Nanostructured High-Performance Systems for Fast Charging and Hybrid Energy Storage

Modern technologies demand increasingly efficient energy sources. Electric vehicles, drones — including combat drones — portable electronics, and systems based on renewable energy all require energy storage solutions that are efficient, lightweight, reliable, fast-acting, and as compact as possible.

Today, two main technologies dominate the field: batteries and supercapacitors. Batteries can store large amounts of energy but require time to recharge. Supercapacitors charge almost instantly but offer significantly lower energy capacity. Our project aims to develop an entirely new approach that combines the advantages of both technologies.

We propose constructing layered capacitors made from nanoparticles — particles even a thousand times thinner than a human hair. We use conductive and insulating nanomaterials with opposite surface charges, deposited layer by layer in a precisely defined sequence. This creates a stable structure with excellent electrical conductivity and ability to store electric charge.

The project will explore various materials: silver, metal oxides, carbon nanostructures, silica, and conducting polymers. These will be deposited using an in-house-designed automated platform featuring a rotating system, fluid dispensers, and a real-time quality control camera. The entire process will be supported by artificial intelligence algorithms that help optimize deposition parameters.

Initial experiments have shown that such architectures offer significantly improved performance compared to conventional supercapacitors. Although the project will enable the construction of prototype devices, its primary objective is to gain a deeper understanding of how the size, chemical composition, and charge of nanoparticles affect the electrical properties of the entire capacitor systems.

In the long term, these solutions may find applications in next-generation electronics, energy recovery systems, and sustainable energy technologies. However, the project remains firmly within the domain of basic research — its main goal is to elucidate the structure–function relationships in nanolayered energy storage systems.

The project is carried out by the Jerzy Haber Institute of Catalysis and Surface Chemistry of the Polish Academy of Sciences, in consortium with the Academic Centre for Materials and Nanotechnology at AGH University of Krakow, in collaboration with international experts from Belgium, Germany, and South Korea.