Igor Orestovich Kulik
To the 75th birthday anniversary

Igor Orestovich Kulik — a prominent physicist and an outstanding representative of Kharkov's school of theoretical physics, Corresponding member of the National Academy of Sciences of Ukraine and Ukrainian State Prize Laureate — will be 75 on November 19 this year. During his long scientific career he has obtained an impressive number of groundbreaking results in several areas of modern Solid State Physics, such as the theory of superconductivity, the physics of metals, and solid state spectroscopy. The theory of the electrodynamics of Josephson weak links, developed by Igor Kulik, brought him fame and world recognition as did his theory of coherent current states in point contacts. Another important result is his prediction of the vortex structure of superconducting surface sheaths in inclined magnetic fields, now known as «Kulik's vortices». Together with his group members and students he furthermore developed the theory of point-contact spectroscopy of elementary excitations in solids. He is (together with I.K. Yanson, A.N. Omelyanchouk, R.I. Shekhter and Yu.V. Sharvin) co-author of the Discovery (reg. numb. N238) of «The phenomenon of a current carrier's energy redistribution occurring in point contacts at low temperatures».

The most important of Igor Kulik's contributions to Solid State Physics — theoretical predictions, which were truly made well ahead of their time — concerned what we know now as mesoscopic phenomena. Being a manifestation of the prominent role of a single electronic degree of freedom in samples containing billions of particles, mesoscopic behavior originates from in particular two important sources: the quantum coherence of electrons and the Coulomb interaction between electrons. Igor Kulik and his collaborators were the first who predicted pronounced mesoscopic features originating from both these sources. These predictions concerned the existence of persistent currents in normal (nonsuperconducting) metal rings and cylinders, and that effect of electric-charge discreteness, which we now refer to as the Coulomb blockade of single-electron tunneling. Experimental confirmation of these predictions came only after 20 years, together with worldwide recognition of the importance of these and other early works on mesoscopic phenomena for the explosive development of modern nanoscience. Today, almost 40 years after Kulik's pioneering contributions, mesoscopic physics is a central part of and a basis for modern nanophysics. Several new research directions concerned with quantum coherence and Coulomb correlations and motivated by unprecedented experimental achievements are in the focus of attention today. We would like to mention some of them here.

Almost 40 years after Igor Kulik predicted the existence of persistent currents in mesoscopic rings and cylinders, we now witness a revival of interest in this topic stimulated by experimental observations of the predicted phenomenon in both ballistic and diffusive nanoscale samples. The nature of dissipation and the possible relaxation of the coherent current states in nonsuperconducting metal samples are in the focus of modern research in this area.

Active experimental and theoretical studies of electric weak links such as small size tunnel junctions, point contacts and micro-constrictions is a prominent feature of modern solid state research. Both normally conducting and superconducting weak links of nanometer size reveal mesoscopic behavior originating from electronic quantum coherence and quantization of electric charge states and current-carrying states in Josephson nanostructures. Mesoscopic weak superconductivity has been employed to implement quantum bit elements for possible quantum computation. New materials including nonconventional high-temperature superconductors, magnets and carbon-based materials (graphene and carbon nanotubes) have been employed as elements of superconducting nanostructures.

The interplay between quantum coherence and charging effects has been widely discussed during the last several years in connection with the properties of disordered and composite materials (granular metals, quantum-dot arrays, disordered thin films). The outstanding question concerning the nature of the experimentally discovered quantum phase transition from a superconducting to a dielectric state, experimentally observed in quench-condensed ultra-thin films, is one of the motivations for this activity.

Finally, progress in the self-assembly approach to manufacturing nanostructured metal-organic composite materials has lead to an interest in the mechanical deformations caused by single-electron tunneling. Due to prominent Coulomb-blockade effects, electronic and mechanical degrees of freedom of metal-organic composites become coupled and lead to a nanoelectromechanical (NEM) charge transport mechanism. Mesoscopic features of electronic states induce special NEM effects and a number of devices based on mesoscopic NEM phenomena have been suggested during recent years.

All the research directions mentioned above are represented by original papers and review articles in this special issue of «Fizika Nizkikh Temperatur», which is devoted to the 75th anniversary of Igor Orestovich Kulik. We are confident that these reports on frontline research in the currently very active field of mesoscopic Solid State Physics will contribute to a better understanding of the physics of quantum coherence and Coulomb correlations in superconducting and normal-metal nanostructures and in this way honour the work of Igor Kulik.

A.N. Omelyanchouk and R.I. Shekhter