aptamers on core-shell (Fe3O4-Au) MNPs surface to selectively capture key biomarkers (Aβ40, Aβ42, p-Tau), enabling rapid and low limits of detection (LOD) across disease stages.

Their output is highlighted in high sensitivity to detect trace amounts of biomarkers, rapid detection for fast readout times and suitability for point-of-care (POC) diagnostics, multiplexing allowing for multiple targets detection in parallel and quantitative results enabling precise concentration measurements in a compact biosensor able to detect magnetic field changes linked to target analyte binding.

This work is supported by the European Union under GA No. 101120706 – project 2D-BioPAD.

Invited Presentation

Prof. Konstantin Arutyunov

HSE University

Russia

Proximity induced superconductivity in electroactive polymer

K.Yu. Arutyunov[1,2*], V. V. Zavialov[2,1], A.R. Yusupov[3], A. F. Galiev[3], D.D. Karamov[3], A.N. Lachinov[3]

[1]*National Research University Higher School of Economics, 101000, Moscow, Russia*
[2]*P. L. Kapitza Institute for Physical Problems RAS,119334, Moscow, Russia.*
[3]*Bashkir State Pedagogic University, 450008, Ufa, Russia.*
Email: karutyunov@hse.ru

Polydiphenylenephthalide (PDF) belongs to the class of carbocyclic organic electroactive polymers, which exhibit electric conductive properties when an external electrostatic field and/or mechanical stress is applied. In this work, the transport properties of thin-film layered superconductor–PDF–superconductor structures were experimentally studied in a wide temperature range. As the superconducting electrode materials we used lead and indium. At sufficiently high temperatures, the samples demonstrate metallic dependence of resistance vs. temperature. At temperatures below the corresponding critical temperatures (~7.5 K for lead and ~3.4 K for indium), the sandwiches with sufficiently thin layer of PDP exhibit features that can be explained by the effect of induced superconductivity in a thin film of conducting polymer enclosed between two massive superconductors. An extensive analysis with scanning and transmission electron microscopy revealed no signs of trivial metal-to-metal shortcuts. The mechanism of the effect is not yet clear.

The work was supported by the "Mirror laboratory" project between HSE University and Bashkir State Pedagogic University.

Special Presentation

Prof. Tomasz Cichorek

Institute of Low Temperature and Structure Research, Polish Academy of Sciences

Poland

Constraints on an order parameter in the candidate chiral superconductor 4Hb-TaS_2 from a study of the lower critical field

J. Juraszek[1], Y. M. Thiebes[2], W. Afzal[1], Ł. Luszynski[1], M. Konczykowski[3], R. Niewa[2], T. Cichorek[1]

[1]*Institute of Low Temperature and Structure Research, Polish Academy of Sciences, 50 422 Wrocław, Poland,*
[2]*Institute of Inorganic Chemistry, University of Stuttgart, 70569 Stuttgart, Germany,*
[3]*LSI, CEA/DRF/IRAMIS, École Polytechnique, CNRS, Institut Polytechnique de Paris, F 91128 Palaiseau, France*
Email: t.cichorek@intibs.pl

In the van der Waals heterostructure 4Hb-TaS_2, the interplay of a quantum spin liquid with itinerant conduction electrons is a likely source of unconventional superconductivity, characterized by an order parameter that is odd under time-reversal symmetry. Below the critical temperature $T_c \simeq 2.7$ K, this polymorph of tantalum disulfide, consisting of alternating layers as occurring in 1T-TaS_2 and 1H-TaS_2 (half of 2H-TaS_2), exhibits a sign of spontaneous time-reversal symmetry breaking, as seen in the mSR signal [1]. Furthermore, several peculiar properties of the vortex state, including topological edge modes [2] and the magnetic memory effect [3] studied by scanning tunneling microscopy, point to chiral superconductivity in this highly interesting superconductor. However, the symmetry of the superconducting order parameter in 4Hb-TaS_2 is poorly understood from bulk measurements. This includes the possible influence of multiband effects.

Here, we investigate vortex penetration into 4Hb-TaS_2 for a magnetic field parallel to the layers stacking direction. Using micro-Hall probe magnetometry [4,5], we focus on the field of first flux penetration and the resultant temperature dependence of the lower critical field $H_{c1}(T)$ in the entire superconducting state down to $0.002T_c$. For platelet-shaped samples with the thickness $d < 10$ μm, we found that the out-of-plane $H_{c1}(T)$ dependence can be well described by the conventional relation derived from the BCS theory, indicating marginal multiband effects and suggesting a nodeless superconducting order parameter of 4Hb-TaS_2. However, with increasing thickness we observed an anomalous enhancement of the penetration field deep in the superconducting state. Specifically, samples with $d \simeq 200$ μm show the pronounced enhancement of H_{c1} at $0.5T_c$, which consists of a non-saturating T dependence down to 0.007 K (the lowest temperature in the experiment) being preceded by a concave curvature below 0.5 K. Our results appear to be consistent with the theoretically predicted effect of Andreev bound states on the Bean-Livingston barrier, and thus provide macroscopic evidence for a sign-changing gap function in the candidate chiral superconductor 4Hb-TaS_2.

This work was supported by the Polish National Science Centre NCN (Project OPUS23 No. 2022/45/B/ST3/04117).

References

[1] A. Ribak, R. Majlin Skiff, M. Mograbi *et al.*, *Sci. Adv.* 6, eaax9480 (2020).
[2] A. K. Nayak, A. Steinbok, Y. Roet *et al.*, *Nat. Phys.* 17, 1413 (2021).
[3] E. Persky, A. V. Bjørlig, I. Feldman *et. al.*, *Nature* 607, 692 (2022).
[4] J. Juraszek, R. Wawryk, Z. Henkie *et al.*, *Phys. Rev. Lett.* 124, 027001 (2020).
[5] J. Juraszek, G. Chajewski, D. Kaczorowski *et. al.*, *arXiv*:2502.14423 (2025).

Invited Presentation

Dr. Mariia Efremova

Eindhoven University of Technology

The Netherlands

Femto-Nm Torques Generated by Single Magnetic Particles for Cell Actuation Measured by AFM Magnetometry

M. Efremova[1], L. Boer[1], L. Edelmann[1], L. Ruijs[1], J. Li[1], M.A. Verschuuren[2], R. Lavrijsen[1]

[1]*Department of Applied Physics, Eindhoven University of Technology, P.O. Box 513, 5600MB Eindhoven, The Netherlands*

[2]*SCIL Nanoimprint Solutions, High Tech Campus 11, 5656AE Eindhoven, The Netherlands*

Email: m.efremova@tue.nl

Magnetomechanical cancer treatments rely on forces or torques (typically in the femto-Nm range) generated by magnetic particles (MPs) via their mechanical movement in an external magnetic field [1,2]. However, these torques are only theoretically estimated and then correlated with the observations of cancer cell viability change. In this work, we had a challenging aim to directly measure the torques generated by single MPs [3], which allows for a better understanding of how magnetomechanical cell actuation actually works.

MPs were placed on a cantilever for Atomic Force Microscopy (AFM) and installed in an AFM setup with a magnet underneath. The forces generated by MPs led to the cantilever deflection and resulted in an AFM signal, which can be converted into the torque, knowing the properties of a cantilever and MPs themselves. In our setup, we investigated synthetic antiferromagnetic platelets (SAFs) with 1.88 µm diameter and 52 nm thickness [4]. The basic SAFs stack (repeated 5 times in a platelet) has two ferromagnetic CoFeB layers with opposite magnetization directions, resulting in 'off' SAFs (with no magnetic moment) at a zero field and 'on' SAFs upon the application of a magnetic field above a ~150 mT threshold. Due to a high out-of-plane magnetic anisotropy, the platelet induces a mechanical torque (force) to align with the applied field direction causing the deflection of an AFM cantilever.

This way, we measure torques between ~ 0.25 and ~$1.5 \cdot 10^{-15}$ Nm generated by a single 1.88 µm-diameter SAF platelet in a 75-373 mT field, respectively. This naively translates into a ~1 nN force generated by single SAF MPs using their radius as an arm (900 nm), making them promising candidates for magnetomechanical cell actuation. Importantly, it also shows the applicability of our technique for measuring the torques generated by other MPs (e.g., [5]), which potential for magnetomechanical cancer treatment is being explored.

***Acknowledgments**: This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement no. 899987.*

References

[1] D. W. Wong, W.L. Gan, Y.K. Teo *et al.*, *Cell Death Discov*. 4, 49 (2018).
[2] R. Mansell, T. Vemulkar, D.C.M.C. Petit *et al.*, *Sci. Rep.* 7, 4257 (2017).
[3] M.V. Efremova, L. Boer, L. Edelmann *et al.*, *Appl. Phys. Lett.* 126, 092406 (2025).
[4] J. Li, P. van Nieuwkerk, M.A. Verschuuren *et al.*, *Appl. Phys. Lett.* 121, 182407 (2022).
[5] S. Adhikari, J. Li, Y. Wang *et al.*, *ACS Photonics* 10, 1512-1518 (2023).

Invited Presentation

Prof. Bilal Gökce

University of Wuppertal

Germany

Advanced Processing of Ni-Mn-Sn Heusler Alloys for Magnetic Hysteresis Design via Additive Manufacturing

S.-K. Rittinghaus[1], H. Shokri[1], N. Shkodich[2], M. Farle[2], B. Gökce[1]

[1]*Materials Science and Additive Manufacturing, University of Wuppertal, Gaußstr. 20, 40234 Wuppertal, Germany.*
[2]*Faculty of Physics and Center of Nanointegration (CENIDE), University of Duisburg-Essen, Lotharstr. 1, 47057 Duisburg, Germany.*
Email: goekce@uni-wuppertal.de

Ni-Mn-X Heusler alloys, with X = In, Sn, Ga, or Al, are a promising class of magnetocaloric materials, particularly in the form of $Ni_{50}Mn_{50-y}X_y$ alloys, which show significant potential for solid-state refrigeration due to the magnetocaloric effect. When alloyed with Ga, In, Sn, or Sb, these ferromagnetic materials undergo a coupled spin-lattice martensitic transformation, generating thermal energy in response to external stimuli like magnetic fields or pressure. Notably, $Ni_{50}Mn_{50-y}Sn_y$ alloys are of interest due to their large magnetic entropy changes, desirable Curie temperatures near room temperature, and good mechanical properties, with elements that are widely available.

Additive manufacturing, particularly powder bed fusion (PBF), offers a versatile method for producing near-net-shape geometries from powder materials while enabling unique microstructures. In typical X_2YZ Heusler alloys, increasing the Y content promotes a transition from a fully ordered $L2_1$-type structure to a disordered $L2_1$-B2-type structure. This makes PBF a feasible approach for processing these alloys.

In this study, powder bed fusion using both laser (PBF-LB) and electron beam (PBF-EB) methods (Fig. 1) was employed to fabricate a magnetocaloric Ni45Mn44Sn11 (at.-%) alloy. Despite challenges like intergranular cracking due to anisotropic volume change during phase transformation, the feasibility of producing crack-free samples using PBF-EB was successfully demonstrated (Fig. 2). EDX measurements indicated slight evaporation of elements during processing, and post-annealing at 900°C resulted in homogeneous recrystallization with grain sizes of 70-100 µm. SEM imaging and XRD analysis confirmed almost fully martensitic microstructures with no secondary phases detected. All relevant measurements, including magnetic entropy change and other findings, will be reported in the talk.

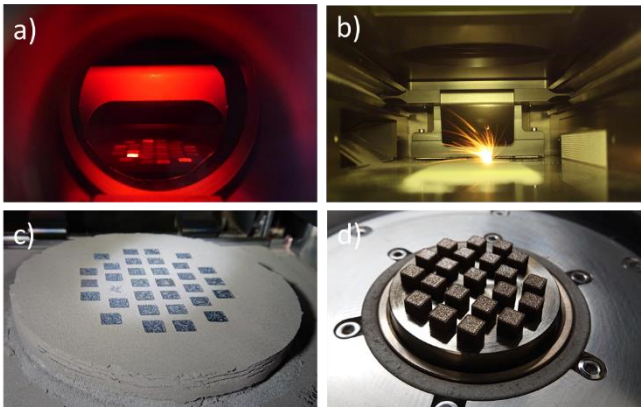


Fig. 1. Processing (a,b) and photographs (c,d) of PBF-EB (a,c) and PBF-LB (b,d) Ni-Mn-Sn samples

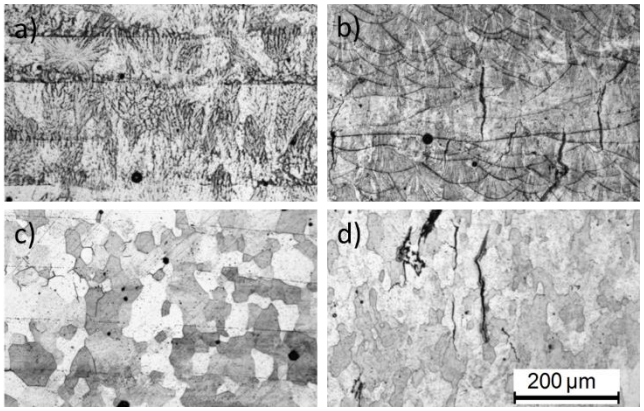


Fig. 2. Microstructure of PBF-EB (a,c) and PBF-LB (b,d) Ni-Mn-Sn samples, as-built (a,b) and heat treated (c,d)

References

[1] Y. Sutou, Y. Imano, N. Koeda *et al.*, *Appl. Phys. Lett.* 85, 4358 (2004).
[2] L. Manosa, D. Gonzalez-Alonso, A. Planes *et al.*, *Nat. Mater.* 9 (6), 478–481 (2010).
[3] C. Passamani, V.P. Nascimento, C. Larica *et al.*, *Journal of Alloys and Compounds* 509 (30) (2011).
[4] V. Laitinen, A. Salminen, K. Ullakko *J. Laser Appl.* 31 (2019).
[5] S.-K. Rittinghaus, H. Shokri, N. Shkodich *et al.*, *Addit. Manuf. Lett.* 7, 100159, (2023).

Invited Presentation

Dr. Laura H. Greene

Florida State University

United States

Planar Tunnel Spectroscopy of $CeCoIn_5$: Investigation of local-moment pairing

L.H. Greene[1,2], M. Irfan[1,2], R. Huber[1,2], N. Mashraqi[1,2], R.E. Baumbach[3]

[1]*National High Magnetic Field Laboratory, Florida State University*
[2]*Florida State University*
[3]*University of California, Santa Cruz*
Email: lhgreene@magnet.fsu.edu

Planar tunneling spectroscopy (PTS) measurements on the 115 heavy fermion superconductor $CeCoIn_5$ (T_c = 2.3 K) suggest the direct involvement of local moments in the Cooper pairing process. [1] Our high-quality, reproducible PTS data on junctions along the three major crystallographic orientations with AlO_x barriers consistent with the STM measurements [2,3] identifying preformed pairs persisting to $T_p \approx 5$ K. Further support of the existence of pre-formed pairs is reported using Shot noise spectroscopy. [4] Another interpretation is that the excess conductance arises from a hybridization-controlled pseudogap. [5]. Our PTS results at low temperature, either below T_c or below T_p, as a function of applied magnetic field reveal a field induced splitting or gap (FIG), that grows linearly up to the highest field measured, 18 T. That this splitting only occurs below T_p supports the pre-formed pair interpretation, noting that there is hybridization naturally occurring at these temperatures. To understand any barrier effect and the reproducibility of these features, we extend our PTS investigations with MgO as a tunnel barrie.

This work was supported by the NSF/DMR-2003405, NSF/DMR- 2128556, and the State of Florida.

References

[1] Shrestha *et al., Phys. Rev. B* 103, 224515 (2021).
[2] Ernst *et al., Phys. Stat. Sol. B* (2010).
[3] Y. Fasano *et al., Physica B* (2018).
[4] K. M. Mastiaans *et al., Science* 374 608 (2021).
[5] H. Jang *et al., Phys Rev B* 130, 076301 (2023).

Invited Presentation

Dr. Ivan Maggio-Aprile

University of Geneva

Switzerland

Vortex-core states, conductance modulations and Lifshitz transition revealed in Bi-2212 with Scanning Tunneling Spectroscopy

I. Maggio-Aprile, T. Singar, Ch. Renner

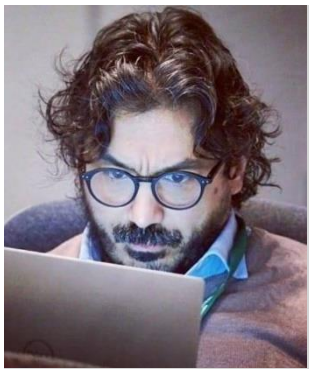
DQMP, University of Geneva, 24, Quai E-Ansermet,1211 Geneva 4, Switzerland
Email: ivan.maggio-aprile@unige.ch

The electronic structure of the Abrikosov vortices is one of the outstanding puzzles of high temperature superconductivity (HTS) [1]. For long, vortices explored with Scanning Tunneling Microscopy in HTS cuprates were systematically lacking the electronic signatures predicted by Wang and MacDonald for d-wave superconductors [2]. It is only recently that the zero-bias conductance peak expected from theory at the center of the flux lines was observed in heavily-overdoped $Bi_2Sr_2CaCu_2O_{8+\delta}$ (Bi-2212) single crystals [3]. However, other vortex cores measured in similar regimes still reveal the unusual electronic features reported previously, including dispersive periodic conductance modulations in the vortex halos and low energy subgap states. We present here how these electronic states and charge orders evolve in a broad doping range. At a doping level of $p \sim 0.21$, we find striking transformations in the electronic structure of the vortex halos : the checkerboard modulations vanish, and a pronounced zero-bias anomaly emerges. This abrupt change is consistent with a Lifshitz transition, which involves a significant reconstruction of the Fermi surface topology, and may be indicative of an underlying quantum critical point.

References

[1] I. Maggio-Aprile *et al.*, *Physica C* 615, 1354386 (2023).
[2] Y. Wang, A.H. MacDonald, *Physical Review B* 52, R3876 (1995).
[3] T. Gazdić, I. Maggio-Aprile, G. Gu *et al.*, *Physical Review X* 11, 031040 (2021).

Invited Presentation



Prof. Davide Peddis

University of Genova,

Italy

Interplay between intra- and interparticle effects in bi-magnetic core/shell nanoarchitectures

A. Omelyanchik[1,2], M. Vasilakaki[3], K. N. Trohidou[3], D. Peddis[1,2]

[1]*Department of Chemistry and Industrial Chemistry & INSTM RU, nM2-Lab, University of Genoa, 16146 Genoa, Italy*

[2]*Institute of Structure of Matter, National Research Council, nM2-Lab, Via Salaria km 29.300, Monterotondo Scalo, 00015 Rome, Italy*

[3]*Institute of Nanoscience and Nanotechnology, National Center for Scientific Research Demokritos, Athens 15310, Greece*

Email: davide.peddis@unige.it

Magnetic Nanoarchitecture exhibit distinctive and peculiar physical properties making them uniquely suitable for advanced technological and biomedical applications. Among various designs, bi-magnetic core/shell nanoarchitecture composed of spinel ferrites stand out due to their tunable magnetic responses arising from the interplay of intra- and interparticle effects [1, 2].

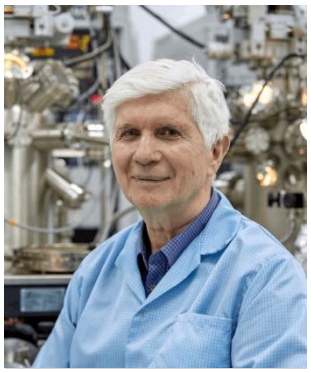
This talk focuses on the magnetic behavior of bi-magnetic core/shell nanoarchitectures, composed by cobalt ferrite ($CoFe_2O_4$, CFO) and nickel ferrite ($NiFe_2O_4$, NFO) in both direct (CFO/NFO) and inverse (NFO/CFO) configurations. Systematic variation of the shell thickness and particle architecture significantly affects magnetic properties (i.e., magnetic anisotropy, saturation magnetization, and magnetization dynamics). Observed effects cannot be fully described by simple additive models, pointing to a complex interaction between magnetic intraparticle (proximity effect) and interparticle interactions. Experimental insights obtained using remanent magnetization analyses (Δm-plot) and supported by Monte Carlo simulations allow us to unravel this intricate interplay, underscoring the importance of nanoscale architecture [1, 2].

Our findings emphasize the importance of nanoarchitecture in precisely tuning magnetic behaviors and suggest potential for designing materials with tunable magnetic properties. We also discuss several critical open questions: the mechanisms through which intraparticle and interparticle interactions influence each other; the distinct roles of dipolar and exchange interparticle interactions; the impact of core/shell nanoparticle architecture, including core and shell materials, layer dimensions, and shape; and how these interactions can be harnessed for designing materials with tailored magnetic properties. These examples highlight the broader possibilities awaiting discovery and optimization for applications in data storage, sensors, and biomedical devices.

