Abstract for the general public

Modern society increasingly relies on energy storage systems – from batteries in mobile phones and laptops to accumulators in electric vehicles and renewable energy installations. As a result, there is growing demand for new battery materials that are not only more efficient and long-lasting but also safer for both users and the environment. Graphite, the current standard material for lithium-ion battery anodes, is approaching its performance limits, which motivates scientists to search for better alternatives. The aim of this project is to develop and thoroughly investigate a new class of anode materials based on hybrid heterostructures combining two types of two-dimensional (2D) nanomaterials: MXenes and transition metal dichalcogenides (TMDs). MXenes are known for their excellent electrical conductivity and chemical stability, making them ideal for fast electron transport. TMDs, such as molybdenum disulfide (MoS_2) or tungsten disulfide (WS_2), are notable for their high capacity to store ions, a critical feature for efficient battery operation. This project proposes to create hybrid structures that merge the best properties of MXenes and TMDs into a single anode material. The resulting electrodes are expected to show enhanced capacity, improved cycle life, and increased stability during charging and discharging. Key methods include synthesis via chemical vapor deposition (CVD) and solution-based electrostatic self-assembly. These materials will be characterized using advanced microscopy techniques (electron microscopy, atomic force microscopy), as well as surface spectroscopy. Electrochemical tests will follow to evaluate the performance of these materials in half-cell configurations. This research topic was chosen in response to the urgent need for next-generation battery technology. Current solutions do not fully meet expectations in terms of safety, longevity, and manufacturing costs. By developing new anode materials, the project moves closer to enabling batteries with higher energy density, faster charging, and longer lifespans. Moreover, it contributes to a deeper understanding of nanoscale processes that are fundamental to material science. The project is expected to yield practical, reproducible methods for fabricating hybrid electrodes and to provide new insights into the relationship between structure and electrochemical properties. In the long term, the results may support the development of safer, more sustainable energy storage technologies essential for daily life and the global energy transition.