How to utilize the hidden magnetism of electrons in a crystal?

Diversity of materials possessing magnetic properties is enormous and much larger than it seems to be. Souvenir magnets on the fridge that we bring from travels, toys for children in the form of railroad cars that connect with each other thanks to the invisible force and finally hard disc drives – all of these items that we call informally as ‘magnetic’ contain ferromagnetic elements. Despite that they behave in a spectacular way, in reality it is one of many possible behavior of matter resulting from the positioning of atoms in the crystal and their magnetic moments. There is much wider abundance of antiferromagnets in the world that surrounds us but it is more difficult to identify them. Their magnetic properties are more hidden because of alternating order of the magnetic moments of atoms that make the crystal compensated. However, they still have been the objects of intensive research for the last decade due to the potential applications in electronics.

This research has led to surprising results. The new, distinct class of materials has been predicted to exist that shares some features with ferro- and antiferromagnets, called altermagnets. Although they are magnetically compensated, due to the alternating alignment of the magnetic moments of atoms, the magnetic moment of electrons, which travel through the crystal can spontaneously order in one direction. Then, it is a part of the whole crystal – travelling electrons – that becomes ‘magnetic.’ Unfortunately, there is a set of challenges that make observation of such effects difficult. Firstly, electronic states must be filled appropriately, which is described by the Fermi level. Secondly, the journey of the electrons – electrical current – must take place along a particular direction of the crystal. Therefore, there are only limited, recent reports confirming the altermagnetic behavior in ruthenium oxide.

There should be much more materials like this! This project subject are semiconductive altermagnets such as manganese telluride or manganese selenide – optimizing the process of obtaining the crystals, research on the Fermi level and methods of controlling it as well as the exploration of differences in electrical properties along multiple directions in altermagnetic crystals, which will allow to verify the utility of these materials for potential application in electronics, especially for generation of the spin currents or giant/tunnelling magnetoresistance effects. The generation of the spin currents from semiconductive altermagnets can have a significant impact on the electronics based on spin (spintronics). It may reduce the power necessary for the operation of devices and data storage, which has important economical, societal and ecological aspects reaching beyond physics.