References

[1] A. Omelyanchik, S. Villa, M. Vasilakaki *et al.*, *Nanoscale Adv.* 3, 6912 (2021).
[2] A. Omelyanchik, S. Villa, F. Locardi *et al.*, *Chem. Mater.* 36(16), (2024).

Invited Presentation



Prof. Vladimir Pudalov

P.N. Lebedev Physical Institute,

Russia

Superconductivity in Hydrides at Nearly Room Temperature

V.M. Pudalov, A.V. Sadakov

V.L. Ginzburg Center, P.N. Lebedev Physical Institute, Moscow, Russia
Email: pudalov@lebedev.ru

The discovery of superconductivity at megabar pressures in hydrogen sulfide (H3S), then in metal polyhydrides, starting with binary (LaH_{10}, etc.) and ending with ternary (including $(La,Y)H_{10}$, etc.), revolutionized the field of condensed matter physics. These discoveries not only set a record for the critical superconducting temperature, T_c=250-260K. More importantly, they demonstrate the capabilities of the electron-phonon pairing mechanism and refute a number of previously proposed limitations on the electron-phonon coupling constant. This talk reviews the major experimental findings in the field of hydride superconductivity [1-5], such as (i) isotope effect, (ii) temperature- and magnetic field resistivity dependences, (iii) upper critical field temperature dependence, (iv) the influence of magnetic and non-magnetic impurities on T_c, and (v) magnetic field shielding. The available experimental data for all hydrides provides evidence for the singlet-type pairing, electron-phonon pairing mechanism, and strong coupling regime. The normal state properties of hydrides were found to be non-trivial and quite different from the conventional Fermi liquid behavior.

References

[1] D.V. Semenok, I.A. Troyan, A.V. Sadakov *et al.*, *Adv. Materials* 34, 2204038, (2022).
[2] I.A. Troyan, D.V. Semenok, A.G. Ivanova *et al.*, *Adv. Science* 10 (30), 2303622 (2023).
[3] D.V. Semenok, I.A. Troyan, A.G. Ivanova *et al.*, *Materials Today* 48, 18-28 (2021).
[4] I.A. Troyan, D.V. Semenok, A.V. Sadakov *et al.*, *ZhETF* 166, 74, (2024).
[5] D.V. Semenok, A.V. Sadakov, D. Zhou *et al.*, *Mater. Today Phys.* 49, 101595, (2024).

Invited Presentation

Prof. Andrei Rogalev

The European Synchrotron Radiation Facility

France

X-ray Magnetic Circular Dichroism as a Probe of Emergent Magnetic States in Unconventional Superconductors

A. Rogalev, F. Wilhelm

ESRF- The European Synchrotron, Grenoble, France
Email: rogalev@esrf.fr

Discovery of X-ray Magnetic Circular Dichroism (XMCD) over 35 years ago marked a major breakthrough in magnetism research, enabling investigations that were previously unattainable. Unlike conventional magneto-optical techniques, XMCD offers the unique capability of quantitative determining spin and orbital magnetic moments with element-specificity and orbital-selectivity, inherent to X-ray absorption spectroscopy.

The availability of high-brilliance, circularly polarized X-rays at third- and fourth-generation synchrotron sources has made XMCD widely accessible. In parallel, the development of sophisticated experimental stations has expanded its applicability, enabling studies under extreme conditions such as high magnetic fields, low temperatures, and high pressure.

One particularly intriguing domain where XMCD has proven invaluable is the study of the coexistence of ferromagnetism and superconductivity - a quantum conundrum at the forefront of condensed matter physics. Three examples are selected to illustrate how XMCD contributes to advancing our understanding of emergent states at the intersection of these competing orders:

1. Plutonium paramagnetism in the vortex phase of the exotic superconductor $PuCoGa_5$[1] where XMCD reveals the persistence of magnetic moments in the superconducting state.
2. The intrinsically coexisting ferromagnetic superconductor UCoGe, where XMCD provides direct access to the uranium 5f spin and orbital moments, offering insight into the coupling between magnetism and unconventional superconductivity [2].

The dual nature of uranium 5f electrons in the heavy-fermion superconductor UTe_2[3], highlighting the simultaneous itinerant and localized character of 5f states.

References

[1] N. Magnani, R. Eloirdi, F. Wilhelm *et al.*, *Phys. Rev. Lett.* 119, 157204 (2017).
[2] M. Taupin, J.-P. Sanchez, J.-P. Brison *et al.*, *Phys Rev. B* 92, 035124 (2015).
[3] F. Wilhelm, J.-P. Sanchez, D. Braithwaite *et al.*, *Comm. Physics* 6, 96 (2023).

Invited Presentation

Dr. Anna Semisalova

University of Duisburg-Essen

Germany

Correlating enhanced spin pumping efficiency and atomic dislocation densities at Fe/Rh bilayer interfaces

A. Semisalova

Faculty of Physics and Center of Nanointegration (CENIDE), University of Duisburg-Essen, 47057 Duisburg, Germany
Email: Anna.Semisalova@uni-due.de

Spintronic devices rely on the efficient generation, transport and detection of spin currents, making the study of spin transport phenomena at ferromagnet/nonmagnet (FM/NM) interfaces essential. Spin accumulation for use in spintronic devices is a highly interface-dependent effect. A key aspect influencing spin transport is the interface structure, which directly affects the spin mixing conductance and hence the efficiency of spin pumping. Understanding this will allow the fine-tuning of existing devices that exploit the spin degree of freedom. In this study we investigate the interfacial properties of the magnetic bilayer Fe/Rh. We report the results of a comprehensive study of the interface structure, dislocation density and magnetic structure of differently prepared Fe/Rh bilayer interfaces (Fig. 1) and determine the evolution of the Rh magnetic moment at the interface. These results will be discussed in relation to the enhanced spin pumping efficiency approaching the values of the better known Fe/Pt and Fe/Pd interfaces [1]. We demonstrate that the knowledge of the atomically resolved interface strain and arrangement is needed for a quantitative understanding of spin pumping at interfaces and efficient spin-to-charge conversion.

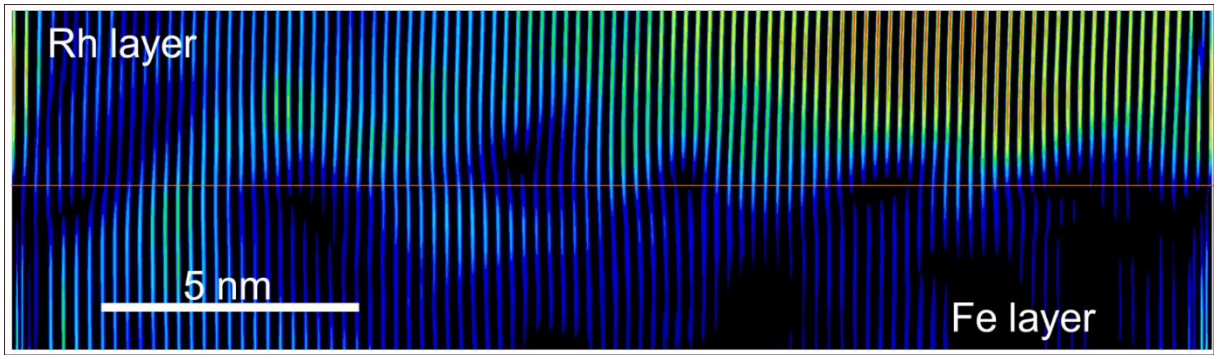


Fig. 1. FFT filtered STEM image of the Fe/Rh interface, only the Rh[0±20] and Fe[0±1 ± 1] diffraction peaks were used for iFFT filtering. The horizontal orange line is a guide to the eye indicating the position of the interface. Each vertical line represents rows of atomic columns. The text-book-like bending of these rows reveals edge dislocations (dark areas of missing color information), which allows the Rh to relax at the Fe surface. The observed dislocation density matches the one expected from the lattice mismatch of Rh and Fe.

This work was supported by the Deutsche Forschungsgemeinschaft (DFG) within CRC/TRR270 (Project ID 405553726) and SE 2853/1/1, and was performed in collaboration with M. Farle, N. van der Sand, J. Wiemeler (University of Duisburg-Essen), H. Ali, A. Kovacs (ER-C, Forschungszentrum Jülich) and F. Wilhelm, A. Rogalev (ESRF).

References

[1] J. Wiemeler, A.C. Aktas, M.Farle *et al.*, *Applied Physics Letters* 124, 212404 (2024).

Invited Presentation

Dr. Natalia Shkodich

University of Duisburg-Essen

Germany

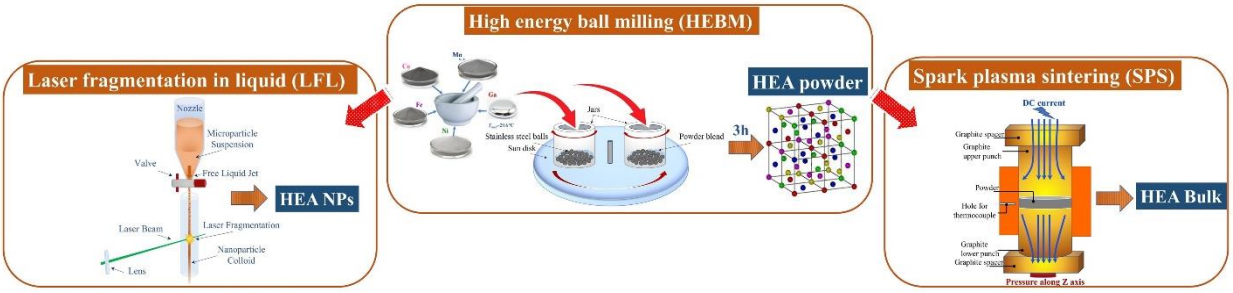
Room-temperature ferromagnetism in nanocrystalline CoMnFeNiGa high entropy alloys: Across different length scales

N.F. Shkodich

Faculty of Physics and Center of Nanointegration (CENIDE), University of Duisburg-Essen, 47057 Duisburg, Germany

Email: Natalia.shkodich@uni-due.de

High entropy alloys (HEAs) have garnered significant attention in recent years due to their unique synergy of structural, physical, chemical, and magnetic properties, which arise from their multiprincipal element design [1]. Typically composed of five or more principal elements in near-equiatomic ratios, HEAs exhibit significant chemical disorder that strongly influences the configurational entropy (ΔS_{conf}), Gibbs free energy, phase selection and stability. The high ΔS_{conf} favors simple solid solution phases and suppresses intermetallics, enabling unique property combinations beyond conventional alloys. Magnetic HEAs typically composed of *3d* transition metals, with Fe, Co, and Ni contributing to strong magnetization (*M*), while antiferromagnetic Mn reduces the net *M* due to competing interactions. Further addition of *sp* elements like Al, Ge, or Ga can significantly alter magnetic behavior and enhance ferromagnetic order, improving thermal stability, leading to the formation of a BCC structure. The influence of Ga on magnetic ordering has only been studied in bulk samples produced via conventional multistep melting, which often yields compositional inhomogeneity, coarse grains, and poor compositional control due to the low melting point of Ga (T_m = 302.9 K). Magnetic complexity in HEAs stems from locally varying exchange interactions, influenced by the processing route, morphology, and microstructure—even at identical compositions. In this talk, I will present our recent advances in designing nanocrystalline CoMnFeNiGa HEAs across different scales—from bulk to nanoparticles—demonstrating the versatility of combining HEBM [2], SPS, and LFL approaches (see schematics below).



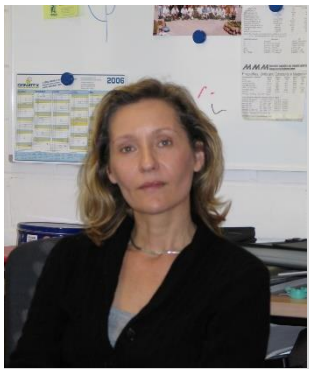
This work was supported by the Deutsche Forschungsgemeinschaft (DFG) within CRC/TRR270 (Project ID 405553726), and FA209/27-1 and benefitted from the collaborations with the groups of M. Farle, B. Gault, S. S. Barcikowski.

References

[1] L. Han, Z. Rao, I.R. Souza *et al.*, *Adv. Mater*. 33, 2102139 (2021).

[2] N.F. Shkodich, T. Smoliarova, H. Ali *et al.*, *Acta Mater*. 284, 120569 (2025).

Invited Presentation



Dr. Marina Spasova

University of Duisburg-Essen

Germany

Tuneable magnetic remanence of nanoscale antiferromagnetically coupled Fe_3O_4 halves in a silica shell

M. Spasova

Faculty of Physics and Center for Nanointegration (CENIDE), University of Duisburg-Essen, 47057 Duisburg, Germany

Email: marina.spasova@uni-due.de

Synthetic antiferromagnets (SAFs) [1] consist of magnetic layers separated by diamagnetic spacers, leading to ferromagnetic or antiferromagnetic coupling and enabling predictable responses to weak magnetic fields for applications in magnetomechanical therapy [2] and magnetic hyperthermia [4].

Here, we prepared nanoparticles consisting of ferrimagnetic Fe_3O_4 half-shells whose magnetizations can be non-invasively set to an antiparallel coupling (zero stray field) or ferromagnetic coupling (maximum stray field). The hybrid particle is enclosed by a diamagnetic SiO2 coating protecting them against the environment and allowing functionalization for specific drug targeting. By micromagnetic simulations we demonstrate the feasibility to non-invasively tune the magnetic remanence of these synthetic ellipsoidal magnetic particles from zero for the antiferromagnetic coupled state to a maximum magneization for the ferromagnetic coupled state.

Magnetic state of a single nanoellipsoid was visualized by means of electron holography as well as scanning transmission X-ray microscopy.

The experimental studies confirm the prediction of micromagnetic simulation and show that the Fe_3O_4 halves can be stabilized in either ferromagnetic or antiferromagnetic orientations by external magnetic field pulses, offering unique biomedical advantages: a strong net moment for robust manipulation and imaging (ferromagnetic) or minimal stray fields and enhanced biocompatibility (antiferromagnetic). Under an applied ac- field, both configurations allow controlled torque mechanical actuation and localized heating for magnetic hyperthermia.

References

[1] P. Grünberg, *Phys. Rev. Lett.* 57, 2442 (1986).
[2] T. Courcier, *Appl. Phys. Lett.* 99, 093107 (2011).
[3] G. Varvaro, *Nanoscale* 11, 1891 (2019).

Abstracts of Oral Presentations

Oral Presentation

Normal Zone Propagation and Thermal Stability in Multi-Tape Superconducting Cables for High-Field Applications

D.A. Aleksandrov, I.V. Martirosian, S.V. Pokrovskii, A.Y. Malyavina

National Research Nuclear University MEPhI (Moscow Engineering Physics Institute), Moscow, Russia
Email: cfrfcfrfdima123@gmail.com

The performance and reliability of superconducting cables are critical for their application in high-field magnets, power transmission systems, and fusion energy devices [1]. A key challenge in these systems is understanding and controlling normal zone propagation (NZP) [2].

This study aims to characterize NZP behavior in multi-tape superconducting cables, focusing on the influence of geometrical configuration, thermal coupling, and current-sharing mechanisms. Special attention is given to how different arrangements affect quench propagation and the overall stability of the cable. By examining key parameters such as NZP velocity, heat dissipation, and transverse heat transfer, the study seeks to provide insights that contribute to the development of resilient superconducting cables for high-current and high-field applications.

The results reveal significant differences in NZP behavior depending on the cable configuration and material properties. The influence of tape arrangement, thermal properties, and current distribution on NZP velocity is analyzed. It is found that multi-tape configurations, depending on their geometrical arrangement, significantly modify NZP dynamics compared to single-tape systems. The presence of multiple current-sharing pathways introduces additional mechanisms for stabilizing the superconducting state, while also leading to variations in heat dissipation patterns. Additionally, the effects of substrate materials, insulation layers, and cooling conditions on NZP behavior are examined. The results indicate that enhanced transverse heat transfer reduces the risk of quenching. These findings are essential for optimizing the design of multi-tape superconducting cables for high-current, high-field applications, where quench resilience is a primary concern.

The work was carried out under the State Assignment (project FSWU-2025-0008) with the support of the Ministry of Science and Higher Education of the Russian Federation.

References

[1] H. Maeda, Y. Yanagisawa, *IEEE Trans. Appl. Supercond* 24(3), 1 (2014).
[2] M. Marchevsky, *Instruments* 5(3), 27 (2021).

Oral Presentation

On methods of direct measurement of magnetocaloric effect in the temperature range of 4-400 K under AC magnetic fields

A. M. Aliev, A.A. Mukhuchev

Amirkhanov Institute of Physics of Dagestan Federal Research Centre of RAS, 367003, M.Yaragskogo 94, Makhachkala, Russia
Email: lowtemp@mail.ru

The magnitude of the magnetocaloric effect (isothermal change in entropy ΔS_M and/or adiabatic change in temperature ΔT_{ad}) can be estimated by indirect methods, or the ΔT_{ad} value can be measured by direct methods. In recent years, methods for measuring ΔT_{ad} in alternating magnetic fields using Lock-in detection technique have been increasingly used. Significant advantages of this method are high temperature sensitivity, the possibility of measuring in weak fields, and the possibility of measuring the MCE in small-sized samples. But such methods also have significant disadvantages and limitations. For example, alternating magnetic fields induce an EMF in a thermocouple, which affects the measured MCE value. If in the area of room temperatures or even in the area of nitrogen temperatures these signals can be dealt with by twisting the thermocouple and extension wires bifilarly, then in the area of helium temperatures this method does not give the desired result, since against the background of decreasing sensitivity of the thermocouple with decreasing temperature, even a small induced EMF can lead to significant changes in the measured signal. In the area of helium temperatures other problems can arise. For example, the use of external alternating magnetic fields can lead to a significant change in the temperature of the entire system (cryostat + sample) due to Foucault currents in the copper screen of the cryogen free helium cryostat. The use of linear actuators for input and output of the temperature insert with the sample can also lead to the impossibility of temperature stabilization. Therefore, it is necessary to look for new methods of periodic action of the magnetic field on the sample.

In this paper, various methods of creating alternating magnetic fields acting on the material under study are considered, including using superconductors. The advantages and disadvantages of each method are discussed. The results of direct measurements of adiabatic temperature changes in materials with different temperatures of magnetic phase transitions, including in the region of helium temperatures, using different methods are presented.

The study was supported by a grant from the Russian Science Foundation (No. 24-12-00362).

Oral Presentation

Electrically Controlled Crossed Andreev Reflection in Two-Dimensional Antiferromagnets

A. Qaiumzadeh

Center for Quantum Spintronics (QuSpin), Norwegian University of Science and Technology (NTNU), NO-7491 Trondheim, Norway
Email: alireza.qaiumzadeh@ntnu.no

In this talk, I first review our recent theoretical works on antiferromagnetic-superconductor junctions in both clean and dirty limits [1-4]. Next, I show how these junctions can be used to generate a perfect crossed Andreev reflection (CAR) and hence a novel Cooper pair splitter to generate entangled pairs.

In this talk, I first review our recent theoretical works on antiferromagnetic-superconductor junctions in both clean and dirty limits [1-4]. Next, I show how these junctions can be used to generate a perfect crossed Andreev reflection (CAR) and hence a novel Cooper pair splitter to generate entangled pairs.

We report generic and tunable CAR in a superconductor sandwiched between two antiferromagnetic layers. We consider recent examples of two-dimensional magnets with hexagonal lattices, where gate voltages control the carrier type and density, and predict a robust signature of perfect CAR in the nonlocal differential conductance with one electron-doped and one hole-doped antiferromagnetic lead. The magnetic field-free and spin-degenerate CAR signal is electrically controlled and visible over a large voltage range, showing promise for solid-state quantum entanglement applications.

References

[1] M.F. Jakobsen, A. Brataas, A. Qaiumzadeh, *Phys. Rev. Lett.* 127, 017701 (2021).
[2] M. F. Jakobsen, K. B. Naess, P. Dutta *et al.*, *Phys. Rev. B* 102, 140504(R) (2020).
[3] E. H. Fyhn, A. Brataas, A. Qaiumzadeh *et al.*, *Phys. Rev. Lett.* 131, 076001 (2023).
[4] E. H. Fyhn, A. Brataas, A. Qaiumzadeh *et al.*, *Phys. Rev. B* 107, 174503 (2023).

