Elaboration of unconventional nanostructured perovskites and zinc oxide through compositional and morphological engineering for game-changing improvements in light harvesting devices

Solar energy offers a promising alternative to fossil fuels due to its low environmental impact and ever present energy source. Conversion of sun-derived energy into electricity is performed in solid-state devices called photovoltaic cells. An ideal cell is characterized by high power conversion efficiency (PCE), long-lasting stability as well as resistance for all atmospheric conditions, and its production process is straight forward and inexpensive. Photovoltaic cells are typically sandwich-like devices fabricated in a layer-by-layer process. Each layer is composed of different material and plays a different role. The performance of the cell is determined primarily by the material constituting the layer responsible for absorbing sunlight. Since 1970s till now, crystalline silicon has mostly been used for this purpose. However, silicon-based technologies suffer from high fabrication cost, significant device thickness and its low elasticity. In respond to these challenges, the last two decades witnessed development of a variety of thin film solar technologies, which applied other absorbing materials such as organic dyes, polymers, and quantum dots. In the last decade, devices based on organic–inorganic halide perovskite absorbers have been extensively studied and are regarded as exceptionally promising. The PCE of perovskite solar cells increased from 3.8% to over 25% in only a few years recently getting close to a theoretical limit. To fulfill the expectations for its practical use, perovskite-based photovoltaics still needs to overcome challenges by, for example, increasing the cells' long-term stability, developing straightforward, inexpensive, and efficient fabrication processes, as well as decreasing environmental costs of the technology.

The presented project will encompass the development and upgrade of perovskite materials preparation by environment-friendly mechanochemical methods, in which chemical reactions are conducted between solid substances with no use of solvents or heating. Most importantly, new compositions of perovskite layer will be developed, which will lead to increased cell stability, and new perovskite materials with decreased or even no lead content will be elucidated. Additionally, it is planned to develop methodologies of mechanochemical synthesis of 2D perovskites, which have never been obtained this way before. According to the most recent findings, the solar cell performance is determined not only by chemical composition of the perovskite layer, but also its morphology, which is size and shapes of its particles. Therefore during the project, devices consisting of perovskite in different nanoforms, such as nanotubes, will be constructed, and novel deposition methods will be tested. Another outcome of the project will be the better understanding of mechanochemical processes of perovskite formation. This will be possible by following these reactions in situ, which has not been done before. Along with the absorber, the essential layer of a solar cell is the one transporting absorber-extracted electrons in order to generate electric field. Material constituting this layer is ideally characterized by high electron mobility and band gap compatible with absorber. Nanocrystalline zinc oxide is regarded as one of the most promising electron transporting materials for perovskite-based cells. Based on our experience in rational design and synthesis of zinc oxide nanomaterials, a variety of new materials will be synthesized and characterized. Then, the impact of various factors such as particle size, morphology, type of organic outer shell, doping by metal ions will be examined on both properties of the electron-transporting layer, as well as the performance and stability of the whole cell.