

Electric energy is considered the most universal form of energy that modern societies can utilize. One of the most important priorities of the world economy is the sustainable production of electric energy from renewable, dispersed sources, usually highly dependent on the weather. In order to effectively use these potential energy sources, the application of high-performance energy storage devices is required. Currently available supercapacitors deliver a small amount of energy, not exceeding 8-10 Wh/kg, and lithium-ion batteries exhibit limited lifetime and low-power characteristics. Additionally, Li-ion technology is highly dependent on cobalt and natural graphite, which the EU classifies as critical raw materials (CRM).

A solution to the problems associated with current energy storage systems may be the new generation of sodium-ion batteries (NIBs), which has been intensively researched in recent years because of their unique advantages over traditional lithium-ion systems. NIBs use manufacturing technology similar to that used for Li-ion batteries, but the availability of sodium is much greater than that of lithium, which translates into lower production costs. In addition, tin (Sn) can be used for anode materials in sodium ion batteries, and its theoretical capacity is 847 mAh/g, more than double of the graphite anode capacity in Li ion batteries.

Unfortunately, Sn-based anode materials show significant changes in volume (expansion and contraction) during the charging and discharging process, leading to degradation of the active material and loss of contact between the electrode and the current collector, ultimately resulting in a progressive loss of capacitance. The aforementioned issues inhibit the development of efficient and stable NIBs technology. Therefore, a breakthrough is needed to improve the Coulombic performance and stable lifetime of the tin-containing anode.

The project is aligned with the strong developing trends in environmental protection by improving the parameters of electrochemical storage systems. Na-ion batteries are becoming one of the most promising technologies after Li-ion batteries, so their development may contribute to the decarbonisation of the EU and the achievement of the objectives of the European Green Deal 2050.

The aim of the project is to develop and synthesize carbon-tin composites based on two types of materials: composites using hard carbons and graphene aerogels as the active material of the NIBs anode. The combination of carbon and tin material results in stabilization of Sn nanoparticles in the electrode material, which will translate into improved electrochemical properties of the anode and increased stability during long-term operation. The use of hydrothermal and evaporation-induced self-assembly methods for the synthesis of carbon materials and composites is planned. In addition, the project involves the use of analytical techniques in *post-mortem* research and the use of innovative *operando* X-ray diffraction and electrochemical dilatometry techniques (during the electrochemical operation of the cell). With the results obtained, it will be possible to understand the changes that occur during electrochemical processes and the anode degradation mechanisms during the operation of the cell.

The presented project has a great opportunity to contribute to the development of a new generation of highly efficient energy storage devices, Na-ion batteries. The results obtained within the project may contribute to further insight into the processes that take place in the anode material and the conscious design of carbon-tin composites for stable and efficient sodium-ion batteries.