Oral Presentation

From superconductivity to non-superconductivity in LiPdH: a first principle approach

Z. Alizadeh[1], Yue-Wen Fang[2], I. Errea[2,3], M. R. Mohammadizadeh[1]

[1]*Superconductivity Research Laboratory (SRL), Department of Physics, University of Tehran, North Kargar Av., P.O. Box 14395-547, Tehran, Iran*

[2]*Centro de Física de Materiales (CFM-MPC), CSIC-UPV/EHU, Manuel de Lardizabal Pasealekua 5, 20018 Donostia/San Sebastián, Spain*

[3]*Fisika Aplikatua Saila, Gipuzkoako Ingeniaritza Eskola, University of the Basque Country (UPV/EHU), Europa Plaza 1, 20018 Donostia/San Sebastián, Spain*

Email: Alizade.zahra@ut.ac.ir

The layered structure of LiPdH was theoretically suggested to be a superconductor as a result of its larger electron-phonon coupling constant compared to that of PdH. However, the experimental results reported contrary findings, with no trace of superconductivity. We study the electronic, vibrational, and superconducting properties of the ambient pressure tetragonal phase of LiPdH (P4=mmm) within first principles density functional theory methods, both in the harmonic and anharmonic approximations for the lattice dynamics. It is concluded that it exhibits an extremely low superconducting transition temperature, below 0.1 K. High-pressure crystal structure prediction calculations indicate that no structural transition is expected to occur under pressure up to 100 GPa in LiPdH. Our theoretical calculations demonstrate that increasing pressure reduces the density of states at the Fermi surface and consequently weakens electron-phonon interactions, leading to a further suppression of the superconducting critical temperature.

*	This work (Harmonic)	This work (Anharmonic)	This work (within the McMillan-Hopfield equation)	Prev. Theo. Work [1]	Prev. Exp. Work [2,3]
λ_H	0.13	0.09	0.17	0.20	-
λ_{Li}	0.05	0.06	0.2	0.42	-
λ_{Pd}	0.07	0.08	0.06	0.07	-
λ_{Tot}	0.24	0.23	0.43	0.7	-
$T_c\ (K)$	0.1	0.06	<10	>10	<2

Table I. Calculated λ and T_c using the Allen-Dynes-modified McMillan formula with the Coulomb pseudopotential parameter μ^* of 0.1 for comparison with the reported values for LiPdH.

References

[1] D. Singh, R.E. Cohen, D.A. Papaconstantopoulos. *Physical Review B*, 41(1):861 (1990).
[2] D. Noréus, Ö. Rapp, *Physical Review B*, 42(16):10730 (1990).
[3] W. Liu, E. Wang, G. Chen *et al.*, *Philosophical Magazine*, 998(7):623–631 (2017).

Oral Presentation

Recent advances in biomedical applications of magnetocaloric materials: case of FeRh

A. Amirov

National University of Science and Technology MISIS, 119049, Leninskiy Prospekt 4, Moscow, Russia
Email: amiroff_a@mail.ru

The potential applications of magnetocaloric materials extend beyond the traditional topics in which they have been considered, such as energy and solid-state cooling. The idea of using the magnetocaloric effect for biomedical purposes is a relatively new trend and is aimed at exploring ways to make practical use of the thermal effect resulting from the application of a magnetic field. The potential uses of magnetocaloric materials in biomedicine, ranging from magnetic hyperthermia to "smart" implant devices for drug delivery, have been explored in various studies [1-2].

Among magnetocaloric materials, FeRh alloys and their composites represent the most promising candidates for biomedical applications due to their record values of MCE in the range of physiological temperatures, and good biocompatibility. Recent trends in research of FeRh alloys for potential biomedical applications are devoted to the development of fabrication technology in micro(nano) scale with ordered to the CsCl-type structure.

The report presents the recent research results on FeRh alloys and composites based on them for various biomedical applications: magnetically controlled drug release, microfluidics, and magnetic resonance imaging. In particularly, the ability to control the physical properties of the thermoresponsive polymer PNIPAM by the magnetocaloric effect was demonstrated by in situ experiments on the PNIPAM/FeRh smart composite. The concept of drug release from a smart composite under the application of 3 T magnetic field was demonstrated using doxorubicin as a model drug. The resulting release of the drug under the application of a magnetic field was detected using a combination of IV-VIS and Raman spectroscopy. In vitro, studies have demonstrated a high degree of PNIPAM/FeRh scaffold biocompatibility for primary mouse embryonic fibro-blast (PMEF) cell culture. PMEFs effectively adhered to the PNIPAM/FeRh scaffold surface and showed high metabolic and proliferative activity for 72 hours after seeding [3].

This work was supported by the Russian Science Foundation (project no. 24-19-00782, https://rscf.ru/en/project/24-19-00782/).

References

[1] A. Tishin, J. Rochev, A. Gorelov, patent US 9,017,713, B2. – USA, 2015.
[2] A.M. Tishin, Y.I. Spichkin, V.I. Zverev *et al.*, *International Journal of Refrigeration* 68, 177 (2016).
[3] A. Amirov *et.al.*, *ACS Appl. Eng. Mater.* 3(2), 410 (2025).

Oral Presentation

Electron-phonon interaction and spin triplet superconductivity in layered square lattice bilayers

V. Apinyan[1], M. Sahakyan[1,2]

[1]*Institute of Low Temperature and Structure Research, ul. Okólna 2, 50-422, Wrocław, Poland*
Division of Condensed Matter Theory
[2]*Institute of Low Temperature and Structure Research, ul. Okólna 2, 50-422, Wrocław, Poland*
Division of Magnetic Research
Email: v.apinyan@intibs.pl

The question of whether electron-phonon coupling leads to superconducting pairing has been a topic of considerable debate in condensed matter physics. Various t-J models have been proposed to explain the phenomenon of high temperature superconductivity without addressing the electron-phonon interaction mechanisms. In this study, we referred to the layered square-lattice bilayer system and consider the problem of possible superconductivity in such a prototype system by considering the intralayer electron-phonon coupling mechanism [1]. The Hamiltonian in our model consists of two parts: the non-interacting part, that includes the free phonon Hamiltonian, nearest-neighbors and next-nearest neighbors hopping terms, and interlayer hopping term; and an interacting part encompassing local intralayer and interlayer Hubbard interactions, intralayer electron-phonon coupling, and coupling with an external interlayer electric field potential. Our starting point is the discretization of elementary single particle excitations as a product of two simultaneous quasiparticle excitations with the same energy. Additionally, we consider possible excitonic states between the layers of the metallic bilayer. By applying functional field integration techniques, we derive the effective electron-phonon interaction action and obtain a set of self-consistent equations for the spin-triplet superconducting gap, excitonic order parameter, chemical potential, and average charge-density imbalance between the layers. We numerically solve this system of equations by using finite difference approximation techniques employing the Newton's fast convergence algorithm [2]. The temperature dependence of aforementioned physical quantities is investigated across different electron doping regimes. Furthermore, we plot the superconducting critical phase transition diagram as a function of electron doping. In our case, the undoped system corresponds to the Anderson localization limit with fully occupied bands. Moreover, the superconducting gap is plotted for different limits of the electron-phonon interaction parameter within the half-filling regime. We demonstrate the coexistence of superconducting and excitonic states over a wide range of temperatures and doping levels. At the fixed temperature, we calculate numerically the excitonic and superconducting order parameters as a function of electron and hole doping in the system. Notably, at hole doping the excitonic order parameter enhances, whereas for electron doping, the superconducting order parameter is much larger and persists over a broader interval of doping.

We also show that for both electron and hole doping, charge imbalance is maximized at the half-filling regime, while charge neutrality is achieved in the Anderson localization limit and at very high doping levels. In the limit of low electron-phonon coupling, the superconducting transition temperature is on order of $T_C = 25.76\,\mathrm{K}$, while in the strong coupling limit, we obtain a transition temperature as high as room temperature, on the order of $T_C = 287.3\,\mathrm{K}$. Moreover, we identify a range of values for the next-nearest neighbor hopping parameter, within which the superconducting

gap is sustained. The proposed model may serve as a new mechanism for superconductivity in high-T_C cuprate superconductors due to intralayer electron-phonon coupling.

References

[1] V. Apinyan, M. Sahakyan, *Eur. Phys. J.B* 97, 75 *(2024).*

[2] M.J.D. Powell, *Numerical Methods for Nonlinear Algebraic Equations,* 87-161 (1970).

Oral Presentation

Synthesis of CoMnFeNi high entropy alloy doped with In, Ga and Sn for permanent magnet applications

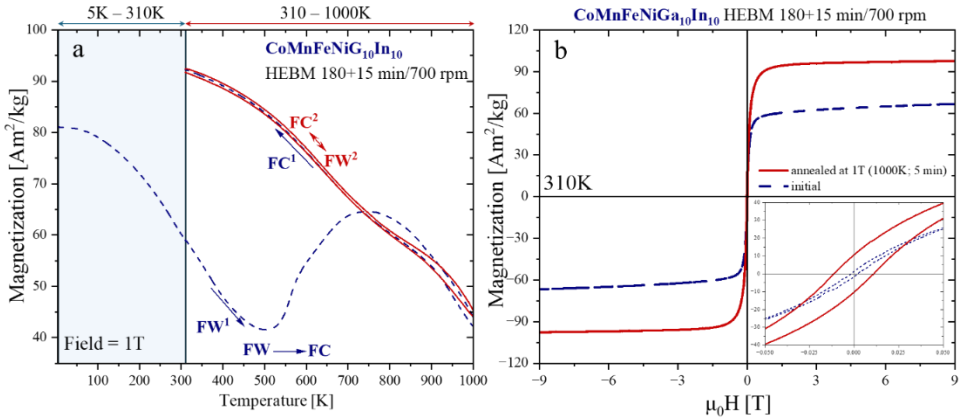
A.L.M. Feitosa[1], T. Smoliarova[2], N. Shkodich[2], B. Gault[1], M. Farle[2], D. Raabe[1]

[1]*Max-Planck-Institute für Nachhaltige Materialien, Max-Planck-Str. 1, 40237 Düsseldorf*
[2]*Fakultät für Physik: Universität Duisburg-Essen, Lotharstr. 1, 47057 Duisburg*
Email: l.feitosa@mpie.de

High-entropy alloys (HEAs) are mixtures of five or more elements in equiatomic concentrations departing from the conventional design of metallic alloys, while exhibiting efficient properties [1], recently including promising magnetic properties [2]. Climate change and the global energy transition require replacing materials across industries, e.g., permanent magnets less reliant on rare-earth elements. So, HEAs emerge as a possibility.

Magnetic properties depend on structure and composition interaction, influenced by the processing method. High-energy ball milling (HEBM) and spark plasma sintering were combined to synthesize HEAs with controlled microstructures targeting better magnetic properties [3]. We will show how Ga, In and Sn influence the magnetic behavior of CoMnFeNi HEA in correlation to experimentally determined changes of microstructure and locally varying nanoscale composition.

The ferromagnetic $CoMnFeNiGa_{10}In_{10}$ and $CoMnFeNi(GaInSn)_{20}$ HEA powders synthesized by HEBM exhibit a saturation magnetization M_S = 41-61.3 Am^2/kg and coercivity H_C = 1.6-3.5 kA/m, respectively. Field annealing at 1 T (1000 K, 5 min) leads to a drastic enhancement of M_S up to 99.5 Am^2/kg and H_C by 5 times (8.8 kA/m). For both compositions the Curie temperature exceeds 1000K (Figure).



This project is supported by CRC/TRR270 A04, Z01 (Proj. ID 405553726) and the AvH Foundation through the Henriette Herz Scouting programme.

References

[1] Z. Li, K.G. Pradeep, *Nature* 534, 227–230 (2016).
[2] L. Han, F. Maccari, *Nature* 608, 310–316 (2022).
[3] N.F. Shkodich, T. Smoliarova, *Acta Mater.* 284, 120569 (2025).

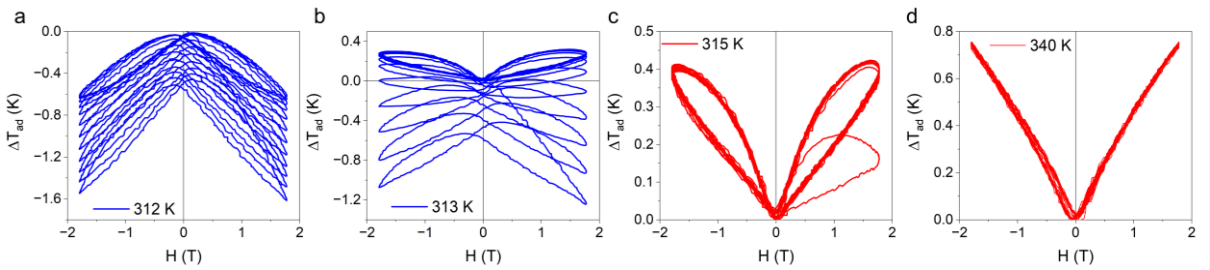
Oral Presentation

Inverse-Direct Crossover Adiabatic Temperature Change in Cyclic Magnetic Fields in $Ni_{36.5}Co_{13.5}Mn_{35}Ti_{15}$ Alloy Near the Martensite-Austenite Phase Transition

A.G. Gamzatov[1,2], A.T. Kadirbardeev[1,2], A.M. Aliev[1], K. Qiao[3]

[1]*Amirkhanov Institute of Physics, DFRC, RAS, 367003, Makhachkala, Russia*
[2]*Chelyabinsk State University, 454001, Chelyabinsk, Russia*
[3]*School of Materials Science and Engineering, University of Science and Technology Beijing, Beijing, 100083, China*
Email: gamzatov_adler@mail.ru; gamzatov.ag@gmail.com

In recent years, new interest has been aroused by Heusler alloys consisting entirely of transition metals (d-d alloys or "all-d metal"), which are less brittle and more plastic, ensuring their mechanical stability under the dynamic influence of external fields; in addition, giant values of MCE have been discovered for them close to the martensite-austenite phase transition [1]. This paper presents the results of direct measurements of the adiabatic temperature change (ΔT_{ad}) in the $Ni_{36.5}Co_{13.5}Mn_{35}Ti_{15}$ Heusler alloy in cyclic magnetic fields up to 8 T. In a magnetic field of 1.8 T, a direct MCE was detected near T_C=340 K with a value of ΔT_{ad}=0.75 K and an inverse MCE at T=313 K with a value of ΔT_{ad}=-1.47 K with a single turn on of the magnetic field. The results of direct measurements of the MCE in a cyclic magnetic field of 1.8 T with a frequency of 0.2 Hz at different temperatures (312, 313, 315 and 340 K) for 20 on/off cycles of the magnetic field are shown in Fig. 1(a-d). When a magnetic field is cyclically applied near the martensite-austenite phase transition, an inverse-direct magnetocaloric crossover effect is observed (see Fig. 1(b)), which is associated with the kinetics of the martensite phase transition [2]. The number of magnetic field on/off cycles required to observe the inverse-direct transition in the dT behavior depends on both the proximity of the temperature being investigated to the austenite onset temperature and the magnitude of the magnetic field.



The study was supported by the Russian Science Foundation grant No. 25-12-20024, https://rscf.ru/en/project/ 25-12-20024/.

References

[1] B. Beckmann *et al.*, *Acta Materialia*, 282, 120460 (2025).
[2] A. G. Gamzatov *et al.*, *Appl. Phys. Lett.* 113, 172406 (2018).

Oral Presentation

Magnetic hyperthermia effect and equilibrium susceptibility in core-shell Fe-Fe_3C nanoparticles

H. Gyulasaryan[1], A. Sargsyan[1], R. Morgunov[2], M. Farle[3], M. Spasova[3], A. Mukasyan[1], A. Manukyan[1]

[1]*Institute for Physical Research, National Academy of Sciences of Armenia, Ashtarak-2, 0203, Republic of Armenia*
[2]*Federal Research Center of Problems of Chemical Physics and Medicinal Chemistry RAS, Chernogolovka, 142432 Russia*
[3]*Faculty of Physics and Center of Nanointegration (CENIDE), University of Duisburg-Essen, Duisburg, 47057, Germany*
Email: gharut1989@gmail.com

Magnetic nanoparticles (MNPs) are widely investigated for biomedical applications, particularly in magnetic hyperthermia where localized heating under an alternating magnetic field (AMF) can be applied for cancer therapy [1,2]. The heating efficiency strongly depends on particle size, structure, and magnetic properties. Composite nanostructures Fe–Fe_3C core–shell magnetic nanoparticles in carbon matrix exhibit tunable magnetic properties, making them suitable candidates for magnetic particle hyperthermia.

The aim of this study is to investigate the structural, magnetic, and hyperthermia performance of Fe–Fe_3C core–shell nanoparticles synthesized by solid-state pyrolysis of ferrocene and to correlate experimental heating efficiency with theoretical models.

The resulting nanoparticles (~20 nm) have a Fe: Fe_3C ratio of ≈2:1, consistent with their room-temperature saturation magnetization. Specific loss power (SLP) was systematically studied as a function of nanoparticle concentration, AMF amplitude, and frequency. Using Rosensweig theory, a relaxation time of $\tau = 2.9 \times 10^{-7}$ s was estimated from field-dependent SLP fits. Equilibrium susceptibility was obtained by two methods: $\chi_0 = 0.22 \pm 0.03$ from frequency-dependent SLP and $\chi_0 = 0.33 \pm 0.04$ from field-dependent SLP, both matching the experimental $\chi_0 = 0.27 \pm 0.03$ within error. A COMSOL-based numerical model reproduced the experimental concentration-dependent SLP, confirming the reliability of the approach.

These results demonstrate that Fe–Fe_3C core–shell nanoparticles synthesized by ferrocene pyrolysis combine structural stability with efficient heating under clinically safe AMF conditions, offering strong potential for biomedical hyperthermia applications.

References

[1] R. Hergt, S. Dutz, R. Müller, M. Zeisberger, *J. Phys.: Condens. Matter* 18, S2919–S2934 (2006).
[2] C.S.S.R. Kumar, F. Mohammad, *Advanced Drug Delivery Reviews* 63, 789–808 (2011).

Oral Presentation

Design and engineering of Iron-Carbon nanocomposites

D. Hambardzumyan[1], H. Gyulasaryan[1], M. Spasova[2], M. Farle[2], A. Mukasyan[1], A. Manukyan[1]

[1]*The Institute for Physical Research (IPR) NAS RA: Ashtarak-2, 0204, Ashtarak, Armenia*
[2]*Faculty of Physics and Center of Nanointegration (CENIDE), University of Duisburg-Essen, Germany*
Email: hambardzumyan.374@gmail.com

Magnetic nanoparticles (MNPs) are currently the focus of extensive research, thanks to their unique properties [1]. MNPs hold great potential for a wide range of applications in both technology and biomedicine [2]. One of the important applications of magnetic nanoparticles in the field of biomedicine is magnetic particle hyperthermia [3].

Magnetic nanoparticles (MNPs) of different compositions are currently examined as enhanced-performance hyperthermia agents. Among them Fe-based nanocomposites due to their biocompatibility and tunable magnetic properties are promising materials in cancer theragnostic [4]. Encapsulating Fe-based nanoparticles within various materials, such as precious metals, surfactants, polymers, silica, or carbon, has shown promise in preventing aggregation.

Carbon, in particular, is a favorable choice due to its thermal/chemical stability and biocompatibility [5]. However, there are limitations related to the biomedical application of carbone nanotubes [6] and necessity to control amount of carbone to reach optimum magnetic properties of MNPs [7].

In this work, to avoid formation of carbon nanotubes, magnetic iron-cementite (Fe-Fe_3C) nanoparticles in a carbon matrix were synthesized via novel two-stage solid-phase pyrolysis of ferrocene ($FeC_{10}H_{10}$). In the first stage, pyrolysis was carried out in a closed quartz ampoule at 700°C for 5 min, and in the second stage, the resulting material was heated at 850°C for 45 min.

To control the amount of carbon the fabricated MNPs were additionally treated in a CO_2 environment at 780°C for 5 min, which allowed effectively remove an excess of carbon ballast that does not cover the metal nanoparticles. It has been demonstrated that the reaction between carbon and CO_2 can be used as a tunable method to control the carbon content in a nanocomposite matrix without significant oxidation of the Fe core. Thus obtained MNPs possess the enhanced hypothermic performance.

References

[1] B. Rezaei, P. Yari, S. Sanders *et al.*, *Small*, e2304848 (2023).
[2] R. Singh, D. Yadav, P. Ingole *et al.*, *Biomaterials advances*, 163, 213948 (2024).
[3] M. Szwed, A. Marczak *Cancers*, 16 (2024).
[4] S. Zhao, X. Yu, Y.Qian *et al.*, *Theranostics*, 10, 6278 - 6309 (2020).
[5] S. Akhmedov, S. Afanasyev, M. Trusova *et al.*, *Biomedicines*, 9 (2021).
[6] S. Prajapati, A. Malaiya, P. Kesharwani *et al.*, *Drug and Chemical Toxicology*, 45, 435 - 450 (2020).
[7] H. Gyulasaryan, L. Avakyan, A. Emelyanov *et al.*, *JMMM*, 169503 (2022).

