Epitaxial growth and morphological, optical and transport studies of PbSnSe nanostructures in the aspect of their applications for infrared detection and emission

Within this project we want to grow and comprehensively investigate nanostructures made of semiconductor with a narrow band energy gap - PbSnSe surrounded by semiconductor with a much larger energy gap - CdSe. In the further part of the project we plan to focus our research on the case in which PbSnS nanostructures will be introduces into the active area (i-CdSe) of p-n junctions (p-ZnTe, n-CdSe). Our previous preliminary studies of such junctions show that they make sensitive detectors for near infrared radiation. Moreover, thanks to the high energy barriers produced by CdSe, the detectors can operate nearly at the room temperature [39,40]. In addition, we expect that p-ZnTe / i-CdSe / PbSnSe / i-CdSe / PbSnSe / i-CdSe / n-CdSe infrared detectors will be much faster than detectors produced solely on the basis of lead salts since their combination with II-VI materials will reduce the dielectric constant of these, thus, their capacity and in consequence, the RC time constant of the p-n junctions.

To achieve the prospective goal of sensitive infrared detectors, we need to carry out a whole range of technological and fundamental research. PbSnSe nanostructures will be produced by molecular beam epitaxy (MBE), so our first task will be to master the technology of their production. We have a lot of experience with MBE technology, but the epitaxial growth of PbSnSe / CdSe structures faces many challenges. It is because IV-VI and II-VI semiconductors do not mix with each other due to the different structures in which they crystallize. Our results obtained by studying a similar material system - PbTe/CdTe – show the scale of technological difficulties [5, 41]. The technological research that we intend to carry out will concern the relationship between the epitaxial growth conditions and the morphology of the structures produced. Specifically, we want to answer the question under what conditions appears the self-organization which leads to zero-, one- or two-dimensional structures, just as it does in the case of PbTe/CdTe [5]. These studies will be carried out by electron microscopy. Then we plan to focus our attention on diode structures such as: p-ZnTe / i-CdSe / PbSnSe / i-CdSe / n-CdSe for use as detectors and possibly infrared emitters. The first studies of similar structures are very promising [40]. The p-n junctions will be tested by optical (photoluminescence, electroluminescence) and transport methods (I-V, EBIC, etc.). The main focus will be on determining the detectivity of these devices and, in combination with technology, on maximizing the detectivity at the highest possible temperatures. In addition, we will try to determine the spectral range of the light sensitivity depending mostly on the composition of PbSnTe, but also the dimension, size and strain of PbSnSe nanostructures.

There are two main reasons for taking up this research topic. Firstly, immiscible material systems such as PbSe/CdSe are analogous to spinodal liquid systems, and the physics of their formation and decomposition is very interesting because these processes (1) proceed in solid phase and (2) ton a nanometer scale [5]. Secondly, radiation detectors in the near and middle range of infrared, ie electromagnetic waves of lengths ranging from 1 to several microns, find many different applications, among others. Remote sensing devices (pyrometers) and imaging devices (thermovision, thermography), solar radiation (actinometer, pyranometer), telecom satellites, missile launchers, artillery missiles, bombs, motion detectors, To analyze the chemical composition of liquids, solids and gases - including extraneous air composition analysis for medical diagnostics, etc. Since infrared detectors are typically manufactured from narrow energy-efficient semiconductors, increasing the sensitivity and detec- tion of such devices requires cooling to cryogenic temperatures. Therefore, there is a great interest in the development of such devices. Our project belongs to this interest and we are deeply convinced it is worth taking this direction of research.