Electrons are classified as fermions which means that they occupy energy levels one by one, starting from the lowest energy level to the highest energy level and there can only be one electron in a given state. In case of free electrons in metals, the highest energy level occupied by an electron can always be found. Such a level is known as the Fermi level. The Fermi energy is very important in the case of semiconductors as well. Specifically, the ability to control the energy of the Fermi level by doping has led to creation of a p-n junction. Just as atoms constitute macroscopic objects, so is the p-n junction the primary component of all electronic integrated circuits. Additionally, the p-n junction serves as a source of light in light-emitting diodes or laser diodes. Yet another application thereof are photovoltaic cells.

The situation is slightly different when it comes to dielectric (insulating) materials with very few free electrons. The fact that the electrons are bound to atoms is the reason why the energy of the Fermi level wasn't considered a useful parameter to describe such systems. The situation changed considerably when dielectric materials doped with transition metal ions and rare earth ions began to be manufactured for industrial purposes such as phosphors or scintillators. In such materials, under the influence of external energy, light is emitted (such phenomenon is called luminescence, and the metal dopants are called luminescent centers). The means, by which the dopants are excited to luminescence (excitation by light in phosphors, excitation by high energy radiation in scintillators) may significantly increase the number of free charge carriers (electrons or holes) present in the material. When studying or designing such luminescent materials, it can no longer be ignored that the electrons are subject to Fermi-statistics and thus the Fermi energy can determine the radiative recombination process and quantum yield. However, this fact has not been taken into account so far.

The aim of the this project is to study the energy of the Fermi level of monocrystalline layers of dielectric materials such as garnets, perovskites and orthosilicates produced using the method of liquid-phase epitaxy. The focus will be primarily on finding the dependence of the Fermi energy on the type of rare earth ion (typical luminesce centers) or a transition metal ion dopant. In previous papers we have shown that the location of the Fermi level can be changed in polycrystalline orthosilicates via aluminum or lithium ion doping. We wish to draw on this experience in order to regulate the value of Fermi energy in monocrystalline layers. We intend to dope the layers, in a carefully controlled way, with lanthanide ions and ions that can act as donors or acceptors, that either increase or decrease the value of Fermi energy (Fermi level engineering). We will be studying the influence of the Fermi level on the luminescent properties of the layers. Then, by layering one layer over another, we plan on creating the p-n junction and subsequently researching its current-voltage and luminesce characteristics. We have chosen the monocrystalline layers in order to minimize the number of uncontrollable defects that can be found in polycrystalline materials. Apart from obtaining a basic knowledge on the Fermi energy in dielectrics, we also expect to observe some new effects, including electroluminescence and photovoltaic effect, which up till now have only been observed in semiconductor p-n junctions. The huge success of semiconducting p-n junction in electronics lets you have hope that similar multilayer structures of dielectrics can find the application in the new areas. For instance in semiconductors the bandgap has the energy smaller than 4 eV, that that allow for p-n junction (light emitting diode LED) to emit light longer than 320 nm, whereas the dielectric materials have the bandgaps up to 10 eV. Thus the p-n junction synthesized with dielectrics can potentially emit light with wavelength 125 nm, which is very deep ultraviolet. Although the project concerns basic research we see possible The possible applications are related to electroluminescence and photovoltaic devices. Specifically, UV sensitive devices can find application in the long term space projects. In space the UV radiation is not absorbed by atmosphere and devices based on dielectrics can significantly increase photovoltaic cell conversion efficiency in hybrid systems containing dielectric and semiconductor junctions.