The aim of this work is to design modern, alternative materials with tunable catalytic properties based on liquid metal complexes for the model fine chemical production and electrochemical processes.

The novelty of the project is focused on both, designing of materials with specified properties as well as on the presentation of their innovative applications. The constantly growing number of environmental regulations with regard to the safety and waste disposal have forced the development of sustainable catalytic methods for the *fine chemicals* production. The pursuit for new non-toxic, environmentally benign and safe to handle catalysts is an important goal of this project. Basic research in the field of chemical technology with elements of catalysis and kinetics will be carried out in this project. Catalytic processes are of fundamental importance for chemical industry. Continued interest in the development of sustainable production methods, especially for *fine chemicals* has intensified basic studies under the development of new catalytic systems that can affect the material and energy efficiency of processes remaining consistent with the main principles of *green chemistry*.

On the other hand, rechargeable batteries are crucial to the EU energy management strategy. EU considers energy storage solutions as the key components in providing grid flexibility and supporting renewable energy integration in the energy system. Lithium-ion batteries are currently the state-of the art technology - but suffer from high cost and flammability. Li-ion batteries are abundant in mobile electronic devices and find their way into transportation, and more recently into grid applications. Their advantages include high energy density, design flexibility, self-discharge, good cycle life and low maintenance. However, lithium is not an abundant element, which increases its cost and decreases sustainability of long-term reliance on lithium. Progress in commercialising Al-ion batteries is hindered by the lack of suitable electrolyte. Al-ion batteries were never commercialised due to technical difficulties: failures to reversibly electroplate/strip aluminium, poor stability of Al-ion cells and corrosion issues. The search for a suitable electrolyte, halted by the Li-ion batteries boom, has been recently revived with ionic liquids electrolytes.

Two groups of liquid metal complexes based on ionic liquids were selected for this project. The first group consists of solvate ionic liquids (SILs) which are a unique and niche group of compounds belongs to the ionic liquids family and are synthesised from a metal salt, MX_n, and donor molecule, L. The anion of the salt, X, is weakly coordinating and bears a single negative charge; ligand, L (usually a glyme), is used in stoichiometric quantities. While SIL-based electrolytes for Li-, Na-, K-, and Mg-ion batteries are already described in the literature, the use of Al is not known so far. In this project, we plan to incorporate cost-effective metal, like Al to the SILs structure to obtain promising candidate for the large-scale electrochemical energy storage systems. The new SILs based on Al^{3+}, Ga^{3+} and Sn^{2+} will also open a new perspective for the application of such systems as solvents or Lewis acidic catalysts.

The second group of liquid metal complexes used in this project are metallate ionic liquids based on Al^{3+}, Ga^{3+}, Sn^{2+}, Ag^{+} and Sc^{3+} as metals. Ionic liquids are able to dissolve metal salts possessing the same anion, creating a new metal ion containing species (complex anion).

The study will involve designing, fabrication and characterization of new materials which will be tested as catalysts in model chemical processes, *e.g.* Diels-Alder cycloaddition, esterification, Baylis-Hillman reaction, and in the biomass valorisation, for the conversion of α-angelica lactone and furfuryl alcohol to alkyl levulinates. Liquid metal complexes will be designed to serve as homogenous catalysts as well as will create the biphasic liquid/liquid systems or heterogeneous catalysts *via* immobilization of an active phase on the surface of solid carriers: multiwalled carbon nanotubes (MWCNTs) or inorganic oxide materials, *e.g.* ZrO_2-SiO_2, TiO_2-SiO_2.

The next challenge is the electrochemical characterisation of liquid metal complexes to evaluate their potential as electrolytes for Al-ion batteries. Development of the next generation of electrolytes for Al-ion batteries is another goal of the project. Current state-of-the-art electrolytes for Al-ion batteries are ionic liquids with solubilised $AlCl_3$ salts, which contribute to corrosion (chloride ions), in addition to high cost and viscosity. Innovative electrolyte form proposed in this project will be inspired by transforming the Al^{3+} salts directly into liquid metal complexes, rather than dissolving them in traditional ILs. The absence of $AlCl_3$ will be particularly important to avoid the corrosion issues.

In conclusion, the search for new highly effective, environmentally friendly materials for the model fine chemical production and electrochemical processes are currently the object of many studies. The proposed project involves the use of new, yet poorly known ionic materials as Lewis acids, solvents and electrolytes for model chemical processes.