Oral Presentation

Topological materials exhibiting surface and bulk superconductivity

M. Kargarian

Department of physics, Sharif University of Technology, Tehran, Iran
Email: kargarian@sharif.edu

Topological superconductors pave the way for realizing Majorana bound states—the cornerstone of robust, topologically protected qubits and quantum computing [1]. Despite significant theoretical breakthroughs in recent years, identifying suitable materials remains an elusive challenge. Although early proposals to develop topological superconductors via semiconductor–superconductor heterostructures have shown experimental promise [2], the quest to discover materials with intrinsic topological pairings is even more intriguing. In this talk, I examine several low-temperature superconducting materials that may harbor such exotic pairings. Specifically, our findings reveal that superconductivity is confined exclusively to the surface of the Dirac nodal semimetal $ZrAs_2$ [3]. Furthermore, I discuss the bulk superconductivity in the Kramers-Weyl semimetal RhGe [4] and the infinite-layer nickelate compound $LaNiO_2$ [5] with pairings that could be topologically nontrivial.[1]

[1]*This talk is based on the results that have been published or are under review in journals. Please see Refs. [3,4,5]. I would like to thank Microsoft's Copilot for slightly refining the original draft.*

References

[1] C. Nayak, S. H. Simon, A. Stern *et al.*, *Rev. Mod. Phys.* 80, 1083 (2008).
[2] J. Alicea, *Rep. Prog. Phys.* 75, 076501 (2012).
[3] M.S. Hossain, R. Islam, Z.-J. Cheng, Z. Muhammad *et al.*, *Nature Communication* (in press 2025). *arXiv*:2502.09878
[4] S. Mardanya, M. Kargarian, R. Verma *et al.*, *Phys. Rev. Materials* 8, L091801 (2024).
[5] R. Zhang, C.-Y. Huang, M. Kargarian *et al.*,*arXiv*:2311.03302 (2023).

Oral Presentation

Enhanced magnetization and coercivity of CoCrFeMnNi (Cantor) high entropy alloy by Ag addition

E. Kasotakis[1], T. Smoliarova[1], I. Tarasov[1], M. Grzywa[2], M. Farle[1], N. F. Shkodich[1]

[1]*Faculty of Physics and Center of Nanointegration (CENIDE), University of Duisburg-Essen, 47057 Duisburg, Germany*

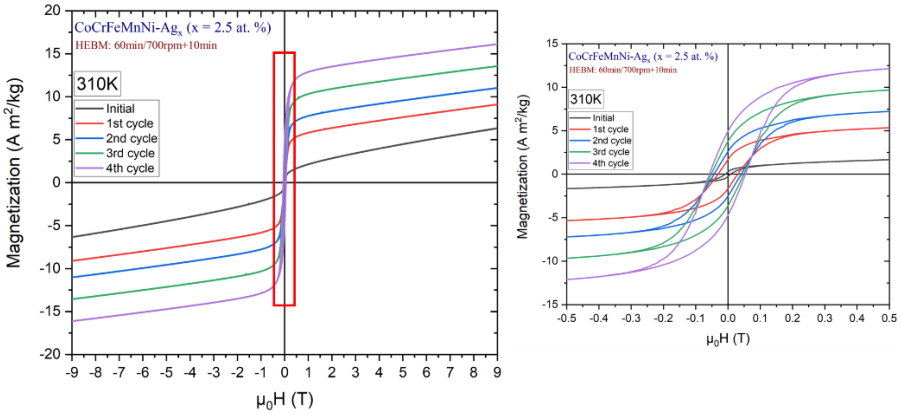
[2]*Rigaku Europe SE, Hugenottenallee 167, 63263 Neu-Isenburg, Germany*

Email: emmanouil.kasotakis@uni-due.de

CoCrFeMnNi, commonly known as the Cantor alloy [1], is a widely studied high-entropy alloy (HEA) with a single *fcc* structure. It exhibits exceptional strength, ductility, and fracture toughness, particularly at cryogenic temperatures. Its thermal stability, corrosion resistance, and strain hardening make it ideal for fundamental research and applications in extreme environments [2]–[4]. High-energy ball milling is an up scalable, cost-effective, and efficient technique used to produce nanocrystalline HEA powders with superior homogeneity compared to other melting routes [5].

The VEC of CoCrFeMnNi is 8 and it remains paramagnetic at room temperature [6]. The motivation of this work is to enhance the magnetic response of CoCrFeMnNi by increasing both magnetization (M) and coercivity (H_c) by Ag addition. The Ag serves as a non-magnetic coating, preventing exchange coupling, while Ag granules act as pinning centers, hindering domain wall movement. Its immiscibility with Co, Cr, Fe, Mn, and Ni hinders the formation of binary alloys with these elements [7].

In this study, we report a systematic investigation of the structure, morphology, and magnetic properties of CoCrFeMnNi-Ag_x (x = 0; 1; 2.5; 5.5 at. %) nanocrystalline HEA powders synthesized by HEBM. Our findings demonstrate precise control over particle morphology and Ag distribution by varying the Ag concentration, transitioning from flaky particles with Ag segregation at the edges to homogeneous spherical particles. Furthermore, in-field annealing up to 710 K significantly enhances M and H_c across all compositions, showing the most pronounced improvement for the CoCrFeMnNi-Ag_x (x = 2.5 at. %) sample, where M (9T, 310K) increased 2.5-fold (16 Am^2/kg) and H_c = 46 kA/m.



Field-dependent M(H) curves at 310 K for CoCrFeMnNi-Ag_x (x = 2.5 at. %) after each annealing cycle showing an increase in M (300 K, 9 T) and H_c.

Financial support by DFG, CRC/TRR 270 (project ID 405553726) and DFG FA209/27-1 is acknowledged.

References

[1] B. Cantor, I.T.H. Chang, P. Knight *et al*., *Mater. Sci. Eng. A* 375–377, 213 (2004).
[2] Y.K. Kim, S. Yang, K.A. Lee, *Sci. Rep.* 10, 65073 (2020).
[3] Y.Q. Zeng, M. Zhu, Y.F. Yuan *et al*., *J. Mater. Eng. Perform.* 33, 3020 (2024).
[4] F. Otto, A. Dlouhý, C. Somsen *et al.*, *Acta Mater.* 61, 5743 (2013).
[5] N.F. Shkodich *et al.*, *Acta Mater.* 284, 120569 (2025).
[6] O. Schneeweiss *et al.*, *Phys. Rev. B* 96, 014437 (2017).
[7] R.F. Zhang *et al.*, Sci. Rep. 7, 09704 (2017).

Oral Presentation

Magnetic and Transport Properties of Mn_2FeSn

V. Khovaylo[1], R.Y. Umetsu[2], A. Bogach[3]

[1]*National University of Science and Technology MISIS, Moscow 119049, Russia*
[2]*Institute for Materials Research, Tohoku University, Sendai 980-8577, Japan*
[3]*Prokhorov General Physics Institute of RAS, Moscow 119991, Russia*
Email: khovaylo@misis.ru

Studies of Mn_2YZ (Y is transition metal, Z is the main group element) inverse Heusler alloys have attracted considerable attention over decade [1]. Contrary to the most of these alloys, which possess cubic symmetry of the crystal lattice, the Mn_2FeSn compound has been reported to crystallize in a hexagonal structure. The specific feature of this compound is a non-collinear spin arrangement which brings about a large topological Hall effect [2,3]. It should be noted, however, that basic magnetic, transport and magnetotransport properties of the stoichiometric Mn_2FeSn have not been studied in details so far.

To study physical properties of the stoichiometric Mn_2FeSn, we prepared polycrystalline ingot by induction melting of chemically pure Mn, Fe, and Sn in an argon atmosphere. The ingot was subjected to homogenizing annealing in a vacuum quartz tube at a temperature of 1073 K for 10 days, followed by quenching in cold water. X-ray diffraction analysis revealed that annealed Mn_2FeSn crystallizes in a hexagonal crystal structure with lattice parameters a = 0.558 nm and c = 0.446 nm.

Results of the magnetic measurements pointed to a number of magnetic phase transitions. Specifically, upon cooling down from high temperatures, Mn_2FeSn transforms to long-range magnetically ordered state at $T_C \approx 300$ K. Upon further cooling, a spin-orientation transition is observed at ≈ 200 K. Below this temperature, a strong bifurcation of ZFC and FC magnetization curves is observed in a magnetic field of 100 Oe. The splitting of ZFC-FC curves is diminished upon application of stronger magnetic fields and disappears almost completely in $\mu_0 H = 2$ T. Temperature dependence of electrical resistivity ρ is atypical for metallic systems. Specifically, ρ is large, exceeding 300 μΩcm at room temperature, and decreases with increasing temperature. Magnetoresistivity does not exceed 2% in the whole measured temperature interval (4.2 – 300 K).

This work was supported by Russian Science Foundation (grant No. 25-42-01024).

References

[1] C. Felser, L. Wollmann, S. Chadov *et al., APL Mater.* 3, 041518 (2015).
[2] J. Liu, S. Zuo, X. Zheng *et al., Appl. Phys. Lett.* 117, 052407 (2020).
[3] J. Liu, S.L. Zuo, J. Shen *et al., Mater. Today Phys.* 29, 100871 (2022).

Oral Presentation

Dextran coated iron oxide nanoparticles: magnetic hyperthermia and cytotoxicity

Kh. Kirakosyan[1], G. Sevoyan[2], D. Hambardzumyan[1], H. Gyulasaryan[1], Z. Karabekian[2], A. Manukyan[1], A. Mukasyan[1]

[1]*The Institute for Physical Research (IPR) NAS RA: Ashtarak-2, 0204, Ashtarak, Armenia*
[2] *Orbeli Institute of Physiology of NAS RA, 22 Orbeli Bros. str. 0028 Yerevan, Armenia*
Email: mkhachatur@gmail.com

Nowadays, cancer remains one of the most challenging diseases worldwide, as current therapies such as chemotherapy, radiotherapy, and surgery often limited by toxicity and resistance. Nanotechnology provides promising new strategies, particularly magnetic nanoparticles (MNPs) for hyperthermia, where localized heating under an alternating magnetic field can selectively destroy tumor cells [1,2]. Iron-based nanoparticles are especially attractive due to their biocompatibility, tunable magnetic properties, and potential for surface modification [3-5].

In the current work, we report on the development of functionalized dextran-coated iron oxide "core–shell" magnetic nanoparticles (γ-Fe_2O_3@f-Dextran NPs) designed for improved colloidal stability and controllable magnetic characteristics. The nanocomposites were synthesized by hydrothermal and co-precipitation methods and characterized using TEM, SEM, EDS, XRD, and magnetometry. Conducted analysis confirms the successful synthesis of γ-Fe_2O_3 nanoparticles embedded in a f-Dextran matrix with nearly size distribution.

The hyperthermia performance of γ-Fe_2O_3@f-Dextran sample was evaluated by preparing aqueous solutions of 20 mg/ml concentration and exposing them in AC magnetic field with parameters 1006 kHz/19 mT. The SLP value was obtained 46 W/g which is typical for γ-Fe_2O_3 NPs.

Preliminary cell viability studies using the standard MTT assay demonstrated a clear dose-dependent inhibitory effect of γ-Fe_2O_3@f-Dextran NPs on MDA-MB-231 Breast cancer cells as well as on HaCat and HEK normal cells. The results indicate that the NPs exhibit no detectable toxicity toward HEK cells. While some inhibition at concentration above 10 mg/mL was observed in HaCat cells. However, observed sensitivity to the NPs in HaCat cells was significantly lower than that for the MDA-MB-231 Brest cancer cells. Notably, a concentration of 10 mg/mL of MNPs resulted in approximately 50% inhibition of MDA-MB-231 Breast cancer cells, whereas HaCat normal cells required nearly double concentration (20 mg/mL) to reach a comparable level of inhibition.

MDA-MB-231 Breast cancer cells were incubated with a γ-Fe_2O_3@f-Dextran NPs solution for 48 hours at 37 °C and 5% CO_2 in nutrient medium, followed by TEM analysis. The images (Fig. 1) clearly revealed that γ-Fe_2O_3 NPs penetrated into the cancer cells. These findings suggest that γ-Fe_2O_3@f-Dextran NPs are effectively taken up by cancer cells, highlighting their potential as efficient mediators for magnetic hyperthermia in cancer therapy.

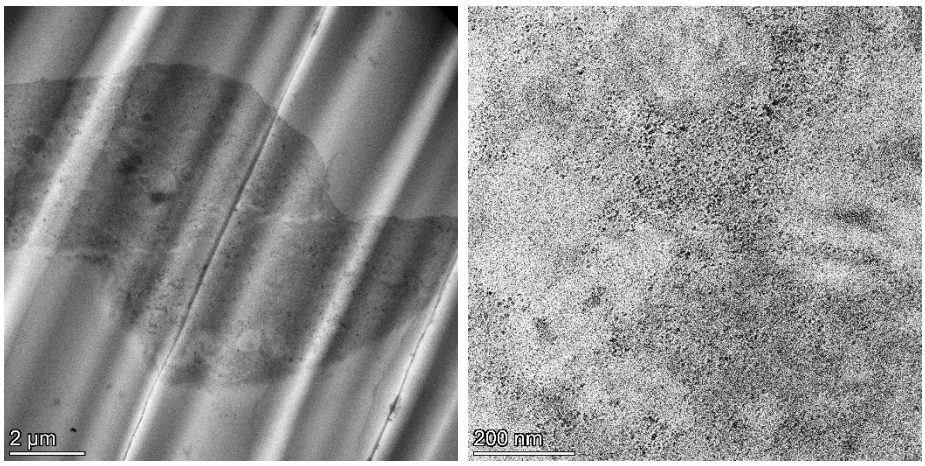


Fig. 1. TEM BF images of cancer cell with NPs (80keV) with different magnification.

References

[1] M.E. Davis, Z.G. Chen, D.M. Shin, *Nat. Rev. Drug Discov.*, 7, 771-782 (2008).

[2] D. Horak, V. Pustovyy, A. Babinskyi *et al.*, *Int. J. Nanomedicine*, 12, 4257-4268 (2017).

[3] Y. Wang, Q. Zhao, N. Han *et al.*, *Nanomedicine: Nanotechnology, Biology and Medicine*, 11, 313–327 (2015).

[4] W. Xie, Z. Guo, F. Gao *et al.*, *Theranostics*, 8, 3284–3307 (2018).

[5] F. Sabir, M. Zeeshan, U. Laraib *et al.*, *Cancers*, 13, 3396 (2021).

Oral Presentation

Study of structural, electronic and magnetotransport properties of functional materials based on cobalt oxide, irradiated to improve operational characteristics in ultra-high-frequency spintronics devices

E.A. Klevtsova[1], V.V. Kobets[1], A.A. Baldin[1], S.I. Tyutyunnikov[1], O.V. Belov[1], A. Trifonov[1], A. Skrypnik[1], V. Shabratov[1], E. Acosta-Martinez[1], S. Abou El-Azm[1], R. Svetogorov[3], A. Trigub[3], R. Lanovsky[3], M. Bushinsky[3], V. Efimov[1], V. Sikolenko[1]

[1] *Joint Institute for Nuclear Research, 141980 Dubna, Moscow region, Russia*
[2] *NRC "Kurchatov Institute", Acad. Kurchatov sq.1, 123182 Moscow, Russia*
[3] *SSPA Scientifical-Pratical material research centre of NAS, Minsk, Belarus*
Email: klevtsova@jinr.ru

This work is aimed at a comprehensive experimental study of exchange interactions, magnetotransport phenomena, spin and phase transitions in magnetic semiconductors, including complex cobalt oxides. It is assumed that samples were irradiated with electron and ion accelerator beams, followed by a study of the modified properties.

The research covers the investigation of functional materials exposed to new sources of strong pulsed magnetic fields, ion and electron irradiation with controlled dose, energy and pulse duration. These compounds exhibit a variety of physical phenomena such as spin crossover, giant magnetoresistance, insulator-metal transition, orbital ordering, ferroelectric and magnetoelectric effects, structural phase transitions [1, 2]. The study of such phenomena is one of the leading areas of modern physics of radiation materials science, both fundamental and applied. It should be noted that the microscopic mechanisms of formation of the properties of complex cobalt compounds remain poorly understood. Modification of the structure and magneto-transport properties of ferro- and antiferromagnetic materials will be carried out at the SOCHI irradiation station at the NICA accelerator complex with an energy from 3.2 MeV/nucleon to 4 GeV/nucleon with intensities from 10^3 to 10^9 particles/sec, a pulse duration of 4 μs. Preliminary results show that irradiation leads to a structural transformation in the studied compounds, including isotropization of the crystal structure and transition to a ferromagnetic phase with dose. However, the influence of irradiation parameters on the stability of the effect remains unclear.

The results of the studies would help us to reveal the relationship between lattice, electron and magnetic degrees of freedom, which would open opportunities for controlling their physical and chemical properties and creating new functional materials for their use [3-5].

References

[1] V.Baltz *et al.*, *APL Mater.* 12, 030401 (2024).
[2] H. Reichlova *et al.*, *APL Mater.* 12, 010902 (2024).
[3] L. Caretta, C. Onur Avci, *APL Mater.* 12, 011106 (2024).
[4] O.J. Amin *et al.*, *APL Mater.* 11, 091112 (2023).
[5] Б. А. Иванов, *ЖЭТФ*, 158, 1 (7), 103–123, (2020).

Oral Presentation

Study of interaction of single-molecular magnets with superconducting particles

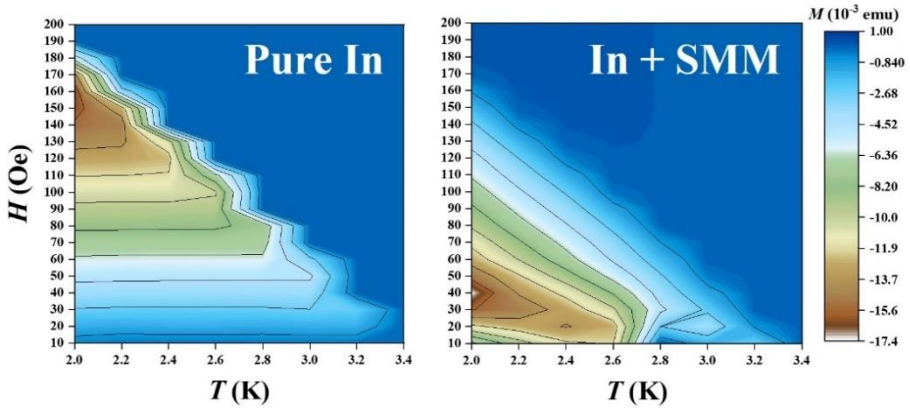
E.I. Kunitsyna[1], R.B. Morgunov[1,2]

[1] *Federal Research Center of Problems of Chemical Physics and Medical Chemistry RAS, Chernogolovka, 142432, Russia*

[2] *Russian Quantum Center, Skolkovo innovation city, Moscow, 121205 Russia*

Email: kunya_kat@mail.ru

Hybrid systems combining superconductors/ferromagnets and single-molecule magnets (SMMs) have attracted attention due to their unique quantum properties and potential applications in spintronics and quantum computing [1]. Single-molecule magnets can retain their spin state, making them promising candidates for storing and rapidly processing quantum information. However, a key challenge remains the integration of these systems into functional devices and the control of their interactions with external environments. Superconductors can be promising matrices for integrating SMMs into real quantum devices. In such systems, it is crucial to consider the possible influence of SMMs on superconducting surfaces, as this interaction can alter their properties [2]. In our new work, we studied the effect of Er^{3+}-based SMMs on a superconducting matrix (In). Our experiments revealed a decrease in the critical temperature and broadening of the superconducting transition in the presence of SMMs. Additionally, we observed temperature hysteresis during the superconducting transition and a modification of the temperature dependence of Debye relaxation. The decrease in the superconducting transition (see Figure) temperature can be attributed to the degradation of intergranular contact formation and the disruption of Josephson junctions. The results demonstrate that the introduction of SMMs into superconducting composites allows one to control their characteristics, which is promising for quantum information science.



This work was supported by supported by the grant of the Russian Science Foundation No. 24-72-00049, https://rscf.ru/project/24-72-00049/.

References

[1] M. Mannini, F. Pineider, P. Sainctavit *et al.*, *Nat. Mater.* 8, 194 (2009).

[2] G. Serrano, L. Poggini, G. Cucinotta *et al.*, *Nat. Commun.* 13, 3838 (2022).

