The great potential of Mg alloys for structural applications in the automotive, aerospace, and biomedical industries has been recognised, and their low density, high specific strength, natural degradability, and biocompatibility have attracted considerable attention. The main drawback of high-strength Mg alloys is associated with poor ductility and poor corrosion resistance.

The project aims to investigate the feasibility and scientific characteristics of processing next generation ultrafine-grained heterogeneous magnesium alloys for load bearing applications where the composition, material design, microstructure and way of manufacturing are optimised to achieve high-strength and high-ductility Mg alloys combined with their improved corrosion resistance. Several processing techniques that are close to the current industrial processing technology will be explored, so that their practical applications have a very low barrier. The proposed research is a comprehensive study in a combined experimental and modelling way. Therefore, the development of advanced mathematical models that support the design and processing of such novel materials is within the main objectives of the project. Modelling the evolution of dislocation density and substructure arrangement is essential for the analysis of microstructure evolution in ultrafine-grained materials. Material samples will be subjected to a comprehensive mechanical testing programme investigating the strength, ductility and corrosion resistance in order to extend the range of potential applications.

The project exploring the development of unique ultrafine-grained structure heterogeneous metallic materials will look at several scientific aspects. Following a new principle for designing hcp metals with mechanical properties that have not been reachable before, this work will open a new frontier toward obtaining high tensile ductility without sacrificing the high strength in ultrafine-grain Mg alloys. The complex mechanisms of microstructure evolution during the processing of cylindrical profiles that evoke both back-stress hardening and dislocation hardening responsible for an extraordinary strain-hardening rate and consequent high ductility will be investigated for the first time following the recent insights. In an ideal scenario, the soft domains are surrounded by the hard domain matrix and will not be able to change their shapes by plastic deformation until the hard domain matrix starts deforming plastically. High back-stress builds up at the domain boundaries in the soft domain due to piling-up of the geometrically necessary dislocations which cannot be transmitted across the domain boundaries, making the soft domains almost as strong as the hard domain matrix, potentially increasing the global yield strength to values significantly higher than those predicted by the rule of mixture. When both types of domains deform plastically, the soft domains produce strain partitioning. Strain gradients in both types of domains near the domain boundaries grow with increasing strain partitioning producing back-stress work hardening, thus increasing ductility. In addition, revealing the effects of potential fluctuation on the micro-galvanic corrosion and the protective film formation associated with such microstructure evolution will contribute to better understanding the corrosion mechanism of Mg alloys with multiple strengthening phases. Material design parameters, such as composition, location, microstructure, ways of material processing and fabrication sequences, are among many important factors that will be considered and optimised for the first time supported by advanced mathematical modelling to achieve multiple functionalities.

The major output from the project will be improved understanding and optimisation of the cooperative relationships between different physical phenomena taking place in processing of novel ultrafine-grained heterogeneous metallic materials achieving the concept of multiple functionalities. The study will lead to a more effective design and processing of the novel materials. Multiscale numerical models, developed and used for optimisation, potentially with minor changes, can be applicable to a wider range of hcp metallic materials, including Ti alloys. The mathematical models can also be applied for optimisation of light weight high-strength components made of similar ultrafine-grained heterogeneous materials, for instance those in the automotive and aerospace industry. The models developed will be of significant interest to the growing number of industry partnerships around the world. This work will address current deficiencies in lightweight structural metallic materials, guide future designs, and open more market opportunities. The project addresses key societal challenges for higher energy efficiency and to reduce both air pollution and carbon emissions by contributing to electrifying public transport, where the application of lightweight structural high-strength materials is of paramount importance.