Abstract for The General Public:

(English version)

Superconductivity is a fantastic property of the materials that conduct the electrical current with nil resistance to the flow of electrons, thus without generating unwanted heat due to Joule heating effects. Additionally, when material is in the superconducting state, the magnetic field is expelled from its volume. All these amazing phenomena occur below a certain critical temperature (T_c), which is usually much below 0°C (273 K) and hence making practical utility very difficult. To discover superconductivity, in 1911, Kamerling Onnes had cooled the mercury down to 4.2 K – 4.2 degrees above absolute zero, that is - 269ºC. These materials are generally characterized by three parameters: T_c, upper critical field H_{c2} and critical current density J_c. The latter two are, surprisingly, even more important for applications than the temperature. Recent discovery of room temperature superconductors under High Pressure Techniques (HPT) has generated more interest in this field.

This project is focused on one of the newest family of High T_c Superconductor (HTS) – The iron-based superconductor (FBS) which were discovered in 2008. Before this discovery, theoretical models predicted that iron with a large magnetic moment is harmful to the emergence of superconductivity. Till today, more than 100 compounds are available under this family with numerous novel properties, which provide unique opportunity to understand the superconducting mechanism.

An exceptional property of FBS is their high critical magnetic field H_{c2}, often around 100 T. This value far exceeds the performance of so called conventional superconductors, NbTi and Nb_3Sn (H_{c2}~25 T), which are presently used in practical applications. There are other superconductors with similarly high H_{c2}, like *RE*BCO (*RE*$Ba_2Cu_3O_x$; *RE* = rare earth), that are, however, very difficult and expensive in large scale production. Nevertheless, a record man-made continuous magnetic field of 45 T was achieved using *RE*BCO superconducting coil placed inside a traditional copper coil – the first one producing 33 T. With FBS, it should be possible to achieve this value or higher magnetic fields without use of the copper coils – this would largely increase the accessibility of such devices.

To develop the material with such capabilities, more fundamental research is currently needed. The critical temperature T_c of FBS falls in a range between 5 and 60 K, and strongly depends on subtle changes in the crystal structure. These effects are not only informative on basic properties of materials, but also determine their applicability. At the current time, T_c of at least 30 K is expected by the industry. Additionally, high critical current at high magnetic fields is essential, especially to produce superconducting magnets. The J_c is the maximum electric current density that can flow through a superconducting material at a particular temperature and field. FBS has a fantastic property – their high critical current J_c does not decrease too much with magnetic field. Generally, the vortex dynamics control the entire electro-magnetic response of these superconducting materials including its current carrying capacity. However, the vortex physics of HTS are still unclear. Due to these problems, one could not design the samples with good initial current carrying properties, which is challenging for recently discovered compounds.

Our research project has a unique feature – High Pressure and High Temperature Synthesis method (HP-HTS). It distinguishes us from other groups around the world that mostly use processing at normal pressure. High pressure technique is a unique, rare and sophisticated technique. Few reports based on the high-pressure studies of FBS have proved that this technique is more advantageous in comparison to the conventional methods, such as the controlled modification of the phase diagram, enhanced reactivity, and prevention of the evaporation, etc. and also enhanced the superconducting properties, but a systematic and series of samples are needed to reach the intrinsic properties of FBS.

To overcome these problems, our project is designed to explore the intrinsic vortex pinning behaviours of HTS through systematic studies of FBS, and its application to understand the critical current (J_c) properties and anisotropic nature using a unique and rare high-pressure technique. Two challenging FBS families: 1111 (*RE*FeAsO; *RE*: rare earth) (as a doped family) and 1144 (*AeA*Fe_4As_4; *Ae* = Ca, Eu; *A* = K, Rb) (as stoichiometric family) are considered in this project, potentially. We will design and set-up HP-HTS technique and also the basic transport characterization sample holder attached to Cryogen free low temperature and high magnetic field facility. We will optimize various synthesis parameters to grow the high-quality single crystals and thin films by HP-HTS. Prepared samples are planned to characterize with a wide range of measurements to confirm the sample quality, and to analyse the superconducting properties and especially various pinning parameters. The outcomes of this project will provide the deeper understanding of the intrinsic vortex pinning mechanism and critical current properties of FBS under the shadow of chemical and applied pressure effects which will be appeared in many good international journals. Finally, the success of this project will reliably predict the electromagnetic properties of real superconducting materials. This project also allows to build and develop a successful work team that will focus on the fundamental studies through HPT in Poland.

This project will also strengthen the Polish cooperation in this research field and aware that challenging results can be expected using the unique facilities. We will also collaborate with different Polish groups and will share knowledge and the samples for more advanced characterizations.