Spin Hall effect in antiferromagnets (SPINORBITRONICS)

The aim of the project is both theoretical and experimental investigation of hybrid antiferromagnet/ferromagnet (AFM/FM) structures for maximization of spin currents generated using spin Hall effect. Within a project, test structures consisting of different combination of buffer/AFM/FM mutlilayers will be fabricated, where the coexistence for spin-orbit torque, magnetoresistance and spin Hall effect will enable the design of a new class of spintronic circuits.

When a charge current passes through a thin-layer heterostructure consisting of heavy metal (e.g. Pt, W, Ta) which exhibit a strong spin-orbit coupling and ferromagnet (e.g. Co, CoFeB), perpendicular spin current is generated. This in turn causes an accumulation of spin-polarized electrons on the structure opposite sides. This phenomenon is called the spin Hall effect. The spin Hall angle, a ratio of spin to charge currents, provides a quantitative measure of the spin-Hall effect, and as shown in our recent experiments the highest value was achieved for W/CoFeB system.

As previously mentioned, in non-magnetic heavy metals and ferromagnets a charge current induces a spin current. This propagation of spin-current causes the ferromagnet to switch its magnetization vector, resulting in low and high resistance states. These states may be used as digital 0/1 signals in spin-transfer torque (STT) and spin-orbit torque (SOT) RAMs (Random Access Memories).

Recently though, the same phenomenon has been investigated, both theoretically and experimentally, in structures consisting of PtMn and $IrMn_3$ antiferromagnets. It was demonstrated that in these materials, the spin-orbit torque excites a high frequency (THz) dynamics and causes the switching of magnetization.

One aspect of this topic that has not been researched in detail, is the influence of structural and magnetic ordering of the antiferromagnets/ferromagnets interface, described by the interfacial spin Hall angle, on generated the spin-current. In this project we would like to compare the influence that the interface exerts on the bulk spin Hall angle for two types of antiferromagnets, NiO oxide and metals such as PtMn and $IrMn_3$.

As a part of this project, two distinct theoretical models will be developed. The first model, based on the spin-current diffusion and Landau-Lifshitz-Gilbert equations, will enable us to calculate the interfacial spin-Hall angle. The Second one, based on the microscopic theory, will be used to provide an accurate description of interactions between spin-orbit coupling and antiferromagnetic ordering as well as to quantify their influence on the spin-orbit torque.

We believe that an antiferromagnet-based SOT-RAM will exhibit stronger spin-Hall angle resulting in switching time which is shorter than STT-RAM one. We also assume that the SOT-RAM will consume considerably less energy than its STT counterpart.

All things considered, it is safe to assume that this project, with all of its planned experiments, fits well in the industrial trends of green electronics and informatics, or green-IT.