Dynamics of strongly correlated spin systems with reduced dimensionality and/or frustration

In recent years, a large number of studies have been devoted to finding suitable environments and systems for the implementation of modern high-tech projects, such as: quantum computing systems, miniaturization and reduction of energy consumption of information storage media, ultrasensitive sensors for measuring of various physical characteristics, and so on. In many, if not saying the most of such systems, the processes associated with spin interactions are considered fundamental for achieving the stated goals. Therefore, ongoing active studies of spin dynamics processes under conditions of their significant correlation are aimed not only at improving the currently known properties of functional systems and materials, but also at finding fundamentally new phenomena that can open new horizons for the application of magnetism in future technologies. The studies presented in this issue are devoted to various aspects of the manifestations of spin interactions, complicated in many cases by frustrations, the contribution of relativistic interactions, the conditions of nonlinear regimes of excitation, the presence of extended defects such as interface boundaries, a reduced dimensionality of magnetic structures, topologically protected states, and interaction with carriers of current.

The authors of opening article V. O. Cheranovskii, V. V. Slavin, and D. J. Klein investigated some class of frustrated one-dimensional periodic spin systems with Heisenberg exchange interaction. The considered cases include structures with quantum spin 1/2, the unit cells of which contain triangular fragments and/or short linear segments with odd number of sites. Using DMRG method and perturbation theory some interesting results, were achieved. The excitation spectrum was appeared to be gapless in spite of even number of total sites in the unit cell. The authors investigated the tendency of considered systems to Peierls instability and their dependence on the parameters of the models. In some systems a quantum phase transition was discovered, which is associated with the ground state symmetry.

Another article by the author E. V. Ezerskaya investigated similar one-dimensional systems, but with the Ising type of interactions between complex unit cells. The thermodynamics of such systems also has interesting features. It was shown that the field dependences of the magnetization at low temperatures for some of the models under consideration have an intermediate magnetization plateau, when the interactions have an antiferromagnetic Ising character. Moreover, the temperature dependence of the specific heat can demonstrate several maxima even at zero magnetic fields. Among the important results of the article, one can note the covering of the fact that different geometry of exchange bonds connecting neighboring unit cells can have a decisive effect on the temperature and field dependences of heat capacity and magnetic susceptibility even with the same values of the main interactions within unit cells.

The work of M. M. Bogdan and O. V. Charkina presents the investigations of nonlinear dynamics of the one-dimensional ferromagnetic sine-Gordon systems. The most interesting result of this paper belongs to the detection of the continuous spectrum wave irradiation during the nonstationary process of relaxation. At the same time the energy of the system is localized inside topological inhomogeneities, domain walls, in the form of breather. Authors also note that their results can be applied to other physical systems, which are described by the sine-Gordon model such as the long Josephson junctions with their fluxon dynamics.

In the paper of A. Gudyma and Iu. Gudyma the one-dimensional magnetic system was theoretically investigated using the transfer matrix formalism in the aim of determining the influence of external factors, temperature and pressure, onto the position of crossover from high to low spin state. Thermodynamic characteristics of the system, such as magnetic susceptibility and specific heat capacity, are also obtained. For that purpose the authors of the paper modify the transfer-matrix method to the form, which allow them to derive exact results for these basic thermodynamic quantities and pair correlation functions.

A. I. D'yachenko, V. N. Krivoruchko and V. Yu. Tarenkov investigated experimentally the volt-ampere characteristics and their temperature dependence in the complex superconducting matter, chaotic two-component nanocomposites consisting of micron-sized grains of *d*-wave superconductor $Bi_2Sr_2Ca_2Cu_3O_{10+x}$ surrounded of nanometer-sized particles of half-metallic $La_{2/3}Sr_{1/3}MnO_3$ ferromagnet. They have revealed that in the samples with 4:1 volume content of the components the Berezinskii–Kosterlitz–Thouless like transition take a place, which is characteristic for two-dimensional superconductors. The authors made the explanation of that feature basing on the presence of two spatial scales in this type of systems: significant difference between geometrical dimensions of the constituent components, and appearance of related superconducting correlation length of "additional" (triplet) superconducting state induced by the proximity effect in half-metallic manganite nanoparticles. They showed that the reduction of effective dimensionality for superconducting correlations can result in the resistive losses determined by the current flowing through the ferromagnetic nanogranules which cover the superconductor grains. At the temperature decreasing the Berezinskii–Kosterlitz–Thouless like transition occurs in effectively 2D manganite cover that undergoes to a superconducting state due to the proximity effect. The authors accentuate that apart from the pure fundamental interest, the transport properties of high-T_c superconductor–half-metal composites are relevant for superconducting spintronics as potential functional materials.

