Superconductivity is the set of physical properties observed in certain materials where electrical resistance vanishes and magnetic flux fields are expelled from the material. Any material exhibiting these properties is a superconductor. Unlike an ordinary metallic conductor, a superconductor has a characteristic critical temperature (T_c) below which the resistance drops abruptly to zero. In this specific state, an electric current through a loop of superconducting wire can persist indefinitely with no power source. The superconductivity phenomenon was discovered in 1911 by Dutch physicist Heike Kamerlingh Onnes, in a metal solid cooled to extremely low temperature of about -269°C. Since that discovery, many new families of superconducting materials have been discovered and studied.

The proposed project concerns the study of superconducting high entropy alloys (HEAs). HEAs are loosely defined as solid solution alloys that contain more than five principal elements in equal or near equal atomic percent. The concept of high entropy introduces a new path of developing advanced materials with unique properties, which cannot be achieved by the conventional alloying approach based on only one dominant element. Up to date, the designed HEAs were reported to have superior mechanical and physical properties, including excellent comparable strength to that of structural ceramics and some metallic glasses, ultrahigh fracture toughness exceeding that of most pure metals and alloys and significant resistance to corrosion. In 2014 the first HEA superconductor was found. After several years of intensive research, it seems that the superconducting behaviour of HEAs is distinct from copper oxide superconductors, Fe-based superconductors, conventional alloy superconductors and amorphous superconductors. Therefore, they can be considered as a separate class of superconducting material and due to that understanding the microscopic physics of superconductivity in HEAs should be the subject of active theoretical and experimental studies.

The most important aims of the project are listed below.

1. Synthesis of already known HEA superconductors using alternative fabrication method (mechanical alloying). Up to the present time, HEA superconductors are fabricated primarily through conventional arc-melting technique.
2. Understanding the influence of lattice defects on superconducting properties of studied HEAs. As it was shown recently for much simpler superconductor, the lattice defects are mainly responsible for changing some basic superconducting properties of Ta metal.
3. Synthesis of new HEA superconductors which contain uranium, thorium or/and lanthanides atoms. In 2020, the discovery of an f-electron containing HEA superconductor, $(TaNb)_{0.31}(TiUHf)_{0.69}$, was reported.
4. Developing a method of finding of new HEA superconductors using theoretical modelling. Until now, their selection and investigation have been done more or less by trial and error.

In my opinion, through this project, a newly established research team will get an exceptional opportunity to expand significantly our knowledge and understanding of HEA superconducting behaviour. In my opinion, the obtained results should have a great impact in the fields of solid state physics and materials science. Moreover, developing of new fabrication method, introducing large number of vacancies as well as preparing new HEA superconductors with uranium, thorium or/and lanthanides atoms may result in obtaining superconductors with improved superconducting properties such as higher critical temperature T_c, upper critical field H_{c2} and critical current j_c. These new materials with enhanced proprieties can be considered as good candidate materials for the fabrication of superconducting magnets which today are mainly constructed using NbTi or Nb_3Sn. At the same time, the development of computational method which could be applied to finding new types of HEA superconductors will significantly accelerate and facilitate those investigations, making them less expensive and more efficient.

The project will be implemented in collaboration with the University of Wrocław and the Institute of Low Temperatures and Structural Research, Polish Academy of Sciences.