Oral Presentation

Prospects for Using Conventional Superconductors in the Design of the Detection Pixel of a Thermoelectric Single Photon Detector

A.A. Kuzanyan, V.R. Nikoghosyan, A.S. Kuzanyan

Institute for Physical Research of NAS of Armenia, Ashtarak-2, 0204, Ashtarak, Armenia
Email: astghik.kuzanyan@gmail.com

In this study, we consider the possibility of creating a detecting pixel of a thermoelectric single-photon detector in the design of which conventional superconductors are used as an absorber and heat sink. The results of both computer modeling of heat propagation in a three-layer detection pixel and determination of the signal power, equivalent noise power and signal-to-noise ratio are presented. The absorption of single photons with energies from 0.8 to 3.1 eV in absorbers made of lead, niobium and molybdenum was studied at the operating temperature of the detecting pixel below the critical temperature of the absorber material. Lanthanum-cerium hexaborides were used as the material of the thermoelectric layer, and a layer of the same superconductor as in the absorber served as a heat sink. The design of the detecting pixel also included a sapphire dielectric substrate. The variable parameter was also the surface area of the absorber. The thicknesses of the detecting pixel layers and substrate did not vary.

We investigated the temporal dependences of the temperature in different areas of the detection pixel and the average temperature at the layer boundaries. The maximum temperature, the time to reach the maximum, the time of temperature decay to the background level of the studied temporal dependences, the temperature and time of temperature equalization at the layer boundaries, the characteristics of the temperature gradient at the boundaries of the thermoelectric layer and the electric voltage occurring on it were determined. Systematization of the obtained data allowed us to determine the optimal design of the detection pixel for efficient registration of single photons in the near infrared and ultraviolet spectral regions.

This work was supported by the Higher Education and Science Committee of the Ministry of Education, Science, Culture, and Sport of the Republic of Armenia, in the frames of the research project №25RG-1C065 "Development of a new sensor design for a thermoelectric detector of single IR photons".

Oral Presentation

Normal Zone Propagation Processes in non-insulated HTS Windings for High-Field Electromagnets

I.V. Martirosian, D.A. Aleksandrov, S.V. Pokrovskii, A.Y. Malyavina

National Research Nuclear University MEPhI (Moscow Engineering Physics Institute), Moscow, Russia
Email: mephizic@gmail.com

Due to the growing prospects for the application of high-temperature superconductors (HTS) in the development of high-field electromagnets for the generation of superstrong magnetic fields, special attention is currently paid to the studies of normal zone propagation (NZP) processes [1], as well as to the methods of additional electrical stabilization of HTS windings. One of the methods of current stabilization of HTS windings is the use of non-insulated superconducting windings (NISW), which provides shunting of the HTS winding by neighboring conductive layers [2].

The present work is devoted to the development of a numerical model and analysis of normal zone propagation processes in current-carrying windings based on HTS tapes. Special attention is paid to the consideration of the relation between thermal and electrodynamic processes, as well as to the evaluation of the influence of the winding insulation level on the dynamics of thermal processes when a local thermal perturbation occurs in one of the layers.

The study's results describe the dynamics and propagation velocities of the normal zone in NISWs under constant and pulsed current excitations, and reveal the influence of defects and inhomogeneities of the critical current of HTS on the processes of NZP development in NISW under different cooling conditions. The results include the dependences of the voltage response on the current pulse, the distributions of local and integral heating of individual layers of NISW as a function of time, and the dynamics of the normal zone propagation front in the longitudinal and radial directions of a non-insulated superconducting winding under constant and pulse current excitations for various cooling conditions. The numerical results have been verified by the experimental data.

This work was supported by a grant from the Russian Science Foundation № 24-79-00278, https://rscf.ru/project/24-79-00278/.

References

[1] M. Janitschke, M. Mentink, F. Murgia *et al.*, *IEEE Trans. Appl. Supercond.* 31(5), 1 (2021).
[2] D. Park, J. Bascuñán, Y. Li *et al.*, *IEEE Trans. Appl. Supercond.* 31(5), 1 (2021).

Oral Presentation

Terahertz-Driven Exchange Mode in a Ferrimagnetic Cavity

C. Reinhoffer[1], I. Razdolski[2,3], C. Kadlec[4], P. Stein[1], F. Kadlec[4], S. Germanskiy[1], A. Stupakiewicz[2], P. H. M. van Loosdrecht[1], E.A. Mashkovich[1]

[1] *Institute of Physics II, University of Cologne, 50937 Cologne, Germany*
[2] *Faculty of Physics, University of Bialystok, Ciolkowskiego 1L, 15-245 Bialystok, Poland*
[3] *Photonics Research Centre, Universiti Malaya, 50603, Kuala Lumpur, Malaysia*
[4] *Institute of Physics of the Czech Academy of Sciences, Na Slovance 2, 182 00 Prague 8, Czech Republic*
Email: mashkovich@ph2.uni-koeln.de

We experimentally demonstrate the excitation of the exchange mode in a ferrimagnetic single crystal of $(Gd,Bi)_3Fe_5O_{12}$ using terahertz (THz) pulses. A strong enhancement of the exchange mode amplitude is observed when its frequency matches a cavity eigenmode formed by the sample interfaces. This resonant condition also results in a fivefold reduction in effective damping. Using a Landau-Lifshitz-Gilbert formalism for two coupled magnetization sublattices, we numerically analyze the magnetization dynamics, accounting for multiple THz pulses generated by reflections from the crystal interfaces. Our results reveal an efficient mechanism for the THz excitation of magnetization in ferrimagnets and provide a systematic understanding of the magnetic response in a ferrimagnetic cavity.

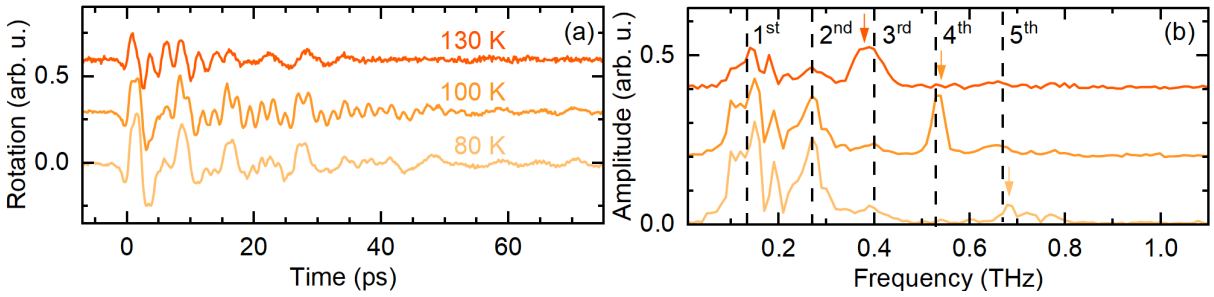


Fig. 1. THz-induced polarization rotation of the probe pulse measured at 80 K, 100 K, and 130 K. (b) Corresponding Fourier spectra; the arrows indicate the tunable exchange mode.

A broadband THz pump pulse was generated using the tilted-pulse-front optical rectification technique in a $LiNbO_3$ crystal [1]. An 800 nm pulse from the same source was used as a probe. Then, standard THz-pump optical-probe spectroscopy was performed. Figure 1a shows the THz-induced polarization rotation measured at three distinct temperatures: 130 K, 100 K, and 80 K. The time-domain traces reveal rich, strongly temperature-dependent dynamics. The corresponding Fourier spectra, shown in Fig. 1b, exhibit multiple peaks with a clearly visible temperature-dependent exchange mode. Notably, two prominent features centered at 0.13 THz and 0.27 THz do not shift with temperature, whereas the peak observed at 0.4 THz at 130 K shifts to 0.7 THz as the temperature is lowered to 80 K.

References

[1] H. Hirori, A. Doi, F. Blanchard *et al.*, *Appl. Phys. Lett.*, 98, 091106 (2011).

Oral Presentation

Effects of High Pressure on Structural and Electronic Properties of High-Temperature Superconductor $YBa_2Cu_3O_{7-\delta}$

M. Matyunina[1], O. Pavlukhina[1], A. Kamantsev[2], V. Koledov[2]

[1] *Chelyabinsk State University, 454001, Bratiev Kashirinykh 129, Chelyabinsk, Russia*
[2] *Kotelnikov Institute of Radioengineering and Electronics of RAS, 125009, Mokhovaya st., 11-7, Moscow, Russia*
Email: matunins.fam@mail.ru

The advancement of magnetic levitation transportation is currently focused on improving magnetic levitation suspension systems through the development of novel materials, particularly the optimization of existing and discovery of new high-temperature superconducting (HTS) materials. The key challenges in this field are increasing the superconducting transition temperature (T_C) and enhancing the critical current density (J_C). Contemporary research follows two main directions. The first is the continuation of the study of the physical and chemical foundations of the phenomenon of superconductivity in lanthanum hydrides [1-3]. For example, the observation of superconductivity at 250 K in lanthanum hydride under high pressure [2], under a pressure of 200 GPa the transition temperature was Tc = 260 K [3]. The second direction is a targeted search for new HTS materials and research into their properties. In recent years, significant progress has been made in developing materials that maintain superconducting properties near room temperature. The majority of studies focusing on practical applications of HTS materials at atmospheric pressure have been devoted to cuprates.

In this study, using density functional theory (DFT) as implemented in the VASP software package [4], we investigated the effects of external pressure on the structural and electronic properties of $YBa_2Cu_3O_{7-\delta}$ alloy.

This work was supported by the Russian Science Foundation Project No. 25-19-20141 (https://rscf.ru/en/project/25-19-20141/).

References

[1] I. Errea, F. Belli, L. Monacelli *et al.*, *Nature* 578, 66–69 (2020).
[2] A. P. Drozdov, P. P. Kong, V. S. Minkov *et al.*, *Nature* 569, 528–531 (2019).
[3] M. Somayazulu, M. Ahart, A.K. Mishra *et al.*, *Phys. Rev. Lett.* 122, 027001 (2019).
[4] G. Kresse, J. Furthmuller, *Phys. Rev. B.* 54, 11169 (1996)

Oral Presentation

Electronic structure of all-d-metal Ni(-Co)-Mn-Ti vs. p-d Ni_2MnSn: Insights from DFT and XAS

O. Miroshkina[1], J. Lill[1], B. Eggert[1], B. Beckmann[2], D. Koch[2], F. Scheibel[2], K. Ollefs[1], W. Donner[2], O. Gutfleisch[2], H. Wende[1], M.E. Gruner[1]

[1] *University of Duisburg-Essen, 47057 Duisburg, Germany*
[2] *Technical University of Darmstadt, 64287 Darmstadt, Germany*
Email: olga.miroshkina@uni-due.de

All-*d*-metal Heusler alloys are a new class of caloric materials for energy efficient solid-state cooling. In this work, we investigate the peculiar differences of the electronic structure between all-*d*-metal Ni(-Co)-Mn-Ti and conventional *p-d* Ni_2MnSn by combining density functional theory (DFT) and x-ray absorption spectroscopy (XAS). The calculated spectra for Mn and Ti accurately reproduce characteristic features observed in experimental XAS profiles. A comparison between the DFT calculated electronic structure and the XAS measurements reveals indications of a complex magnetic configuration in Ni_2MnTi consistent with the presence of ferromagnetic clusters in an antiferromagnetic matrix, as observed in Ni–Mn–(In,Sn) systems [1]. To identify the distinctive characteristics of *d-d* hybridization in spectra of the L_3-edge, we compare the features in the electronic densities of states (DOS) obtained from DFT and XAS. The K-edge XAS for different structures reveals the presence of partial disorder not only in the all-*d*-metal Ni_2MnTi and NiCoMnTi but also in the *p-d* Ni_2MnSn. This is consistent with our earlier findings indicating atomic disorder in the Sn vibrational DOS of near-stoichiometric Ni_2MnSn [2]. In conclusion, we demonstrate that DFT combined with K- and L-edge XAS for Heusler alloys is a powerful tool for probing electronic structure and disorder. Fine-tuning of both offers an opportunity to control magnetic and structural properties, thereby enabling the design of high-performance caloric materials.

This work was funded by the German Research Foundation (Deutsche Forschungsgemeinschaft, DFG) within the CRC/TRR 270 (Project No. 405553726) and MI 3273/1 (Project No. 539118894). Large-scale DFT calculations were performed the Lichtenberg high performance computer of the TU Darmstadt (Project No. p0020039).

References

[1] F. Cugini, S. Chicco, F. Orlandi *et al.*, *Phys. Rev. B* 105, 174434 (2022).
[2] O. Miroshkina, B. Eggert, J. Lill *et al.*, *Phys. Rev. B* 106, 214302 (2022).

Oral Presentation

Strain driven magnetocaloric effect in Gd microwires and films

R. Morgunov[1,2], A.Chernov[2], S.Kashin[1]

[1]*Federal Research Center of Problems of Chemical Physics and Medicinal Chemistry RAS, Chernogolovka, 142432 Russia*

[2] *Russian Quantum Center, Skolkovo innovation city, Moscow, 121205 Russia*

Email: Spintronics2022@yandex.ru

The magnetocaloric effect (MCE) in Gd and its alloys has been the subject of long-term painstaking research, yielding increasingly surprising results in the process of chemical modification of the alloys themselves and in improving the conditions for reversing the magnetization of a sample with a magnetic field. Our work is aimed at the analysis of the effect of elastic and plastic deformation of Gd microwires and thin films on the magnetic properties and MCE's appearing due to spin-reorientation transition and transition from ferro- to paramagnetic state. The influence of elastic plastic deformation by bending and stretching on the magnetization and magnetocaloric effect (MCE) in gadolinium microwires and thin films is revealed (Fig.1).

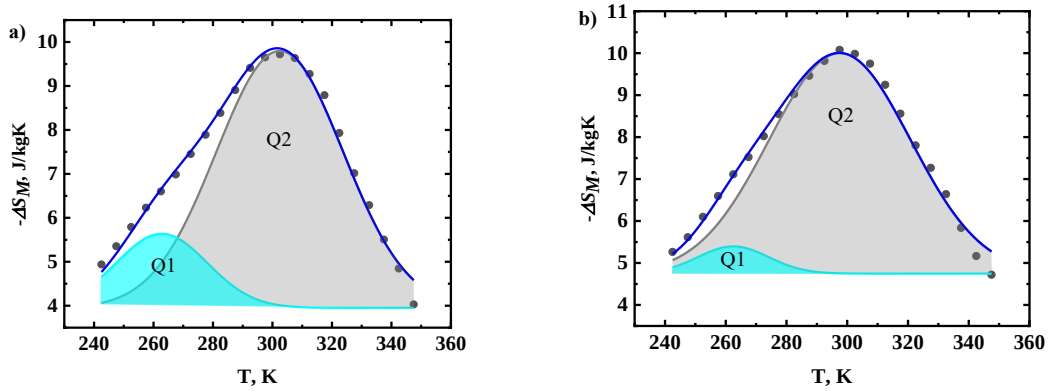


Fig. 1. Temperature dependences of magnetic part of entropy before deformation (a), under deformation (b).

Increase in elastic deformation enhances MCE, while the transition to the plastic deformation mode ceases to affect the MCE. In the microwires, there are two MCEs with maxima at different temperatures. At 260 K, the MCE associates with the spin-reorientation transition, while at 300 K, the MCE appears due to the transition between the ferro- and paramagnetic states. An increase in deformation or magnetic field leads to a redistribution of the MCE intensities Q1 and Q2 in favor of the transition at 300 K. Strain induces magnetic anisotropy, suppressing the spin-reorientation transition and correspondent MCE Q1. Simultaneously deformation sharpens the transition from the ferro- to the paramagnetic state, increasing corresponding part of magnetic entropy Q2.

The work was supported by the program of the Federal Research Center of Problems of Chemical Physics and Medicinal Chemistry RAS AAAA-A19-119092390079-8.

Oral Presentation

Development of technology for remote magnetomechanical control of the structure of molecular systems

A.A. Nikitin[1,2], A.V. Prishchepa[1,2], M.A. Abakumov[1,2]

[1] *Laboratoty of Biomedical Nanomaterials, National University of Science and Technology (MISIS), Moscow 119049, Russia*

[2] *Departament of Medical Nanobiotechnology, Pirogov Russian National Research Medical University, Moscow 117997, Russia*

Email: nikitin.chemistry@mail.ru

Many types of acquired and congenital diseases are associated with the disturbance of biochemical processes at the molecular level, including dysfunction of various enzymes and proteins, which over time transition to different structures with a changing in their activity. Precise control of the structure of biomolecules is of fundamental and practical significance for biophysics, chemistry, biology, and medicine. Currently, activation and remote control of molecular nanosystems is carried out by means of energy acquired by such systems, for example, light energy, thermal energy, chemical reaction energy or ultrasound energy. However, each of these approaches is highly invasive and has a number of spatial, temporal, and instrumental limitations. Thus, each type of molecular nanosystems requires a selection of its own activation conditions, which effectively excludes the possibility of reciprocal transmissions of experiments. Therefore, the development of an effective and universal method for energy transfer using various types of molecular nanosystems is an extremely relevant task in modern science.

Magnetomechanics – one of the possible solutions to this problem. Unlike other types of molecular switch activation, this approach is based on the principles of converting the energy of low-frequency

(<1 kHz) dynamic magnetic fields into mechanical energy using special driving mechanisms – magnetic nanoparticles. The unique physical properties of magnetic nanoparticles make them an ideal tool for different biomedical applications, from diagnostics to targeted cancer therapy. By adjusting both the intrinsic properties of nanoparticles (size, shape, phase composition, etc.) and the external parameters of magnetic fields (amplitude, frequency) and media (viscosity, temperature), it is possible to achieve mechanical forces and torques leading to the destruction of weak intermolecular interactions. The magnetomechanical approach has already shown its effectiveness in the remote control of the catalytic activity of enzymes and cell receptors. However, it has not yet been possible to predict magnetomechanical effects in each specific case.

Here, we present a series of works demonstrating the development and testing of an experimental system based on a DNA-microarrays, which for the first time made it possible to quantify the energy of the magnetomechanical effect mediated by individual magnetic nanoparticles with known parameters [1]. The resulting system was tested in various molecular models. Key parameters of magnetic nanoparticles have been identified that must be strictly controlled for effective remote control of various macromolecules under the influence of low-frequency external magnetic fields. It was found that the magnetomechanical effect is not a monotonic function of the size of the nanoparticle core, as previously thought in theoretical works. Important parameters affecting the effectiveness of the magnetomechanical approach are the superparamagnetic state of magnetic nanoparticles, the magnitude of their magneto-dipole interaction [2] and the shape of nanoparticles and the type of the dynamic magnetic field [3]. It was experimentally shown that the maximum magnetomechanical effect can be achieved for nanoparticles with a coating thickness of a non-magnetic shell comparable to the size of their magnetic core. The data

obtained made it possible to evaluate the effectiveness of the magnetomechanical therapy in vitro, the results of which, as was subsequently found, are fully consistent with the data obtained using the developed model system. We believe that our observed results shed light on the “black box” of fine-tuning the properties of magnetic nanoparticles for addressing specific magnetomechanical tasks.

References

[1] A.A. Nikitin, A.Y. Yurenya, T.S. Zatsepin *et al.*, *ACS applied materials & interfaces*, 13(12), 14458–14469 (2021).

[2] A.A. Nikitin, A.V. Prishchepa, R.A. Rytov *et al.*, *Journal of Physical Chemistry Letters*, 14(40), 9112–9117 (2023).

[3] A.G. Prishchepa,, A.G. Savchenko, N.S. Chmelyuk *et al.*, *JMMM*, 614, 172757 (2025).

Oral Presentation

Electric field driven flat bands in S=1/2 sawtooth chain

V. Ohanyan[1,2], J. Richter[3], J. Schnack[4], J. Schulenburg[3]

[1] *Yerevan State University, 1 Alex Manoogian, 0025, Yerevan, Armenia*
[2] *CNADLE Synchrotron Research Institute, 31 Acharyan Street, 0040, Yerevan, Armenia*
[3] *Magdeburg University, Universitätspl. 2 (16), 39106, Magdeburg, Germany*
[4] *Bielefeld University, Universitätstr. 25, 33501, Bielefeld, Germany.*
Email: ohanyan@yerphi.am

The physics of localized magnons [1] in highly frustrated magnets is a relatively new and rapidly evolving field in modern quantum magnetism [2]. Models and materials exhibiting localized magnons or flat magnonic bands display remarkable magneto-thermal properties, including magnetization plateaus, magnetization jumps to saturation, macroscopic residual entropy, and enhanced magnetocaloric (as well as other caloric) effects. However, in most cases, flat bands arise only under strict constraints on exchange couplings in specific quantum magnetism models. This limitation poses a major challenge for the experimental realization of localized states and the practical exploitation of their advantages. In this work we suggest a way to overcome the fine-tuning issue with the aid of electric field in the models with magnetoelectric coupling, realized via the Katsura-Nagaosa-Balatsky (KNB) mechanism [3]. We consider the simplest frustrated spin model, S=1/2 sawtooth chain. While the magnetic field interacts with the spin system through the conventional Zeeman term, the coupling of an applied electric field to the spins, as described by the KNB mechanism, effectively manifests as a Dzyaloshinskii-Moriya interaction [4,5]. By applying an appropriate electric field, the system can be driven into a flat-band regime, overcoming the need for fine-tuned exchange couplings. In particular, when the electric field is aligned with the basal line of the chain, the saturation magnetic field is reduced. We identify an electric-field-induced magnetization jump and a magnetic-field-induced polarization jump, demonstrating a pronounced magnetoelectric effect. Additionally, the system exhibits an enhanced electrocaloric effect [6].

