Lithium batteries are the most significant energy storage technology today. Due to their outstanding properties, such as high gravimetric and volumetric energy density, they revolutionised the mobile electronics sector in the last 30 years, making mobile phone and laptop technologies so widespread. They are also gamechanger in the automotive industry. The growing popularity of electric cars is based on and dependent on the development of lithium batteries. Especially in this sector, the high capacity of the batteries and their safety are essential. In recent years, the importance of large-scale energy storage has also increased due to the development of renewable energy sources. Energy generation via photovoltaic and wind technologies, which are susceptible to environmental conditions, is associated with the necessity for energy storage.

Despite the many advantages and importance of batteries, some critical issues are still to be resolved and are under intensive research in the last years. They mainly relate to safety and the possibility of further increase of the energy density. The limiting element in both of these issues is the electrolyte. The currently used liquid solutions of lithium salts in anhydrous organic solvents are very reactive towards moisture and therefore create the risk of a violent reaction in the event of leakage, resulting in the release of highly toxic and flammable products. In addition, the narrow range of electrochemical stability of these electrolytes limits the power and energy density and prevents the use of new high-voltage electrode materials. Therefore, standard liquid electrolyte lithium batteries seem to be near the end of their development potential. Other types of batteries can be a solution to this problem. One of the most promising is all-solid-state batteries, which use solid electrolytes. Since they provide improved safety, higher energy density and possibility of charging several times faster than currently used, this technology is the obvious direction of development for the future.

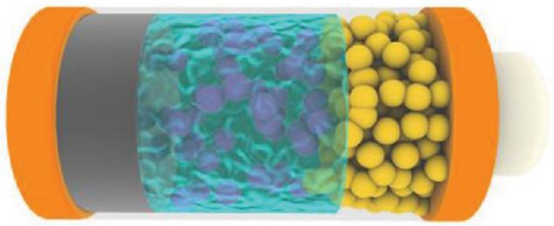

Fig. 1. Schematic illustration of all-solid-state battery with composite electrolyte. From the left: current collector, lithium as anode, composite solid electrolyte, cathode, current collector.

Solid electrolytes are including ceramic materials, polymers or hybrids, which are named composite solid electrolytes. Composite electrolytes, which are the subject of this project, inherit the advantages of flexibility and processability from polymer and also achieve enhanced ionic conductivity and electrochemical stability resulting from the full utilisation of synergistic effects caused by the contributions of organic/inorganic interphases. Schematic illustration of cell with composite electrolyte is present in Fig.1. Although composite electrolytes attract increasing attention, there are still crucial problems to overcome. Regardless of applying fast ion-conducting solid electrolytes, defect interfaces will limit the performance of all-solid-state batteries. Poor contacts at the solid/solid interfaces hinder effective transport of ions and generate a relatively high resistance, which has been reported to contribute more than 60% of the total battery resistance. Since much attention was paid to obtaining high ionic conductive composites, an in-depth assessment of the interfacial phenomena is still largely unknown.

The scientific aim of the project is to elucidate the aspects of the interfaces in Li-ion batteries with solid composite electrolytes, namely, chemical composition characterisation of interphases, their structural evolution during battery operation as well as determination of charge transport mechanism on interfaces. One of the goals of the project is optimisation of composite membranes based on LLZO ($Li_7La_3Zr_2O_{12}$ doped with Al and Ga) and LAGP ($Li_{1.5}Al_{0.5}Ge_{1.5}(PO_4)_3$) ceramics fillers regarding the morphology and Li^+ ions conductivity. Transport properties mainly depend on polymer/ceramic interface inside the composite electrolyte. Composites and high-voltage cathode materials will be used in all-solid-state batteries. The cells will be explored and optimised in terms of phenomena at the electrolyte/electrode interfaces named solid electrolyte interphases (SEI) and cathode electrolyte interphases (CEI) form at the anode and cathode side, respectively.

The proposed project will make an essential contribution to the knowledge about interfaces problems in all-solid-state batteries. Since recent studies suggest that minimising the existing interface problems is even more important than maximising the conductivity of solid electrolytes, this project will greatly interest researchers in the battery field. Overcoming the identified interface phenomena will allow obtaining all-solid-state batteries with improved electrochemical properties in the future.