In the last decades, there has been increased effort to extend functionalities of electronic devices beyond the traditional manipulation of charge currents. One of the routes for achieving this goal is taking advantage of a purely quantum mechanical property of an electron – spin. Spin is detectable as a weak magnetic energy and manipulation of spin requires less energy than manipulation of an electron charge, what could lead to more efficient, powerful and smaller devices offered by spin-based electronics – spintronics. Each electron is characterized by one of the two possible spin orientations, opposite to each other, and the imbalance of electrons with different spin orientations, spin polarization, is a key parameter in spintronics. Many spintronic devices, resulting from advances in metal-based spintronics, have already found their way to commercial applications in data storage and data sensing. Traditional electronics, used, e.g., for data processing, is however based on semiconductors. Very large progress has been made on semiconductor spintronics, but there is still not a spintronic device which could compete with a workhorse of the modern electronics – field effect transistor (FET).

The crucial task in semiconductor spintronics is generation of spin-polarized electrons in a semiconductor, and their subsequent transfer, manipulation and detection, epitomized in the paradigm spintronic device – spin-based FET. In this project, we want to address this issue in novel two-dimensional (2D) semiconductors, namely in transition metal dichalcogenides (TMDC). They belong to the novel class of 2D materials, which are stable even in a monolayer form, and took the research community by storm within the last decade, blowing also the fresh air into spintronics. Layered nature of these 2D materials, with weak van der Waals (vdW) forces binding the layers together, makes possible to stack them individually like Lego blocks, forming vdW heterostructures. Since many types of 2D materials have been found, ranging from insulators, through semiconductors to metals, including ferromagnets and antiferromagnets, complex vdW heterostructures, with exciting spintronic functionalities, can be built out of these components.

In the project, we will explore two paths leading us to generation of spin-polarization in TMDCs. A direct path involves the so-called electrical spin injection, where electrical current is driven across an interface between a ferromagnetic metal and a semiconductor, transferring spin polarization from the magnet into a semiconductor. This method has been well established for conventional bulk semiconductors, but did not give satisfactory results in case of these novel materials. The second path is very subtle, and strictly related to atomically thin nature of layers in vdW heterostructures. It is predicted, that such thin layers can borrow certain physical properties from the neighboring layers via so-called proximity effects. This gives a fascinating opportunity of engineering also spintronic properties in vdW structures. It should follow, e.g., that a semiconductor placed in the close vicinity of the magnet should be able to borrow magnetic properties from the latter, what should lead to finite spin polarization that could later be accessed and controlled via electrical or optical means. High quality, clean interfaces between corresponding layers are essential to these effects, and in our project, we want to pay particular attention to preparing such interfaces.

The understanding of mechanisms behind generation and control of spin polarization in these 2D semiconductors would open new fascinating possibilities in engineering not only spintronic functionalities but also those related to valleytronics, another novel concept in solid-state electronics. It could bring us closer to realization of functional semiconductor spintronic and valleytronic devices.