References

[1] J. Schulenburg, A. Honecker, J. Schnack *et al.*, *Phys. Rev. Lett.* 88, 167207 (2002).
[2] O. Derzhko, J. Richter, M. Maksymenko, *Int. J. Mod. Phys. B* 29, 1530007 (2015).
[3] H. Katsura, N. Nagaosa, A. V. Balatsky, *Phys. Rev. Lett.* 95, 057205 (2005).
[4] M. Brockmann, A. Klümper,V. Ohanyan, *Phys. Rev. B* 87, 054407 (2013).
[5] O. Baran, V. Ohanyan, T. Verkholyak, *Phys. Rev. B* 98, 064415 (2018).
[6] J. Richter, V. Ohanyan, J. Schulenburg *et al.*, *Phys. Rev. B* 105, 054420 (2022).

Oral Presentation

Critical Current Density in Superconducting Tapes by Applying Randomness on the Radii of Pining Centers in Triangular and Conformal Pinning Arrays

Z.Owjifard[1], M.Hosseini[2], A.Tavana[1]

[1] *AMDM Lab., Department of Physics, University of Mohaghegh Ardabili, Ardabil, Iran*
[2] *Department of Physics, Shiraz University of Technology, Shiraz, Iran*
Email: owjifard.zahra@gmail.com

The prospect of increasing the critical current has drawn considerable attention to the study of artificial vortex pinning with various geometries [1-4]. In this study, the effect of randomness in the radii of pinning centers on the critical current density of type-II superconductor tapes with triangular and conformal pinning arrays is investigated. Variations in the radius error ratio and pinning forces are subsequently introduced, and their respective impacts on the critical current density are analyzed. The behavior of vortices is examined using molecular dynamics simulations, where the vortex dynamics equations are solved by accounting for the relevant forces, and the associated critical current densities are computed. The results indicate that conformal structure exhibits greater stability against variations in the randomness of pinning center radii compared to the regular triangular structure. Moreover, at high magnetic fields, the critical current density is higher in the conformal array.

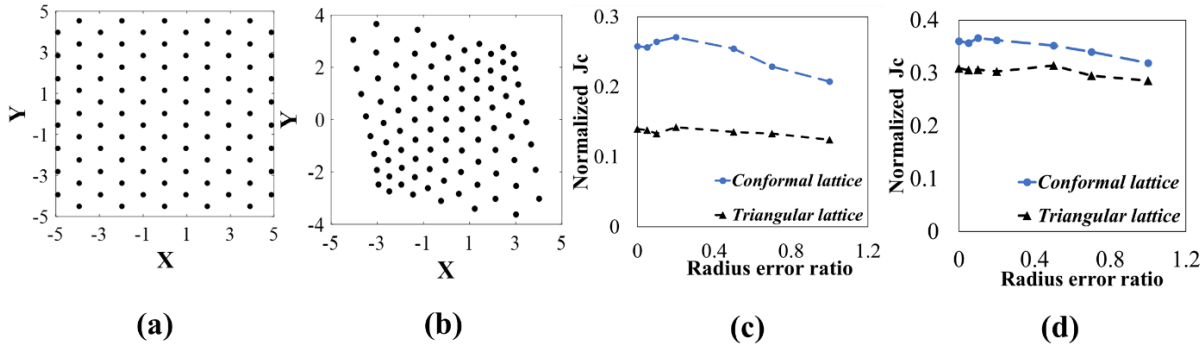


Fig. 1. The triangular pinning array (a) and conformal pinning array (b), Normalized J_c as a function of radius error ratio in the triangular and conformal pinning arrays for pinning forces f_p =1 (c), f_p =2 (d) at high field.

References

[1] Z.Owjifard, A.Tavana, M.Hosseini, *J. Alloys Compd.*, 180676 (2025).
[2] S.Zoveydavi, M.Hosseini, Z.Owjifard *et al., Physica C: Supercond. Appl.* 620,1354498, (2024).
[3] S.Miura, Y.Tsuchiya, Y. Yoshida *et al., IEEE Trans. Appl. Supercond*. 28(4), 1-6, (2018).
[4] Y.L.Wang , L.R.Thoutam, Z.L.Xiao *et al., Phys. Rev. B* 93(4), 045111, (2016).

Oral Presentation

Impurities impact on vortex dynamics in the vicinity of the Bogomolny point

V. Pashkovskaia, A. Vasenko, T. T. Saraiva

HSE University, Moscow, Russia
Email: vpashkovskaia@hse.ru

The Bogomolny point of the Ginzburg-Landau (GL) theory marks a point of infinite degeneracy of the stationary states. The solutions to the Bogomolny equations in superconductors have very particular properties and go beyond Meissner and vortex solutions, e.g. vortex lines and giant vortices. As we decrease the temperature and keep the GL parameter next to 0.707 the degeneracy is broken, the condensate and magnetic characteristic lengths become well defined and several elements of the system may influence in the electromagnetic response of the superconductor. In this work, we investigated non-simply connected 2D systems submitted to a perpendicular magnetic field using a generalization of the Time-Dependent Ginzburg-Landau theory, admitting local variations of temperature due to heat dissipation. We simulated a continuous increase of the external magnetic field for different thermal parameters of the system, i.e. thermal diffusivity, conductivity, etc and different sizes of the sample. We found that in the vicinity of the critical penetration field, Hc1, where the first magnetic fluxes moved through the sample, the local increase in temperature produced a trail of dissipation causing more elongation of vortices, resembling “vortex lines” found in the analytic solutions to the Bogomolny equations.

References

[1] V.D. Pashkovskaia, E.C.S. Duarte, R. Zadorosny *et al.*, *The Journal of Physical Chemistry Letters*, 0(0):10742– 10748, PMID: 39422296 (2024).

Oral Presentation

Ferromagnetic resonance at superconducting proximity effect

N. Pugach, Ya. Turkin, D. Seleznyov

HSE University, 101000, Moscow, Russia
Email: npugach@hse.ru

Superconducting spintronics has emerged in the last decade as a promising new field that seeks to open a new dimension for nanoelectronics by utilizing the internal spin structure of the superconducting Cooper pair as a new degree of freedom. Currently, the discipline finds itself at the crossroads for developing first-generation devices. Among the basic units of superconducting spintronics are hybrid nanostructures consisting of superconducting and magnetic materials in a close proximity, which gives rise to specific kinds of proximity effects. The electro- and magneto- dynamics of such structures now is in focus.

In this work we theoretically studied the interplay of electro- and magneto- dynamics in the bilayer consisting of a superconducting film deposited on the film of a ferromagnetic insulator. Static and dynamic inverse proximity effect have been investigated. Low temperature superconductors like Nb or NbN allow work at the frequency range up to THz, which makes them promising for cryogenic THz electronics and magnonics.

Our study is performed within a quasiclassical Green function framework, wherein Usadel equations are solved with boundary conditions appropriate for strongly spin-polarized ferromagnetic materials. The connected magnetodynamics is described by the Landau-Lifshits-Gilbert equation. The proximity effect between a ferromagnet and a superconductor is analyzed in its influence on the electro- and magneto-dynamics.

An intrinsic damping of electromagnetic microwaves was found at the linear response of such a bilayer. Static and dynamic inverse proximity effect, spin current injection, and some specific magnetodynamic peculiarities were investigated under conditions of ferromagnetic resonance in such structures.

This work was supported by the "Mirror Laboratories" project "Quantum effects in low-dimensional hybrid nanostructures" of the HSE University and M. Akmullah Bashkir State Pedagogical University.

References

[1] D.V. Seleznyov, V.O. Yagovtsev, N.G. Pugach *et al., J. Magn. Magn. Mat.* 595, 171645 (2024).
[2] Ya. V. Turkin, N. Pugach, *Beilstein Journal of Nanotechnology*, 14, 233 (2023).
[3] D. Seleznyov, Ya. Turkin, N. Pugach, *ArXiv*2410.15680 (2024).

Oral Presentation

YBCO Weak Link Construction Using Maskless Lithography

R. Rajabi, M. Piri, M.R. Mohammadizadeh

Superconductivity Research Laboratory (SRL), Department of Physics,
University of Tehran, North Kargar Av., P.O. Box 14395-547, Tehran, Iran
Email: rezarajabi@ut.ac.ir; zadeh@ut.ac.ir

YBCO weak-links are critical components for superconducting electronics and quantum technologies. This work presents a cost-effective approach to fabricating these weak-links using a maskless lithography technique. Our approach utilizes a Blu-ray optical pickup unit (OPU) for high-resolution patterning [1,2], eliminating expensive photomasks. Thin films with desired superconducting properties were prepared, and Blu-ray OPU-based lithography established a weak-link connection, forming the Josephson junction. Preliminary results demonstrate critical current values consistent with theoretical predictions. This technique shows promise for scalable, cost-effective production of Josephson junctions and SQUIDs, enabling broader applications in quantum sensing and superconducting electronics. This research builds upon previous studies of these films [3-5].

References

[1] C.A. Rothenbach, M.C. Gupta, *Optics and Lasers in Engineering*, 50(6), 900-904 (2012).
[2] E. E.T. Hwu, A. Boisen, *ACS Sensors*, 3(7), 1222–1232 (2018).
[3] M. Rasti, M.R. Mohammadizadeh, *Journal of Electronic Materials*, 52(8), 5485–5494 (2023).
[4] M. Rasti, M.R. Mohammadizadeh,*Journal of Superconductivity and Novel Magnetism*, 34(3), 769–780 (2021).
[5] M. Rasti, M. Mohammadizadeh, *IEEE Transactions on Applied* (2020).

Oral Presentation

Manifestation of the Mutual Influence of Superconductivity and Magnetism in Josephson Structures with a Magnetic

Yu. M. Shukrinov[1,2,3], M. Nashaat[1,4]

[1] *JINR, Dubna, Russia*
[2] *Dubna University, Dubna, Russia,*
[3] *MFTI, Dolgoprudnii,Russia,*
[4] *Cairo University, Cairo, Egypt*
Email: shukrinv@theor.jinr.ru; sci_phy_majed@windowslive.com

We discuss the effects of mutual influence of superconductivity and magnetism in the Josephson φ_0 junction, where a direct coupling of the Josephson phase and magnetization is realized [1]. This leads to interesting prospects in the field of superconducting spintronics, in particular, based on the reversal of the magnetic moment by a superconducting current, the manifestation of the Kapitsa pendulum features by the φ_0 junction [2]. The results of studies of the dynamics and current-voltage characteristics (CVC) of the junction under the action of external electromagnetic radiation are presented [3-5]. A new element in the consideration of this problem is the inclusion of the magnetic component of the radiation, which leads to the emergence of new synchronization mechanisms and corresponding steps on the CVC. We discuss the resonant control of magnetization in a shunted φ_0 junction with LC circuit, the locking, hysteresis and chaotic features [6-8]. The combination of Josephson and Kittel ferromagnetic resonances in the φ_0 junction with different types of synchronization, clearly expressed in the dynamics and in the CVC, makes the physics of this system very interesting and opens up a number of new applications.

References

[1] A. Buzdin, *Physical Review Letters*, 101, 107005 (2008).
[2] Yu.M. Shukrinov, *Physics Uspekhi*, 65, 317 (2022).
[3] S.A. Abdelmoneim, Yu.M. Shukrinov, K.V. Kulikov *et al., Phys. Rev. B*, 106, 014505 (2022).
[4] Yu.M. Shukrinov, E. Kovalenko, J. Tekic *et al., Phys. Rev. B*, 109, 024511 (2024).
[5] M. Nashaat M., E. Kovalenko, Yu.M. Shukrinov, *Physical Review B*, 110, 024510 (2024).
[6] A.A. Mazanik, A.E. Botha, I.R. Rahmonov *et al., Phys. Rev. Applied*, 22, 014062 (2024).
[7] R. Rahmonov, Yu.M. Shukrinov, O.A. Kibardina *et al., Cond-mat. arXiv*:2411.6037 (accepted for *APL*, 2025).
[8] M. Sameh, Yu.M. Shukrinov, A.Y. Ellithi *et al., Journal of Physics: Condensed Matter*, 37, 235803, (2025).

Oral Presentation

Ab initio and Monte Carlo approaches for the magnetic and magnetocaloric properties in Ni-Co-Mn-Ti Heusler alloy

V. Sokolovskiy, D. Baigutlin, K. Erager, M. Matyunina, A. Gamzatov, V. Buchelnikov

[1] *Chelyabinsk State University, Chelyabinsk, 454001, Russian Federation*
[2] *Amirkhanov Institute of Physics of DFRC of RAS, Makhachkala 367003, Russia*
Email: vsokolovsky84@mail.ru

Nowadays, caloric materials represent a key component in the development of environmentally sustainable cooling technologies, which operate on the principles of magneto-, elasto-, barocaloric effects. One of the candidates for an effective and inexpensive caloric material is the family of Heusler alloys X_2YZ, where X and Y are transition metals, and Z is an element of III-V groups. At present, quite a lot of compositions are known that demonstrate large caloric effects, however, they exhibit pure mechanical properties [1]. In the last few years, the interest of the scientific community has been focused on the so-called all-*d* metal Heusler alloys, which consist entirely of transition metals [2]. According to the literature, these alloys are less brittle and have higher plasticity and magnetocaloric effect than classic Heusler alloys.

In the present work, we studied all-*d* metal Heusler alloy $Ni_{1.5}Co_{0.5}Mn_{1.375}Ti_{0.625}$ within zero-temperature density functional theory (DFT) and finite-temperature Monte Carlo (MC) simulations. To perform DFT calculations, we used the VASP [3] and SPR-KKR [4] codes. As a result, we defined the ground state energies and magnetic reference states, as well as magnetic exchange coupling constants for cubic austenite and tetragonal martensite states. In terms of MC simulations, we considered the microscopical model, which consists of Heisenberg and Blume-Emery-Griffiths models for descriptions of magnetic and structural subsystems, respectively [5]. We have shown that ferri- and ferromagnetic spin alignments in martensite and austenite phases lead to a small and large magnetization, correspondingly. As a consequence, a large change in magnetization and magnetic entropy is predicted in the vicinity of martensitic transformation. The simulated the temperature dependences of magnetization, magnetic and lattice parts of specific heat and entropy change reproduce well the experimental curves for a similar compound $Ni_{36.5}Co_{13.5}Mn_{35}Ti_{15}$.

The research was supported by the RSF - Russian Science Foundation project No. 25-12-20024.

References

[1] V. Franco, J. Blázquez, J. Ipus *et al.*, *Prog. Mater. Sci*. 93, 112 (2018).
[2] V.G. de Paula and M. S. Reis, *Chem. Mater*. 33, 5483 (2021).
[3] G. Kresse, J. Furthmüller, *Phys. Rev. B* 54, 11169 (1996).
[4] H. Ebert, D. Ködderitzsch, J. Minár, *Rep. Prog. Phys*. 74, 096501 (2011).
[5] *V. Sokolovskiy, O. Miroshkina, M. Zagrebin et al., J. Apl. Phys.* 127, 163901 (2020).

Oral Presentation

Spin Switching and Exchange Bias Effect in Compensated Ferrimagnets

I. Fita[1], E. E. Zubov[2], R. Puzniak[1], A. Wisniewski[1]

[1] *Institute of Physics, Polish Academy of Sciences, Aleja Lotnikow 32/46, PL-02668 Warsaw, Poland*
[2] *Kyiv Academic University, 36 Acad. Vernadsky Blvd., UA-03142 Kyiv, Ukraine*
Email: wisni@ifpan.edu.pl

In single crystals of compensated ferrimagnets RFeO$_3$ (R = Nd, Er) spin switching (SW) and exchange-bias (EB) effect near compensation temperature (T_{comp}) are observed. Since in single crystals there is no interface, the different, nonconventional mechanisms is responsible for EB.

Additionally, ErFeO$_3$ exhibits specific phenomenon: *temperature* driven SW and EB [1]. EB manifests itself as temperature shift of hysteresis loops M vs T, which occurs upon successive cooling and heating in weak magnetic field. The $M(T)$ loops limiting region of coexistence of negative and positive M are shifted towards lower or higher temperatures, depending on sign of applied magnetic field, which causes unidirectional EB anisotropy.

In NdFeO$_3$, spontaneous and *field-dependent* spin switching was observed. Above $T_{comp} \approx 9$ K, spin switching temperature T_{sw} monotonically approaches T_{comp} with an increase in applied magnetic field, but below T_{comp}, a sharp drop in T_{sw} towards low temperatures and simultaneous increase in M jump ΔM at T_{sw} were found. The discontinuity in T_{sw} leads to two different T_{sw}–H phase lines shifted in opposite directions in temperature on the T–H plane and described by two different spin switching energies. The same splitting in switching energy follows directly from magnetization jump data and coincides with the difference in unidirectional anisotropy energies for positive and negative EB, both found near T_{comp}. This indicates that split SW energy responsible for anomaly in the T–H diagram of NdFeO$_3$ arises from coexistence of two different EB of opposite signs [2].

In compensated honeycomb ferrimagnet Ni$_4$Nb$_2$O$_9$ near $T_{comp} = 33$ K, a notable EB effect was also found. Magnetization reversal along the easy a axis, induced by both field and temperature, was observed as well. EB properties of Ni$_4$Nb$_2$O$_9$ are very similar to those previously found in ErFeO$_3$ [3].

The common origin of EB in single-phase compensated ferrimagnets of different type will be discussed.

References

[1] I. Fita, R. Puzniak, E. E. Zubov *et al.*, *Phys. Rev. B*, 105, 094424 (2022).
[2] I. Fita, R. Puzniak, E. E. Zubov *et al.*, *Phys. Rev. B*, 109, 054404 (2024).
[3] I. Fita, R. Puzniak, C. Martin *et al.*, *Phys. Rev. B*, 111, 014420 (2025).

Abstracts of Poster Presentations

Poster Presentation

Stability of adiabatic temperature change of $La_{0.7}Ce_{0.3}Fe_{11.45}Mn_{0.2}Si_{1.35}$ alloys under long-term exposure to cyclic magnetic fields

N.Z. Abdulkadirova[1], A.G. Gamzatov[1], A.T. Kadirbardeev[1], A.M. Aliev[1], Yuan Lin[2], Jing Wang[2], Feng-xia Hu[2]

[1]*Amirkhanov Institute of Physics, DFRC, RAS, 367003, Makhachkala, Russia*
[2] *State Key Laboratory of Magnetism, Institute of Physics, CAS, 100190, Beijing, P.R. China*
Email: gamzatov_adler@mail.ru ; nnurizhat@mai.ru

In recent years, the studies of the magnetocaloric effect (MCE) in cyclic/alternating magnetic fields (under conditions as close as possible to the operating characteristics of magnetic cooling devices with operating frequencies of 0.1-20 Hz [1]) have attracted great interest. It was shown that in materials with giant MCE values, reaching the maximum value of the adiabatic temperature change occurs with some delay, due to which the directly measured adiabatic temperature change (ΔT_{ad}) is often 30 - 50% of the equilibrium value [2], and is closely related to the rate of change of the magnetic field due to the kinetics of phase transformation when magnetic fields are close to critical. Recent studies [3-7] have shown that for most magnetocaloric materials, the magnitude of the adiabatic temperature change decreases with increasing frequency of the cyclic magnetic field. In addition, degradation of the effect is observed under long-term exposure to cyclic fields, which directly hinders their practical application. The nature of the attenuation of the magnetocaloric effect with the frequency of the cyclic magnetic field leads to the fact that the characteristics of magnetocaloric materials in refrigeration units are much less optimistic than theoretically predicted. Therefore, the study and understanding of the nature of the frequency-degradation properties of magnetocaloric materials will allow the synthesis of new magnetocaloric materials with controlled properties.

This paper presents the results of direct measurements of the ΔT_{ad} for the $La_{0.7}Ce_{0.3}Fe_{11.45}Mn_{0.2}Si_{1.35}$ alloy measured by both the classical extraction method (up to 8 T) and the method of magnetic field modulation in cyclic magnetic fields. It is shown that the studied alloy exhibits absolute stability of the ΔT_{ad} value both with an increase in the frequency from 1 to 20 Hz of a cyclic magnetic field of 1.2 T (the magnitude of the effect does not decrease practically), and with long-term exposure at a frequency of 10 Hz for more than 1 million on/off cycles.

The study was supported by the Russian Science Foundation grant No. 24-43-00156, https://rscf.ru/en/project/ 24-43-00156/.

