The general objective of this project is to explore the possibility of producing immiscible systems with ultrafine-grained (UFG) or nanocrystalline (NC) structure by using a modified high-pressure torsion approach. Pure copper features very high electric and thermal conductivity, and thanks to this may be used in various industrial applications. It is foreseen that it may become the principal future structural material if its hardness, strength and thermal stability are improved. Across the broad spectrum of alloys there are many systems "immiscible systems", in which the two constituent elements show little or no mutual solubility even in liquid state up to very high temperatures. The fundamental exploration of alloying theory and phase transformation in such systems, gives a new opportunities for tailoring materials properties. In this project, we would like to study the possibility of production Cu-based immiscible systems using new approach of subjecting layered systems to high pressure torsion (HPT). It is assumed (hypothesis 1) that Cu-W, Cu-Co, Cu-Cr, Cu-Nb immiscible systems having UFG/NC structure can be produced by HPT in a new processing approach described in details in the detailed description. It is also assumed (hypothesis 2) that unique electrical and thermal conductivity of Cu can be mixed with high strength, magnetic properties and high thermal stability properties of reinforcing elements in a form of hybrid materials.

Because many structural factors may affect the properties of such immiscible materials, the specific objectives of the project were formed: 1) To understand the mechanisms of formation of immiscible systems processed via HPT, 2) To evaluate the influence of processing parameters on the microstructure, mechanical and physical properties. 3) To determine the thermal stability of such NC systems, 4) To understand the mechanism responsible in such acquired immiscible systems for the returning to equilibrium state during annealing

The systems will be fabricated in a collaboration with Prof. T.G. Langdon group from Southampton University. The materials will be synthesised in HPT process. A set of, three-layered and multilayered (at least 15) materials will be subjected by HPT processing up to 100 revolutions to fully mix phases. In the second task, the microstructures of processed samples will be studied with LM, SEM, FIB, TEM, STEM, EDX, XRD. Microstructures will be a subject of quantitative and qualitative analysis taking into account grain size and shape, as well as the distribution of elements in the metal matrix and 3D electron tomography studies. In task three, the mechanical properties (tensile tests and through microhardness measurements) as well as electrical and thermal conductivity of obtained systems will be studied. Finally, task four will aim to perform thermal stability tests, which is the main goal of this project. Three separate tests will be carried out. The first one will be differential scanning calorimetry which measures the energy released during thermal annealing of the material related to the microstructural changes. The second test will include conventional annealing of samples at various temperatures and times, which will be correlated with the structural and mechanical properties changes. The third one will be in-situ annealing in TEM to observe the interaction of moving grain boundaries with nanoreinforcement. The project concerns on the most important issue in materials science, namely how to obtain immiscible systems and what properties we may expect from them. There is a great potential for HPT processing to introduce new UFG/NC immiscible systems. However, investigations on the detailed microstructural changes are necessary to fully make use of this approach. In a larger perspective, the project results will have significant impact on various industries by providing in future new UFG thermally stable materials