DESCRIPTION FOR THE GENERAL PUBLIC

Superconductivity – a fascinating state of matter in which the electric current can flow without loss (zero resistance) was discovered more than 100 years ago. The most important achievements in experimental investigations and theoretical description of superconductivity have been honored with numerous Nobel Prizes. Unfortunately, the application of superconductivity in technology is severely limited by the need of expensive liquid helium as a coolant. However, superconducting electromagnets for the generation of strong magnetic fields in scientific laboratories or in medical diagnostics (Magnetic Resonance Imaging) and superconducting sensitive measuring devices (SQUID) are already widely used.

Superconductivity and magnetism – the two quantum phenomena that appear in a macroscopic scale are among the most important issues in contemporary solid state physics. It has long been considered that superconductivity and long-range magnetic ordering are unable to coexist, but in rare cases, coexistence of superconductivity with antiferromagnetism has been observed, and even less often, with ferromagnetism.

The recently discovered family of iron-containing superconductors has attracted a great attention. In these compounds, iron (Fe^{2+}) moments order antiferromagnetically in the form of spin density wave (SDW) and superconductivity occurs when the SDW order is suppressed due to chemical doping or upon application of high pressure. Among the iron superconductors, particularly interesting, unique properties are associated with $EuFe_2As_2$. In this compound, in addition to the SDW order of iron (T_{SDW} = 198 K), europium (Eu^{2+}) also order antiferromagnetically at T_N = 19 K, moreover, chemical doping leads to superconductivity. In $EuFe_2As_2$ doped with phosphorus or ruthenium, the coexistence of superconductivity and ferromagnetic ordering of Eu^{2+} has been reported and the occurrence of spontaneous vortices have been suggested. Thus, $EuFe_2As_2$ seems to be an ideal system for studying the relationship between superconductivity and magnetism.

From a very few literature reports it appears that the partial replacement of iron with nickel in $EuFe_2As_2$ suppresses the SDW order, however, this does not lead to the occurrence of superconductivity. Paradoxically, explaining the reasons for such behavior could make a significant contribution to the knowledge of superconductivity and magnetism of the entire group of iron superconductors.

Recently it has been reported that, substitution of a half the Eu ions by large radii ions like Rb^+ or Cs^+ leads to separation of Eu and Rb (or Cs) on separate planes in the $EuFe_2As_2$ crystal structure. The $EuRbFe_4As_4$ and $EuCsFe_4As_4$ compounds thus obtained exhibit superconductivity and Eu^{2+} ferromagnetic ordering.

The purpose of the proposed project is to investigate the coexistence of superconductivity and magnetic ordering in selected iron superconductors namely $EuFe_{2-x}Ni_xAs_2$, $EuRbFe_4As_4$ and $EuCsFe_4As_4$. We are going to grow a series of single crystals of these compounds and systematically examine their magnetic properties and electronic transport at low temperatures and external magnetic fields both under normal and under high pressure. Experimental studies will be supplemented by "ab initio" calculations of the electronic structure of the materials mentioned.

The results of our investigations and calculations will make a significant contribution to understanding the properties of iron superconductors. We hope to explain the reason for the absence of superconductivity in $EuFe_2As_2$ doped with nickel. The $EuRbFe_4As_4$ and $EuCsFe_4As_4$ single crystals grown for the first time will allow to determine their anisotropic magnetic properties and the mutual relations of magnetic order and superconductivity.