References

[1] A. Greco *et.al., Int. J. Refrig.* 106, 66-88 (2019).
[2] K.A. Gschneidner Jr., V.K. Pecharsky, *Int. J. Refrig.* 31, 945 (2008).
[3] K. Qiao *et.al., ACS Applied Materials & Interfaces*, 14, 18293-18301 (2022).
[4] A. G. Gamzatov *et.al., Journal of Materials Science*, 58, 8503–8514 (2023).
[5] A.M. Aliev, A.G. Gamzatov, *JMMM*, 553, 169300 (2022).
[6] N.Z. Abdulkadirova *et.al., Journal of Alloys and Compounds*, 929, 167348 (2022).
[7] A.M. Aliev *et.al., Int. J. Refrig.* 151, 146–151 (2023).

Poster Presentation

Magnetic phase separation in $La_{0.8}Pr_{0.2}Fe_{13.7}Si_{1.3}$-Hd alloys induced by long-term exposure to cyclic magnetic fields

A.G. Gamzatov[1], N.Z. Abdulkadirova[1], P. Igoshev[1,2], A.M. Aliev[1], Jing Wang[3], Feng-xia Hu[3]

[1]*Amirkhanov Institute of Physics, DFRC, RAS, 367003, Makhachkala, Russia*
[2] *M.N. Mikheev Institute of Metal Physics of the UB RAS, 620108, Ekaterinburg, Russia, Russia*
[3] *State Key Laboratory of Magnetism, Institute of Physics, CAS, 100190, Beijing, P.R. China*
Email: gamzatov_adler@mail.ru; gamzatov.ag@gmail.com

Despite the fact that the process of creating solid-state magnetic refrigerators is entering the practical stage, magnetic cooling technology has encountered many fundamental problems that require further focused research studies. In magnetic refrigerators, the magnetic material will be necessarily exposed to long-term cyclic exposure to a magnetic field. Therefore, one of the crucial problems preventing the start of mass production of magnetic refrigerators is the lack of experimental data on the magnetocaloric properties of magnetic materials under long-term cyclic exposure to a magnetic field. In this paper, we present the results of a study of the effect of cyclic magnetic fields of varying intensity on the magnetic and magnetocaloric properties of the $La_{0.8}Pr_{0.2}Fe_{13.7}Si_{1.3}$ alloy. In particular the results of the study of the magnetic, magnetocaloric, thermophysical properties and XRD-analysis of $La_{0.8}Pr_{0.2}Fe_{13.7}Si_{1.3}$-$H_\delta$ alloys with extra Fe are presented. Direct measurements of the adiabatic temperature change ΔT_{ad} were performed in cyclic magnetic fields up to 8 T value. The specific heat was measured at different magnetic fields (0, 0.62 and 1.8 T) in the vicinity of Curie temperature (T_C). An anomalous increase in the specific heat jump in a magnetic field near T_C was found. In addition to the main specific heat peak, satellite anomalies are observed in a close vicinity of T_C, which are the result of sample degradation in cyclic magnetic fields during ΔT_{ad} measurements. We interpret this as a consequence of a multiphase state (magnetic phase separation) with spatially distributed critical temperatures caused by a cyclic magnetic field. Long-term exposure to a 1.8 T cyclic magnetic field at a frequency of 0.2 Hz leads to a slight decrease in ΔT_{ad} of 0.13 and 0.57 K for $La_{0.8}Pr_{0.2}Fe_{13.7}Si_{1.3}$ and $La_{0.8}Pr_{0.2}Fe_{13.7}Si_{1.3}H_\delta$, respectively, followed by a stabilization of the effect. In a magnetic field of 8 T, ΔT_{ad} shows good stability up to 1000 cycles. The maximum value of ΔT_{ad} reaches 12.7 and 10.9 K at magnetic field value H = 8 T for $La_{0.8}Pr_{0.2}Fe_{13.7}Si_{1.3}$ and $La_{0.8}Pr_{0.2}Fe_{13.7}Si_{1.3}H_\delta$, respectively. In contrast to the case of small magnetic fields, the value of ΔT_{ad} for both samples exhibit the temporal stability in strong cyclic magnetic fields. This is due to the fact that the magnetic field of 8 T exceeds the saturation field which is estimated as 4-6 T. The corresponding mechanisms, including microstructure and phase transition dynamics, are still under development.

The study was supported by the Russian Science Foundation grant No. 24-43-00156, https://rscf.ru/en/project/ 24-43-00156/.

Poster Presentation

Ternary Superconducting Hydrides in Ca-Y-H system

M.A. Grebenuik, G.M. Shutov, D.O. Poletaev, A.R. Oganov

Skolkovo Institute of Science and Technology, Skolkovo, 30c1 Bolshoi boulevard, Moscow, 121205, Russia
Email: Maksim.Grebeniuk@skoltech.ru

Room-temperature superconductivity remains one of the most challenges in modern physics. Among the most promising candidates are ternary hydrides, which have emerged as potential systems for achieving high-temperature superconductivity under high-pressure conditions. However, the vast compositional diversity of these hydrides, combined with the complexity of their structural and electronic properties, poses significant obstacles to systematic computational and experimental exploration. This challenge underscores the urgent need for innovative approaches to efficiently identify and characterize ternary hydrides with optimal superconducting characteristics.

This computational study explores superconducting ternary Ca–Y–H hydrides under high pressure. Using USPEX (evolutionary algorithm) and Phonopy (lattice dynamics toolkit), we assessed thermodynamic (convex hull with zero-point energy correction) and dynamic stability. Electronic properties were analyzed via DFT (VASP, PAW PBE/AM05 (GGA)). Electron-phonon interactions (Quantum ESPRESSO/DFPT) and Migdal-Eliashberg solutions revealed critical temperature trends in clathrate-like hydrides.

The results indicate calcium-yttrium-hydrogen ternary hydrides that are stable at pressures ranging from 100 to 400 GPa. These hydrides feature characteristic polyhedral units, including $Im\bar{3}m$–CaH_6, $Im\bar{3}m$–YH_6, $C2/m$–CaH_9, and $P6_3/mmc$–YH_9. For CaH_6–YH_6-based superhydrides, Eliashberg critical temperatures (T_c) of 200–240 K are predicted at 180 and 200 GPa. At higher pressures (300–400 GPa), the $P\bar{6}m2$–$CaYH_{18}$, $Imm2$–CaY_3H_{36}, and $Pmm2$–Ca_3YH_{36} phases—composed of interconnected CaH_9 and YH_9 polyhedra—are found. The $P\bar{6}m2$–$CaYH_{18}$ structure exhibits a superconducting T_c of 293–314 K at 300 GPa, with an electron-phonon coupling (EPC) constant λ=3.287. At 350 GPa, its T_c increases to 313–336 K (λ=3.461), and further rises to 324–348 K (λ=3.25) at 400 GPa. Meanwhile, $Imm2$–CaY_3H_{36} demonstrates a T_c of 258–279 K (λ=2.631) at 300 GPa, while $Pmm2$–Ca_3YH_{36} achieves T_c =263–286 K (λ=2.389) under the same conditions. These findings highlight the critical role of hydrogen-rich frameworks in achieving near-room-temperature superconductivity under extreme pressures.

The work was carried out with the financial support of Russian Science Foundation, grant 19-72-30043.

Poster Presentation

Design and Numerical Simulation of 1 Tesla High-Temperature Superconducting Magnet

Z. Dastani[1], A. Vedadiyan[2], A. Khademi[2], M.R. Mohammadizadeh[1]

[1] *Superconductivity Research Laboratory (SRL), Department of Physics, University of Tehran, Tehran, Iran*
[2] *Quantum Devices Laboratory (QDL), Department of Physics, Sharif University of Technology, Tehran, Iran*
Email: Zahra.dastani@ut.ac.ir; khademi@sharif.edu

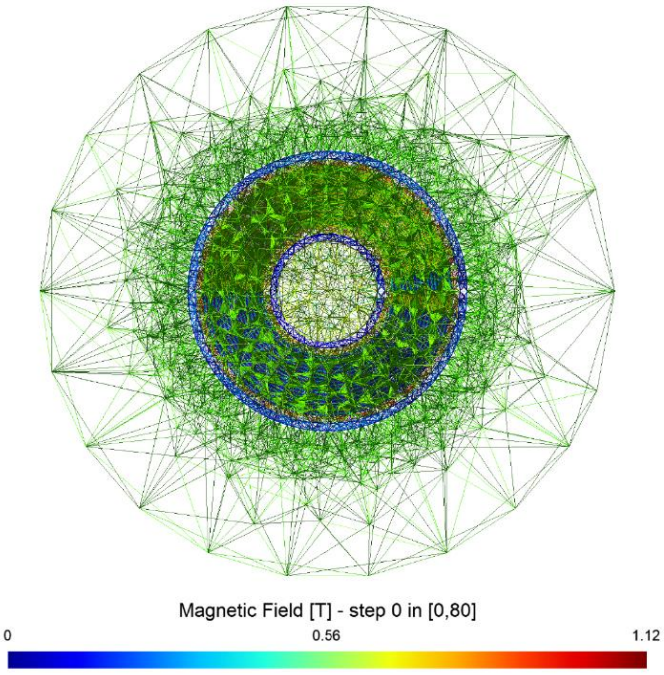
High-temperature superconducting (HTS) magnets are critical for generating the magnetic fields required in advanced applications such as magnetic resonance imaging (MRI), nuclear magnetic resonance (NMR) spectroscopy, fusion energy, particle accelerators, and magnetic levitation (Maglev) transportation systems [1-4]. Despite their widespread use in these fields, their incorporation into condensed matter research and quantum computing remains limited. To address this shortfall, we have undertaken the design and simulation of a 1 Tesla HTS magnet. This magnet is specifically engineered to facilitate experiments that probe quantum phenomena and the behavior of matter under extreme conditions—enabling detailed magnetoresistance measurements to investigate weak localization, superconductivity, and magnetism.

In this research, to design and simulate a 1 Tesla high-temperature superconducting (HTS) magnet, we first conducted numerical simulations with Mathematica software for a four-coil HTS tape wound second-generation HTS tape-based magnet. We computed the magnetic field distribution when a current of 73 amperes is passed through, producing an adequately uniform magnetic field of 1 Tesla at the center of the magnet. Besides that, thermal power calculations for the HTS magnet in a two-stage cryostat were also executed to check the thermal stability of the system.

For further enhancement of our outcomes and more realistic modelling, we have employed the FiQuS/Pancake3D library [5], an open-source Finite Element Quench Simulator developed at CERN, intended to carry out transient simulations of no-insulation (NI) HTS pancake coils in three dimensions. This simulation module is capable of both magnetodynamic and coupled magneto-thermal simulations. Because of using thin-shell approximations, H-ϕ formulation, and anisotropic homogenization techniques, the turn of the coil is solved economically at the mesh level.

We present a comprehensive table of key setup parameters, along with simulation results illustrating the magnetic field distribution and temperature profile. Our findings demonstrate a stable 1 Tesla magnetic field at the magnet's center and confirm the thermal stability of the HTS magnet within the cryogenic system. These results mark a significant step toward advancing HTS magnet technology for applications in condensed matter physics, quantum transport, and quantum science.

Specification	Value
Inner diameter of the coil	18 mm
Outer diameter of the coil	34 mm
Width of high-temperature superconductor (HTS) tape	0.4 mm
Thickness of HTS tape	0.09 mm
Length of HTS tape per coil	7000 mm
Number of turns per coil	87
Distance between coils	130 mm
Critical current at reference point	770 A
Initial temperature	4 K
Applied current	73 A



References

[1] Y. Li, *Superconductor Science and Technology* (2025).
[2] M.V.S. Elipe, I.E. Ndukwe, J.I. Murray, *Magnetic Resonance in Chemistry*, 62(7), 512-534 (2024).
[3] D. Torsello *et al.*, *Superconductor Science and Technology* (2025).
[4] F. Dong *et al.*, *Energy Conversion and Management*, 314, 118725 (2024).
[5] S. Atalay *et al.*, *Superconductor Science and Technology*, 37(6), 065005 (2024).

Poster Presentation

Phase Stability, Structure and Magnetic Properties of Ni-Co-Mn-Ti Heusler Alloys

K.R. Erager, V.V. Sokolovskiy, V.D. Buchelnikov
Chelyabinsk State University, Chelyabinsk, 454001 Russia
Email: eragerk@rambler.ru

The present work is devoted to one of the most important and promising areas of modern materials science: the study of multi-caloric solid-state materials. The subject has gained considerable popularity as a result of the growing issue of energy efficiency. In particular, the issues of phase stability and intermetallic compound stability are of both fundamental and applied interest, as they are crucial for the synthesis of homogeneous alloys with enhanced physical and mechanical properties. Given these considerations, investigating the decomposition trends of Ni-Co-Mn-Ti Heusler alloys into stable components represents an urgent research challenge.

This work is aimed at first-principles studies on the phase stability and segregation resistance of Heusler alloys based on $Ni_{2-x}Co_xMn_{1+y}Ti_{1-y}$ (x = 0, 0.25, 0.5 and y = 0, 0.25, 0.5, 0.75).

The calculations were performed in the scope of density functional theory in an environment of a VASP software package [1, 2] in the PBE functional approximation [3]. The crystal structure of the austenitic phase is set by a 16-atomic cubic cell of space symmetry group No. 225 with magnetic moments arranged both according to the staggered and layer-by-layer packing with ferromagnetic (FM) and ferromagnetic (FiM) ordering. While changing the concentration of the compositions under consideration, excess Mn atoms were embedded into the Ti sublattice. For compositions with a Mn concentration higher than 37.5 at %, we searched through all the possible atomic environments for Mn atoms at Z sites using a 32-atomic supercell, in order to eliminate the defect of the “infinite” plane of Mn atoms.

The calculations results show that the doping Co prefers to occupy the Ni sublattice, and Co atoms tend to substitute the nearest neighboring Ni atoms. It has been shown that alloying with Co provides an increase in the stability of the cubic phase as compared with the tetragonal phase with the staggered ordering of the magnetic moments. The results calculations for the decomposition energy a possible metastability of all the configurations under consideration, i.e., the fact that the synthesis of such configuration under normal conditions is quite possible.

This study was supported by the Russian Science Foundation, project no. 25-12-20024.

References

[1] G. Kresse, J. Furthmüller, *Phys. Rev. B*, 54, 11169 (1996).
[2] G. Kresse, D. Joubert, *Phys. Rev. B*, 59, 1758 (1999).
[3] J.P. Perdew, K. Burke, M. Ernzerhof, *Phys. Rev. Lett.* 77, 3865 (1996).

Poster Presentation

Study of the influence of the density of ceramic targets on the superconducting properties of the $YBa_2Cu_3O_7$ HTSC conductor

A.A. Kamenev[1,2], A.M. Makarevich[2], P.N. Degtyarenko[2], V.N. Chepikov[2]

[1] *LLC Cryogenic technology and materials, 21205 Moscow, Russia, Skolkov, Bolshoy bulvar 42-1*
[2] *LLC S-innovatioms, 117246 Moscow, Russia, Nauchnyi proezd 20-2*
Email: a.kamenev@crotm.ru

The subject matter of this work is the fabrication the ceramic targets for high-temperature superconductor $YBa_2Cu_3O_7$ deposition PLD process. We study of the influence of the properties and characteristics of the ceramic target on the structure and properties of the resulting superconductor films. We produce $YBa_2Cu_3O_7$ ceramic targets of different density for deposition of HTSC layer. It has been determined that the thickness of the deposited HTSC layer increases with increasing density of the ceramic target. It was shown that the thickness increase of the HTSC film leads to an increase in the critical current, while the phase composition of the target and film remains unchanged.

Poster Presentation

Stimulus-sensitive core-shell structures for magnetically controlled drug delivery

M.A. Koliushenkov, A.A. Amirov, T.R. Nizamov

National University of Science and Technology «MISIS»
Email: koliushenkov.ma19@physics.msu.ru

The key concept of theranostics is the development of "smart" drug delivery systems with stimulus-sensitive functionality. [1] Such systems are capable of specifically responding to external and internal physical and chemical stimuli in the body. This study presents the results of the synthesis and characterization of functional nanocomposites based on magnetite nanoparticles for potential use in biomedical theranostic applications. Magnetite nanoparticles were produced by the method of "controlled live growth" in a polyol medium [2, 3], which allows precise regulation of their size and morphology. The influence of various synthesis parameters on the structural and morphological properties of nanoparticles was investigated, demonstrating the flexibility and adaptability of the proposed approach. It has been shown that the obtained particles can be used for hyperthermia (ILP ≈ 2 nH*m^2/kg). Another advantage of this method is that it makes it easy to functionalize the obtained magnetic nanoparticles by different polymers using nitrodophamine. The resultant nanoparticles were employed as cores for the creation of stimulus-responsive nanocomposite materials with polymer coatings. Three polymers were investigated: polyethylene glycol (PEG), thermosensitive poly(N-isopropylacrylamide) (PNIPAM), and a pH-responsive block copolymer (mPEG$_5$k-b-PLE$_{50}$). The thermosensitive polymer, PNIPAM, demonstrated a dramatic change in particle size (from 100 to 900 nm) near its lower critical solution temperature (≈ 32°C). This ensures controlled release of the substance when heated due to magnetic hyperthermia. In turn, the pH-sensitive composite, (Fe_3O_4@mPEG$_5$k-b-PLE$_{50}$), effectively releases the drug in an acidic environment that mimics the tumor microenvironment (the drug release reaches 40% of the maximum level). The obtained results demonstrate the potential of this approach for creating materials for magnetically controlled theranostics.

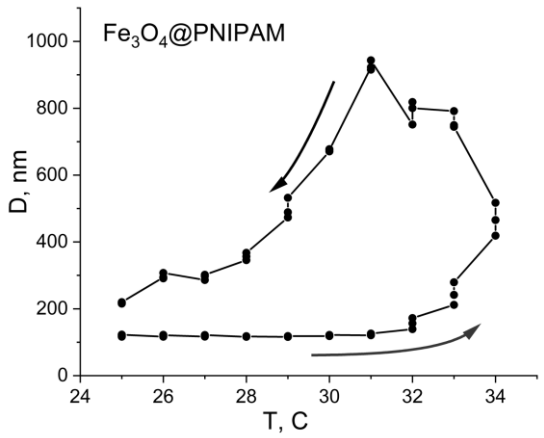


Fig. 1. Graph of the temperature dependence of the size of Fe_3O_4@PNIPAM composite particles.

This work was supported by the Russian Science Foundation (project no. 24-19-00782, https://rscf.ru/en/project/24-19-00782/).

References

[1] Z. Wang, Y. Sun, Y. Shen *et al.*, *Advanced NanoBiomed Research*, 4(3), 2300125 (2024).
[2] T.R. Nizamov, A.A. Amirov, T.O. Kuznetsova *et al.*, *Nanomaterials*, 13(5), 811 (2023).
[3] M. Abakumov, T. Nizamov, L. Yanchen *et al.*, *Mater. Lett.* 276, 128210 (2020).

Poster Presentation

Influence of artificial pinning centers on normal state transition in HTS tapes under the action of short current pulses

A. Malyavina, S.Pokrovskii, I. Martirosyan

National Research Nuclear University 'MEPhI', Moscow, Russia
Email: ayu.malyavina@gmail.com

High temperature superconducting (HTS) tapes based on the $REBa_2Cu_3O_{7-x}$ superconductor are becoming increasingly common in the development of high-field magnets [1], HTS switches [2], superconducting cables [3] and other superconducting devices. The use of artificial pinning centers is one of the ways to enhance the performance of HTS tapes for such applications. Investigating the influence of short current pulses on the process of superconductor transition to the normal state is crucial for understanding the dynamics of superconductors under real operating conditions and for developing more efficient technologies utilizing HTS materials.

This work investigates behavior of HTS tape with artificial pinning centers in two characteristic ranges of current pulse durations: millisecond and microsecond. Second-generation HTS tapes based on the $YBa_2Cu_3O_{7-x}$ superconductor, produced by S-Innovations, were used as a reference sample. The tape has the width of 4 mm and the critical current I_c = 140 A in its own field at liquid nitrogen temperatures.

The experimental data collected under millisecond current influence indicates the existence of a stable switching mode of the superconductor to the normal state at a current amplitude of approximately 1.3 I_c. The resistive switching mode, which occurs at a transport current exceeding 1.7 I_c, results in uncontrolled voltage growth and eventual degradation of the sample. A delay between the onset of the current pulse and the appearance of voltage on the sample was also found to decrease as the amplitude of the current pulse increased. Exposure to microsecond current pulses enables an increase in the amplitude of current pulses up to 3 I_c and allows the detection of a low-resistance switching mode occurring at currents below 2 I_c. This mode is accompanied by a voltage drop across the sample even before the current pulse ends. The appearance of voltage in the sample is caused by the Lorentz force exceeding the pinning force of vortices on defects. The dependence of voltage appearance on the amplitude of the current pulse for samples with different types of pinning has been obtained.