Numerical studies of the frustrated antiferromagnetic Ising model on a body-centered cubic lattice with competing exchange interactions were carried out in their work by the authors of K. S. Murtazaev, A. K. Murtazaev, M. K. Ramazanov, M. A. Magomedov, A. A. Murtazaeva using the replica algorithm of the Monte Carlo method. They showed that, in the model under consideration, a second-order phase transition can be observed in the range of magnetic field values $7.0 \leq H \leq 10.0$, which is replaced by a first-order transition in the region $11.0 \leq H \leq 13.0$. It was also shown that a further increase in the magnetic field strength generally suppresses this phase transition. The obtained results of these studies are important for understanding the role of frustration in the formation of the phase diagram of such three-dimensional highly symmetric magnetic systems.

The magnetic properties of multilayer film spin-valve systems [Fe/Py]/FeMn/Py were investigated depending on the temperature and thickness of the antiferromagnetic FeMn spacer using SQUID magnetometry in the article of author collective of D. M. Polishchuk, O. I. Nakonechna, Ya. M. Lytvynenko, V. Kuncser, Yu. O. Savina, V. O. Pashchenko, A. F. Kravets, A. I. Tovstolytkin, V. Korenivski. They showed a significant change in properties of the considered systems with an increase in the thickness of the antiferromagnetic spacer from 6 nm to 15 nm. Whereas such a sandwich structure demonstrates pinned state of the side ferromagnetic layers in the samples with an interval of 15 nm in the entire temperature range of studies of 5–300 K, ones become de-pinned in the samples with 6 nm thick spacer. Such finite-size effect was explained as a possibility of direct interlayer interaction between ferromagnetic layers through a thin antiferromagnetic spacer. These studies are of direct relevance to spin valve technology for spintronic applications.

The paper by A. Druzhinin, I. Ostrovskii, Yu. Khoverko, N. Liakh-Kaguy is devoted to the study of the magnetoresistance of silicon whiskers doped with nickel and boron, in which a metal-insulator transition is observed. It was shown that the features of magnetoresistance at low temperatures are caused by the "core-shell" structure of the crystals. The authors showed that the transition from the classical to quantum magnetoresistance regime occurs in the near-surface region of the crystal in a critical magnetic field. Due to the effect of giant magnetoresistance, silicon whiskers can be used for design of magnetic field sensors.

In the article by Yu. Gorobets, O. Gorobets, I. Tiukavkina, R. Gerasimenko, the problem of the propagation of a spin wave through a system consisting of two ferromagnets separated by a plane interface was considered. The only difference between the two separated parts is the presence or absence of the Dzyaloshinsky–Moriya interaction in the magnetic properties of the left and right half-spaces. The dependences of the transmission and reflection coefficients of a spin wave are found as a function of the Dzyaloshinskii–Moria constant. The possibility of changing the value of this constant, for example, with respect to temperature, opens up the possibility of applying this effect in the field of magnonics.

In the article by V. S. Kurnosov presents experimental studies of the quasi-one-dimensional antiferromagnet $CsFeCl_3 \cdot 2H_2O$ by the method of Raman spectroscopy. The Ising character of magnetic ions, dictated by the structure of the ground state of Fe^{2+}, determines its unusual magnetic properties, such as the presence of a spin cant as a result of large single-ion anisotropy, which causes some peculiarities in the kinetics of metamagnetic phase transitions. Investigations of the splitting and shifts of Raman lines of electronic origin in an external magnetic field allowed the author to estimate the values of the magnetic moments of the sublattices in the ground state and to determine their spatial orientation relative to the crystallographic directions. The low-energy structure of the electronic spectrum, together with spin configurations in various magnetic phases, determines the low-temperature thermodynamic properties of this and similar compounds, which can serve as model systems for low-dimensional magnetism.

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