While realizing our previous research project OPUS13, we noticed that simple resistors made of multilayered PbTe/CdTe structures show unexpectedly high sensitivity to infrared radiation, even at room temperature. Although the design of these detectors was not optimized (they lacked anti-reflection layers, immersion lenses, optimal electrical contacts, etc.), their detection performance proved to be comparable to that of the best commercial detectors. This surprisingly good detectivity comes from the unique properties of the PbTe/CdTe multilayer structures. Due to the different crystal lattices of PbTe and CdTe, these materials are immiscible, do not dissolve into each other, and do not form alloys. In solid solution they tend to separate forming precipitates of pure PbTe and CdTe with sharp boundaries between them. Because of the mismatch of crystal lattice types at these boundaries appear broken atomic bonds, which can trap free charge carriers (electrons or holes) present in the material, mainly in the PbTe regions. This effect significantly reduces the intrinsic concentration of carriers and thus increases the photoconductivity effect. Another important reason why PbTe/CdTe multilayer structures are great candidates for infrared detectors is probably the strong suppression of infrared-excited carrier recombination. This is the so-called Auger recombination, which is the main mechanism limiting detection in the narrow energy gap semiconductors from which infrared detectors are typically made. In structures made of wide- and narrow-gap materials, as in this case, recombination is strongly suppressed.

The subject of the proposed research will be multilayer PbTe/CdTe structures, i.e., a material constructed from alternating epitaxial layers of PbTe and CdTe grown by molecular beam epitaxy (MBE). Typical thicknesses of PbTe layers are 10-50 nm and CdTe layers are 50-200 nm. The number of repetitions of their layer pairs is a few to, a dozen, so typical thicknesses of the whole structures are on the order of 1 um. Based on our previous studies, we can conclude that the PbTe/CdTe multilayer structures are indeed a new semiconductor material that has different physical properties and behaves differently from its well-known components, PbTe and CdTe. Moreover, we have experimentally verified that the physical properties of PbTe/CdTe multilayer structures depend very significantly on the way they are fabricated, i.e., the parameters of the growth process such as the substrate temperature, the growth times of both components, the number of repetitions of PbTe/CdTe pairs, their stoichiometry, etc. For example, the morphology of such structures generally depends on the growth temperature. Also, such fundamental material properties as charge carrier concentration, mobility, transmission and optical reflectivity are determined by MBE process parameters. In particular, we found that by appropriately manipulating the film growth time, we can obtain PbTe/CdTe multilayered structures with very different electrical conductivity, from metallic to insulating.

In the present project we set ourselves three goals. The first, of a scientific and exploratory nature, is to study the new properties of PbTe/CdTe multilayers. The second, to find and precisely define the relationships between the basic physical properties of PbTe/CdTe multilayers and the parameters of the MBE process in which they are grown. These relationships will then be used to achieve a third objective, the nature of which is more applied. This goal is to fabricate and optimize high-temperature infrared detectors in which the photosensitive region will be PbTe/CdTe multilayer structures. We plan to study two different types of detectors: resistors operating in photoconductive mode and diodes operating in photovoltaic mode. Based on the results obtained so far, we hope to obtain detectors with better parameters than those currently available.

The study of PbTe/CdTe multilayer structures is at a very early stage, as very few papers on this subject have been published so far, and only one in the aspect of application to infrared detection. The fact that the properties of this material can be effectively controlled by MBE growth parameters makes this topic intriguing in purely exploratory terms, and the material itself attractive for practical applications as a material for sensitive infrared detectors operating at room temperature. The results of this project can be expected to have a significant impact on the development of infrared detectors - instruments that are widely used for various purposes such as chemical gas analysis, gas leak detection, infrared imaging, remote temperature measurements etc.