Along with the dynamic development of technology, there is a growing demand for providing stable and reliable power sources. Limited fossil fuels resources affect the development of technologies based on renewable energy sources, such as sun, wind or tides. However, due to the lack of continuity of energy production from unconventional sources, the development of energy storage systems ensuring stability and control over the power system becomes a main problem. One of the most commonly used solutions in the field of electrical energy storage are Li-ion batteries applied among others in a wide range of electronic mobile devices, automotive and small or large-scale energy storage systems. Li-ion batteries owe their popularity to numerously unquestionable advantages, such as high energy density high efficiency of energy storage, reliability, durability, flexibility in choosing their shape and size, quiet operation and no pollution. However, they are not without drawbacks, and one of the most significant one is the fact that the limited lithium resources are unevenly distributed on Earth, with the greatest accessibility in the places that are often politically and economically unstable, which threatens the continuity of supplies of this element.

Over the past few years, more and more attention was devoted to Na-ion batteries. Their operation is based on the electrochemical intercalation of sodium into the transition metals compounds, analogously to their lithium equivalents. During the work of such cell type, sodium ions Na^+ leave the anode, are being transferred through the electrolyte, and then are being inserted into the structure of the cathode material. At the same time, electrons flow in the external circuit in the same direction, resulting in current flow. The great advantage of sodium is its widespread availability in nature, for example in sea water. At the same time, the larger ionic radius, higher mass and higher standard potential than lithium, make reaching power and energy density comparable to Li-ion batteries really challenging. New groups of materials for this technology are being developed all over the world. Cathodes are particularly examined, due to the fact that their potential vs. $Na|Na^+$ and capacity translate into the density of the energy stored in the battery to a decisive extent. High-voltage cathode materials based on layered transition metal oxide Na_xMnO_2 ($0 < x \leq 1$) cause a great interest among the researchers.

The aim of this project is comprehensive research on a group of materials with the general stoichiometric formula $Na_xM_yMn_{1-y}O_2$ (M=Li, Mg, Al; $0 \leq y < 0.3$). These materials, apart from high voltage, are also characterized by an unusual intercalation mechanism, during which not only the transition metal, but also oxygen changes its oxidation state. This phenomenon can affect a significant increase of capacity. The planned research aims to understand the intercalation mechanism in these materials, that is yet not fully explained, as well as connecting the chemical composition and various substitutions (Li^+, Mg^{2+} and Al^{3+}) with structural and transport properties. The optimal synthesis method will be elaborated taking into account solid state reaction and sol-gel methods, and the most promising materials will be used to construct the batteries in an argon atmosphere inside a glove box. Their verification will be carried out by studying the crystal structure thanks to the X-ray diffraction method (XRD), morphology by scanning electron microscopy (SEM) and thermal stability based on thermogravimetry (TG) and differential scanning calorimetry (DSC). The tests of transport properties: electrical conductivity by electrochemical impedance spectroscopy method (EIS) and thermoelectric power using a dynamic method will be necessary for determining the mechanism of charge transport. Electrochemical tests, including: cyclic charge and discharge of batteries under various currents, determination of current-voltage characteristics using cyclic voltammetry method and reversibility tests of electrochemical processes, will allow determination of cell capacities and life-span. Analysis of the chemical composition and oxidation states of transition metals ions in the studied materials thanks to the X-ray photoelectron spectroscopy (XPS) method will contribute to understanding the nature of the oxygen oxidation change phenomenon. The obtained results will be supplemented with theoretical calculations of the electron structure using the MedeA® software together with the VASP program. Comprehensive research will affect the completion and organization of existing knowledge in the field of the studied materials, contributing to the development of sodium batteries technology.