The work was carried out under the State Assignment (project FSWU-2025-0008) with the support of the Ministry of Science and Higher Education of the Russian Federation.

References

[1] H.W. Weijers, U.P. Trociewitz, W.D. Markiewicz *et al.*, *IEEE Trans. Appl. Supercond.* 20, 576 (2010).
[2] J. Hu, J. Ma, L. Hao *et al.*, *IEEE Trans. Appl. Supercond.* 32, 1 (2022).
[3] D.C. Van Der Laan, J.D. Weiss, D.M. McRae, *Supercond. Sci. Technol.* 32, 033001 (2019).

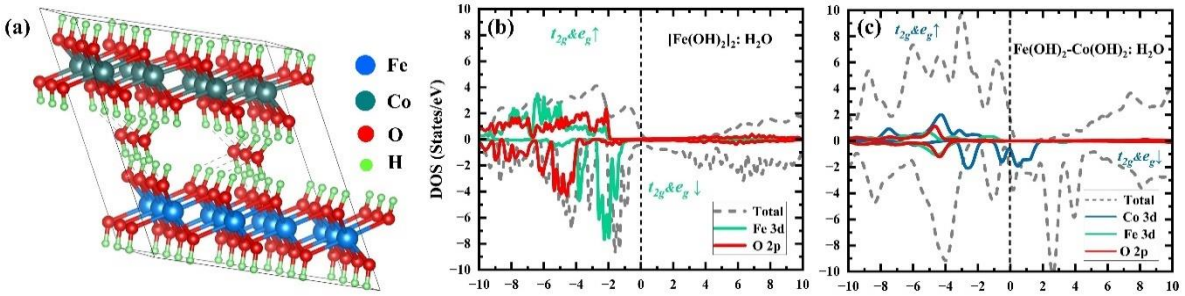
Poster Presentation

Electronic Characterization of Intercalated Magnetic Semiconductor Layered heterostructures for Spin-Enhanced Photovoltaics

S. Mohammadi, A. Shokri

Department of Theoretical and NanoPhysics, Faculty of Physics, Alzahra University, Tehran, Iran
Email: s.mohammadi427@gmail.com

Layered heterostructures have emerged as promising candidates for photovoltaic applications due to their exceptional electronic and magnetic characteristics [1]. It is widely recognized that the efficiency of photovoltaic devices is largely governed by the bandgap and the band alignment at the material interface [2]. The spin photovoltaic effect has the potential to generate a pure spin current under illumination without requiring physical contacts [3]. We propose that a deeper investigation of spin-related effects on their electronic and magnetic behavior could offer valuable insights for the development of next-generation, high-performance photovoltaic technologies. In this study, we employed density functional theory (DFT) to design a two-layer heterostructure by integrating $Fe(OH)_2$ with $Co(OH)_2$. For the $[Fe(OH)_2]_2 : H_2O$, the magnetic moment of each Fe ion was calculated to be 3.82 μ_B, consistent with a high-spin d^6 electronic configuration.



In the case of the $Fe(OH)_2$ / $Co(OH)_2$ heterostructure with water intercalation, each Co ion exhibits a magnetic moment of approximately 3.5μ_B, which aligns with the high-spin d^7 configuration. The bandgap is a critical parameter that governs a material's sensitivity to photoexcitation. For effective electron-hole pair generation under visible light, an $E_g \sim 1.7eV$ is generally considered optimal. Our calculations reveal that the E_g is 2.32 eV for $[Fe(OH)_2]_2 : H_2O$ and 1.68 eV for $Fe(OH)_2$ / $Co(OH)_2 : H_2O$. These findings suggest that by adjusting the heterostructure and intercalated molecules, it is possible to tune the bandgap of these compounds to suit specific photovoltaic or photocatalytic applications.

References

[1] J. Hao, D.L. Zhang, Z. Wang, *et al.*, *J. Surf. Interfac.* 58, 105837 (2025).
[2] R. Karimi, N. Ghobadi, *J. Phys. Chem. Solids.* 199, 112545 (2025).
[3] H. Wang, J. Meng, P. Guo, *et al.*, Appl. Surf. Sci. 692, 162779 (2025).

Poster Presentation

Spin diffusion length in NiFe/Spacer/IrMn structures with varied spacer thickness Ta and Cu

M.V. Bakhmetiev[1,2,3], R.B. Morgunov[1,2], A.I. Chernov[2,3]

[1] *Federal Research Center of Problems of Chemical Physics and Medicinal Chemistry, Russian Academy of Sciences, 142432, Chernogolovka, Russia*
[2] *Russian Quantum Center, Skolkovo innovation city, 121205, Moscow, Russia*
[3] *Moscow Institute of Physics and Technology, 141700 Dolgoprudny, Russia*
Email: Spintronics2022@yandex.ru

The conversion of charge into spin current is usually described by two material parameters, namely the spin Hall angle (SHE) and the spin diffusion length (SDL). SHE determines the efficiency of conversion between charge and spin currents, while the SDL parameter gives the length scale at which nonequilibrium spins can maintain their spin state and closely correlates with the spin relaxation process. Although SDL in NM/FM heterostructures has been widely studied both experimentally and theoretically [1,2], the results still remain controversial. In this work we investigated the influence of the Cu and Ta spacer on the spin diffusion length probed by planar Hall effect in NiFe/Ta/IrMn and NiFe/Cu/IrMn structures (Fig. 1).

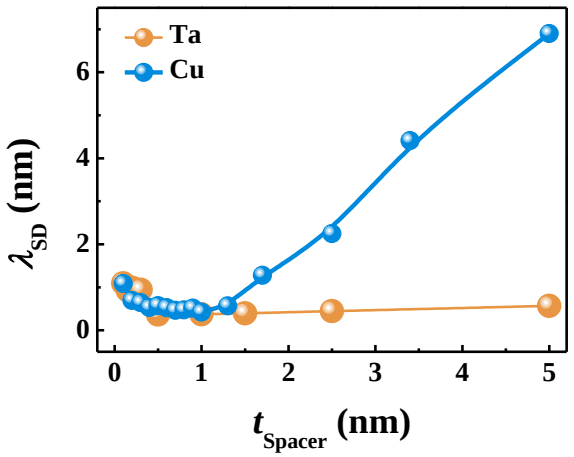


Fig. 1. Dependences of the spin diffusion length on the thickness of the Ta and Cu spacer.

The spin diffusion length λ_{SD} in NiFe/Ta/IrMn and NiFe/Cu/IrMn depends on the spacer thickness and decreases monotonically in the thickness range of t_{Spacer} = 0-1 nm. However, for copper t_{Cu} > 1 nm the spin diffusion length increases and becomes equal to 7 nm at t_{Cu} = 5 nm. These results indicate the contribution of the Dyakonov-Perel mechanism to the spin relaxation process due to the Rashba interface spin-orbit coupling [2] in NM/FM heterostructures.

References

[1] R.B. Morgunov, M.V. Bakhmetiev, *Phys. Sol. State.* 66, 1851-1856 (2025).
[2] G. Mihajlovic, O. Mosendz, L. Wan, *et. al., Appl. Phys. Lett.* 109, 192404 (2016).

Poster Presentation

Electronic structure, electronic and magnetic properties of $Co_{2-x}Mn_{1+x}Al$ (x = 0; 0,25; 0,5; 0,75; 1) Heusler alloys

A.A. Semiannikova[1], A.V. Lukoyanov[1,2], V.Yu. Irkhin[1], E.D. Chernov[1], E.I. Shreder[1], A.A. Markin[1], A.V. Protasov[1], E.B. Marchenkova[1], V.V. Marchenkov[1,2]

[1] *M.N. Mikheev Institute of Metal Physics UB RAS, Yekaterinburg, Russia*
[2] *Ural Federal University, Yekaterinburg, Russia*
Email: semiannikova@imp.uran.ru

The promising $Co_{2-x}Mn_{1+x}Al$ (x = 0; 0.25; 0.5; 0.75; 1) Heusler alloys are useful for spintronic devices since they possess a high degree of spin polarization of charge carriers. The electronic structure of ferromagnetic Mn_2CoAl and Co_2MnAl Heusler compounds can lead to the state of a spin gapless semiconductor (SGS) [1] and properties of a topological semimetal (TSM) [2, 3, 4], respectively. The band structure of ferromagnetic SGS has a wide ($\Delta E \sim 1$ eV) gap near the Fermi level for electronic states with one spin projection, while a zero energy gap occurs for the opposite spin projection. The TSM structure is characterized by Weyl points and nodal rings near the Fermi level and the exotic gapless surface states referred to as Fermi arcs.

The aim of the work is to study the transition from Co_2MnAl with topological properties to the Mn_2CoAl in the SGS state, as well as to establish patterns of the electronic and magnetic characteristic behavior of the $Co_{2-x}Mn_{1+x}Al$ (x = 0; 0.25; 0.5; 0.75; 1) alloys.

The studied alloys were synthesized by arc melting and subjected to rapid melt quenching. The electrical and Hall resistivities were obtained using the standard four-contact method. The magnetization and Hall effect were measured at T = 4.2 K and in magnetic fields of up to 70 kOe. The electronic structure was calculated using DFT methods with different types of exchange-correlation potential.

Since the alloys studied are ferromagnetic, an anomalous Hall effect is observed in addition to the normal one. Using a single-band model, the concentration and mobility of charge carriers prevailing in these compounds were estimated. According to [2, 4], the large value of the anomalous Hall effect in the Co_2MnAl compound indicates TSM features (the Berry curvature). As the concentration of manganese increases, a transition to the SGS state with a vanishingly small energy gap for one spin projection is observed.

The research was supported by RSF (project No. 24-72-00152).

References

[1] X.L. Wang, *Phys. Rev. Lett.* 100, 156404 (2008).
[2] K. Manna, Y. Sun, L. Muechler *et al., Nat. Rev. Mater.* 3, 244 (2018).
[3] S.-Y. Xu, I. Belopolski, N. Alidoust *et al., Science,* 349, 613 (2015).
[4] P. Li, J. Koo, W. Ning *et al., Nat Commun* 11, 3476 (2020).

Poster Presentation

Effect of Coulomb correlations on the electronic structure, magnetic and superconducting properties of iron and iron-based compounds

S.L. Skornyakov[1,2], A.S. Belozerov[1], A.A. Katanin[1,3], V.I. Anisimov[1,2]

[1]*M. N. Mikheev Institute of Metal Physics of Ural Branch of Russian Academy of Sciences, 18 S. Kovalevskaya Street, 620108 Yekaterinburg, Russia,*
[2]*Ural Federal University, 19 Mira Street, 620062 Yekaterinburg, Russia*
[3] *Center for Photonics and 2D Materials, Moscow Institute of Physics and Technology, Institutsky lane 9, Dolgoprudny, 141700, Moscow region, Russia*
Email: skornyakov@imp.uran.ru

The properties of iron and its compounds traditionally attract the attention of a broad circle of researchers. Over the past twenty years, this interest has only enhanced due to the discovery of an entirely new class of superconducting materials based on iron (pnictides and chalcogenides), and the superconductivity of epsilon-iron. At present, much attention is paid to microscopic first-principle modeling of the electronic structure of iron-based systems, aimed at explaining their phase diagram, in particular, understanding the nature of the superconducting state. Here, we employ the dynamical mean-field theory plus density functional theory (DFT+DMFT) method to account for the effect of local Coulomb correlations between Fe 3d electrons and present our results for the electronic structure, magnetic and superconducting properties of epsilon-iron and binary iron-based chalcogenides.

We demonstrate that Coulomb correlations in all considered compounds yield a moderate enhancement of the quasiparticle mass m*/m and their effect on the spectral properties can be described by a renormalization of the DFT spectral functions and electronic bands in the vicinity of the Fermi energy. Specifically, the calculated m*/m for epsilon-iron ranges from 1.5 (33 GPa) to 1.8 (12 GPa) and reaches 2 for the iron-based superconductor FeSe. We show that these transformations of the spectral functions do not induce a qualitative changes of the Fermi surface and the electronic self-energies obey the Fermi-liquid behavior in the temperature range below 1000 K. In addition, we calculate the imaginary time spin correlation functions and the nonuniform spin susceptibility which indicate the presence of strong antiferromagnetic fluctuations and short-lived local moments.

Using the DFT+DMFT local self-energy and particle-hole bubbles obtained for epsilon-iron we solve the multiband Bethe-Salpeter equation. We analyze the evolution of its eigenvalues and eigenfunctions under pressure and speculate on the spin-fluctuation mediated mechanism of the superconductivity. In particular, it was established that the tendency to superconducting pairing becomes weaker under pressure consistent with vanishing of the superconductivity at 30 GPa.

This research was supported by the Russian Science Foundation (Project No. 24-12-00024)

Table of Contents

Topics 1
Organizers 1
Sponsors 1
Supporting Organizations 1
Conference Committees 2
Conference Venue 3

Plenary Speakers & Abstracts of their Presentations

Konstantin Arutyunov 5
Fundamental limitations and perspectives of nanoelectronics development 6

Dariusz Kaczorowski 7
Unconventional superconductivity in Ce-based heavy-fermion compounds 8

Karen Martirosyan 9
Magnetoelectric Materials: Structural Characterization and Multifunctional Applications 10

Ulf Wiedwald 11
Harnessing Bioengineered Magnetic Nanoparticles for Advanced Theranostics 12

Abstracts of Invited & Special Presentations

Magnetic nanoparticles in biomedicine: effects of shape, size and structure on biomedical applications 14
M.A Abakumov

Accurate Derivation of Exchange Interactions from DFT: Mapping Methods, Supercell Optimization, and Functional Benchmarking 15
M. Alaei

Magnetic nanoparticle tuning for active biosensing performance 16
M. Angelakeris

Proximity induced superconductivity in electroactive polymer 17
K.Yu. Arutyunov

Constraints on an order parameter in the candidate chiral superconductor 4Hb-TaS_2 from a study of the lower critical field 18
T. Cichorek

Femto-Nm Torques Generated by Single Magnetic Particles for Cell Actuation Measured by AFM Magnetometry 20
M. Efremova

Advanced Processing of Ni-Mn-Sn Heusler Alloys for Magnetic Hysteresis Design via Additive Manufacturing .. 22
B. Gökce

Planar Tunnel Spectroscopy of $CeCoIn_5$: Investigation of local-moment pairing 24
L.H. Greene

Vortex-core states, conductance modulations and Lifshitz transition revealed in Bi-2212 with Scanning Tunneling Spectroscopy 25
I. Maggio-Aprile

Interplay between intra- and interparticle effects in bi-magnetic core/shell nanoarchitectures 26
D. Peddis

Superconductivity in Hydrides at Nearly Room Temperature 28
V.M. Pudalov

X-ray Magnetic Circular Dichroism as a Probe of Emergent Magnetic States in Unconventional Superconductors 29
A. Rogalev

Correlating enhanced spin pumping efficiency and atomic dislocation densities at Fe/Rh bilayer interfaces 30
A. Semisalova

Room-temperature ferromagnetism in nanocrystalline CoMnFeNiGa high entropy alloys: Across different length scales 32
N.F. Shkodich

Tuneable magnetic remanence of nanoscale antiferromagnetically coupled Fe_3O_4 halves in a silica shell 34
M. Spasova

Abstracts of Oral Presentations

Normal Zone Propagation and Thermal Stability in Multi-Tape Superconducting Cables for High-Field Applications 36
D.A. Aleksandrov

On methods of direct measurement of magnetocaloric effect in the temperature range of 4-400 K under AC magnetic fields 37
A. M. Aliev

Electrically Controlled Crossed Andreev Reflection in Two-Dimensional Antiferromagnets 38
A. Qaiumzadeh

From superconductivity to non-superconductivity in LiPdH: a first principle approach 39
Z. Alizadeh

Recent advances in biomedical applications of magnetocaloric materials: case of FeRh 40
A. Amirov

Electron-phonon interaction and spin triplet superconductivity in layered square lattice bilayers 41
V. Apinyan

Synthesis of CoMnFeNi high entropy alloy doped with In, Ga and Sn for permanent magnet applications 43
A.L.M. Feitosa

Inverse-Direct Crossover Adiabatic Temperature Change in Cyclic Magnetic Fields in $Ni_{36.5}Co_{13.5}Mn_{35}Ti_{15}$ Alloy Near the Martensite-Austenite Phase Transition 44
A.G. Gamzatov

Magnetic hyperthermia effect and equilibrium susceptibility in core-shell Fe-Fe_3C nanoparticles 45
H. Gyulasaryan

Design and engineering of Iron-Carbon nanocomposites 46
D. Hambardzumyan

Topological materials exhibiting surface and bulk superconductivity 47
M. Kargarian

Enhanced magnetization and coercivity of CoCrFeMnNi (Cantor) high entropy alloy by Ag addition 48
E. Kasotakis

Magnetic and Transport Properties of Mn_2FeSn.....50
V. Khovaylo

Dextran coated iron oxide nanoparticles: magnetic hyperthermia and cytotoxicity.....51
Kh. Kirakosyan

Study of structural, electronic and magnetotransport properties of functional materials based on cobalt oxide, irradiated to improve operational characteristics in ultra-high-frequency spintronics devices 53
E.A. Klevtsova

Study of interaction of single-molecular magnets with superconducting particles 54
E.I. Kunitsyna

Prospects for Using Conventional Superconductors in the Design of the Detection Pixel of a Thermoelectric Single Photon Detector 55
A.A. Kuzanyan

Normal Zone Propagation Processes in non-insulated HTS Windings for High-Field Electromagnets 56
I.V. Martirosian

Terahertz-Driven Exchange Mode in a Ferrimagnetic Cavity 57
E.A. Mashkovich

Effects of High Pressure on Structural and Electronic Properties of High-Temperature Superconductor $YBa_2Cu_3O_{7-\delta}$ 58
M. Matyunina

Electronic structure of all-d-metal Ni(-Co)-Mn-Ti vs. p-d Ni_2MnSn: Insights from DFT and XAS 59
O. Miroshkina

Strain driven magnetocaloric effect in Gd microwires and films 60
R. Morgunov

Development of technology for remote magnetomechanical control of the structure of molecular systems.....61
A.A. Nikitin

Electric field driven flat bands in S=1/2 sawtooth chain 63
V. Ohanyan

Critical Current Density in Superconducting Tapes by Applying Randomness on the Radii of Pining Centers in Triangular and Conformal Pinning Arrays 64
Z.Owjifard

Impurities impact on vortex dynamics in the vicinity of the Bogomolny point 65
V. Pashkovskaia

Ferromagnetic resonance at superconducting proximity effect 66
N. Pugach

YBCO Weak Link Construction Using Maskless Lithography 67
R. Rajabi

Manifestation of the Mutual Influence of Superconductivity and Magnetism in Josephson Structures with a Magnetic 68
Yu. M. Shukrinov

Ab initio and Monte Carlo approaches for the magnetic and magnetocaloric properties in Ni-Co-Mn-Ti Heusler alloy 69
V. Sokolovskiy

Spin Switching and Exchange Bias Effect in Compensated Ferrimagnets....70
A. Wisniewski

Abstracts of Poster Presentations

Stability of adiabatic temperature change of $La_{0.7}Ce_{0.3}Fe_{11.45}Mn_{0.2}Si_{1.35}$ alloys under long-term exposure to cyclic magnetic fields....72
A.G. Gamzatov

Magnetic phase separation in $La_{0.8}Pr_{0.2}Fe_{13.7}Si_{1.3}$-Hd alloys induced by long-term exposure to cyclic magnetic fields....73
A.G. Gamzatov

Ternary Superconducting Hydrides in Ca-Y-H system....74
M.A. Grebenuik

Design and Numerical Simulation of 1 Tesla High-Temperature Superconducting Magnet....75
Z. Dastani

Phase Stability, Structure and Magnetic Properties of Ni-Co-Mn-Ti Heusler Alloys....77
K.R. Erager

Study of the influence of the density of ceramic targets on the superconducting properties of the $YBa_2Cu_3O_7$ HTSC conductor....78
A.A. Kamenev

Stimulus-sensitive core-shell structures for magnetically controlled drug delivery....79
M.A. Koliushenkov

Influence of artificial pinning centers on normal state transition in HTS tapes under the action of short current pulses....80
A. Malyavina

Electronic Characterization of Intercalated Magnetic Semiconductor Layered heterostructures for Spin-Enhanced Photovoltaics....81
S. Mohammadi

Spin diffusion length in NiFe/Spacer/IrMn structures with varied spacer thickness Ta and Cu....82
R.B. Morgunov

Electronic structure, electronic and magnetic properties of $Co_{2-x}Mn_{1+x}Al$ (x = 0; 0,25; 0,5; 0,75; 1) Heusler alloys 83
A.A. Semiannikova

Effect of Coulomb correlations on the electronic structure, magnetic and superconducting properties of iron and iron-based compounds....84
S.L. Skornyakov