Modern technologies require materials with an unusual combination of properties that cannot be achieved in conventional materials. To expand the range of conventional properties, a variety of multiphase alloys and composite materials have been developed that possess properties superior to each of the component phases. The materials tested in this work exhibit excellent properties, which can be improved using results of this project, especially concerning their mechanical strength. For example duplex stainless steel, containing two phases: ferrite and austenite, joins the advantages of every included phase, i.e., it is as strong as ferritic phase and corrosion resistant as austenitic phase. Other materials investigated in the present work are the metal matrix composites (e.g., Al/SiC), in which the ceramic reinforcement (SiC) improves significantly mechanical properties (stiffness and hardness) of the metal (Al) and does not increase mass density of the final material. Applications of MMC are widespread in the aerospace and automotive industries, where a reduction of weight of a vehicle will reduce its fuel consumption. The pearlitic steels, also investigated in this project, offer an excellent combination of ductility, strength and cost, and they are the most used plain carbon steels in manufacturing to produce wires for reinforcing tires, cables for suspension bridges, engineering springs. Two and single phase Ti alloys exhibit an excellent combination of strength, corrosion resistance, weldability and fabricability. Ti alloys are used in chemical industry as the corrosion resistant material, in aerospace and aircraft applications as the weight sawing mechanically strong material and for surgical implants because of excellent biocompatibility.

Study of mechanical properties of polycrystalline materials is an important domain in materials science field. Usually the macroscopic properties like elasticity modules, yield stress, work hardening or state of residual macrostress are studied neglecting heterogeneities of these properties occurring at the scale of grains. However, the macroscopic behaviour of materials is determined by processes occurring inside and between grains. The purpose of this project is to develop theoretical and experimental techniques for study of micromechanical properties of single and two phase polycrystalline materials. The study will be performed for bulk materials as well as for surface layers using diffraction methods and the results will be interpreted with help of the self-consistent model. The research will be focused on the investigation of the behaviour of polycrystalline grains during elasto-plastic deformation and damage process, especially the type of active slip systems, their activation, twinning phenomenon, intergranular stresses and microdamage occurring in the grains will be studied. As mentioned above, the developed methodologies will be tested on selected polycrystalline materials, therefore the results can be potentially used to improve mechanical properties of these materials.

In this project, the diffraction measurements will be performed using classical X-rays, synchrotron radiation and neutrons. Diffraction methods for lattice strain measurement can provide useful information concerning the nature of grain behaviour during elasto-plastic deformation. The lattice strains are determined from the shifts of measured diffraction peak positions. In addition, on the basis of the measured elastic strains, the stress state can be found. The advantage of the diffraction methods is that measurements are performed selectively only for the crystallites contributing to the measured diffraction peak. When several phases are present in the sample, measurement of separate diffraction peaks allows the investigation of the behaviour of each phase independently.

The lattice strains will be measured “in situ” during mechanical tests. The comparison of diffraction data with multi-scale models allow us the study of elasto-plastic deformation in microscopic and macroscopic scales. In this work also new methods enabling direct determining of stress localisation on particular grains or phases as well as critical stresses required to activate slips on crystallographic planes and twinning process will be proposed and tested. Finally, we will develop a methodology based on diffraction and used to identify in which phase the microdamage process is initiated. In interpretation of the experimental results, a new version of self-consistent model for damage prediction will be used.

The most important issue of this work is to propose original methods enabling to determine micromechanical properties of grains within polycrystalline materials directly from experiment. Consequently, the new methodologies will not depend on the assumptions of theoretical models used previously for interpretation. What is more, knowing behaviour of the material at the microscopic and macroscopic scales the theoretical models can be verified. This will be certainly very important tool for examination of stress localisation in a polycrystalline grain, which is used in the scale transitions models. The works planned in this project will allow to understand the physical phenomena, occurring during sample deformation and microdamage process at the level of polycrystalline grains. It should be underlined that the diffraction methods are the only ones, which can be used to study directly the mechanical behaviour of polycrystals at the scale of grains, thus the obtained results will be unique and will expand the knowledge about studied materials.