Many of the materials used in everyday life are polycrystalline materials and composites that are exposed to high stresses or large temperature fluctuations during production and further use. Therefore, materials of this type should be characterized by high resistance to temperature changes and external loads. It is very important to know internal structure and the response of the used materials to given external factors, such as elevated temperature or high external stresses. The macroscopic properties of polycrystalline materials are determined by the phenomena occurring in the polycrystalline grains and the interaction of these grains. The mechanical behaviour of the textured material can show very significant differences depending on the direction and type of the applied load.

The mechanical properties of polycrystalline materials at the scale of grains can be studied by various experimental methods, including diffraction methods, the advantages of which lie in their non-destructive nature and the possibility of independent measurements for individual phases or groups of grains. Diffraction methods allow us to determine stresses in polycrystalline materials by measuring of the elastic strains of the crystal lattice. One of the diffraction methods is neutron diffraction. It allows for deep penetration of the sample and measurements of the deformation of the crystal lattice under the influence of external conditions such as the applied stress or temperature. Simultaneous measurements performed for many phases in multiphase materials and many groups of crystallites in polycrystalline materials enable analysis of different physical phenomena such us e.g. crystallographic slips and twinning process. Determining the stresses in the phases of the material is possible by selecting the diffraction peaks originating from the diffraction on each of the phases of the material.

The aim of this project is to study localisation of the stresses in the grains of polycrystalline materials and investigation of the plastic deformation process occurring at the grains scale. The obtained results will be used to describe the mechanisms of plastic deformation at the grain level, i.e. to determine critical resolved shear stresses for slip systems and twinning and the strengthening of the material. The materials which will be studied in the frame of this project are two phase strongly textured brass (and optionally duplex steel) and textured magnesium alloy. The authors of this project have a big experience in the methodologies which will be used to investigate textured materials and they created original experimental methodology based on neutron diffraction which they previously used for the study of plastic deformation in magnesium alloy. In this work the so called crystallite group method will be applied to measure stresses in selected crystallite groups, in multi-phase material (two-phase brass). It is a logical continuation of the research carried out earlier, by combining the localisation of stresses on individual crystallites and on individual phases of the material. The other purpose of this grant is to apply this methodology for single phase alloy (Mg alloy) for which the measurements will be performed for the loads applied in different directions. This will allow to understand the anisotropic behaviour of the material and to find out the sequences of activation of the slip systems and twinning phenomenon for different loadings.

The main research carried out during this project will be neutron diffraction measurements with applied external load. Complementary studies will be performed using X-ray diffraction and microstructure measurements using backscattered electron diffraction (EBSD). On the basis of the obtained results , we expect to observe difference in the stresses localised on two different orientation in beta phase and in one orientation in alpha phase especially during plastic deformation of two-phase brass. The values of critical shear stresses and hardening for active slip systems will be directly determined from measurements. We expect to determine the roles of dislocation hardening and grains interactions in the strengthening of this two phase material. In this project the in-situ diffraction measurements will be done during compression tests performed for different directions with respect to the samples of magnesium alloy. The choice of the load direction will help us determine different sequences of activation of slips and twinning for different preferred orientations. It should be emphasised that the direct measurements of the stresses and mechanisms of plastic deformation are performed for the first time using our methodology, while in the previous studies the interpretation of experimental results was based on models in which assumptions concerning grains interactions were introduced. Therefore the results obtained from the direct method are unambiguous, compared to these obtained with model.

Introducing a new experimental method and using it for different materials we bring to the scientific community a new methodology for the study of mechanisms of plastic deformation at the scale of polycrystalline grains, as well as we describe these mechanisms for specific interesting materials. For example we are able to determine unambiguously the role of stress partitioning between grains and dislocation strengthening in strengthening process during plastic deformation of the material. The results of this work will make progress in the materials science, both in the methodological point of view as well as in the study of properties of particular polycrystalline materials.