1. PHD PROJECT DESCRIPTION (4000 characters max., including the aims and work plan)

Project title: Photothermal characterization of II-VI mixed crystals based on CdTe used in the detection of ionizing radiation

1.1. Project goals

The project aim is to use different photothermal methods to investigate CdTe-based solid solution with Be, Mn, Se, Mg and atoms. The goal is also preparing and applying a coherent model using all the phenomena present in the generation of the photothermal signal for the interpretation of the obtained photothermal spectra. The piezoelectric, photoacoustic and pyroelectric photothermal methods are planned to be used.

For semiconductors, there are three main sources of photothermal signal: thermal, plasma waves (associated with diffusion and recombination of carriers). In the investigation of transport in semiconductors one can also take into account immediate thermalization of carriers and nonradiative surface recombination. Usually only the thermal term is taken into account to interpret the pthotothemal spectra. The aim of the project is to use all the phenomena in the interpretation and the influence on the character of amplitude and phase spectra.

The samples, after the growth are subjected to various surface treatment procedures: mechanical, chemical and thermal. The proper method of surface treatment of the material is essential for the device quality, and the photothermal methods give the possibility to choose and evaluate the appropriate one.

1.2. Outline

Cadmium telluride II–VI CdTe based mixed crystals are industrially used for fabrication of variety of optoelectronic components: high-energy radiation detectors, photorefractive devices, electro-optic modulators, laser windows, solar cells, substrates for epitaxial growth of IR imaging systems [1]. Their physical properties can be altered to a considerable extent by choosing the appropriate dopant and doping level .

The surface recombination velocity (SRV) has a significant influence on the device's performance. In recent years, great efforts have been made toward the improvement in the cell open-circuit voltage and fill factor on CdTe-based devices [2]. A known approach to achieve these goals consists on reducing the back surface recombination velocity by means of surface treatments. Wet chemical etching of CdTe is generally accepted to create a Te-rich region on the CdTe surface, improving back-contact formation [3, 4].

Particularly, low values of SRV are required at the back contact of CdTe-based solar cells in order to prevent degradation . For pure CdTe crystal the proper etching allow surface smoothening, cleaning it from oxides and other contaminations. At the same time, wet chemical etch creates a Te-rich surface layer on CdTe which effectively results in a p+-doped zone that produces a back surface field. The goal of the project will be also to find the proper etching procedure for CdTe-based solid solutions.

Still, there is a lack of investigations and literature data of $Cd_{1-x}Be_xTe$ mixed crystals. Adding beryllium to CdTe matrix should give a similar effect in tuning energy band-gap or lattice constant like in the case of zinc. This fact should be interesting not only for detecting purposes but also for producing better substrates for infrared sensors.

Investigated crystals will be grown in Torun, Poland, at the Institute of Physics NCU with high pressure (HP), high-temperature Bridgman method under argon atmosphere. It is planned to grow several series of ternary and quaternary mixed crystals for a different composition.

1.3. Work plan

The work plan of the proposal can be summed up in several main points:

1. The growth of the mixed crystals
2. The choice and preparation of the mechanical, chemical and thermal treatments of the obtained samples
3. Measurements of piezoelectric photothermal spectra.
4. Construction of the photoacoustic cell and photoacoustic measurements
5. Measurements of pyroelectric photothermal spectra
6. Preparation and application of the theoretical model for the interpretation of the obtained experimental data
7. Thermal and optical parameters determination.
8. Characterization of surface defects due to the prepared model.

1.4. Literature

1. T.E. Schlesinger, J.E. Toney, H. Yoon, E.Y. Lee, B. A. Brunett, L. Franks, R. B. James*Mater. Sci. Eng. R* 32, 103 (2001).
2. O. Vigil-Galán, A Cruz-Orea, C. Mejía-García, J. Fandiño, M.F. García-Sánchez, Thin Solid Films 519 (2011) 7164–7167
3. Ivan Rimmaudoa, Andrei Salaveia, Elisa Artegiania, Daniele Menossia, Marco Giarolab, Gino Mariottob, Andrea Gasparottoc, Alessandro Romeo, Solar Energy Materials & Solar Cells 162 (2017) 127–133
4. V.D. Popovych, Yu.V. Pavlovskyy, Journal of Crystal Growth 584 (2022) 126585

1.5. Required initial knowledge and skills of the PhD candidate

Some experience according to the following points will be appreciated (but not necessary):

- experience in experimental physics
- basic knowledge about solid-state physics
- programming in Mathcad or similar application

1.6. Expected development of the PhD candidate's knowledge and skills

- skills of the characterization of the material with different photothermal experimental methods (piezoelectric spectroscopy, photoacoustic spectroscopy, photopyroelectric calorimetry – thermal and optical parameters, optical properties)
- theoretical basics of applied practical methods
- programing in Mathcad
- skills in collecting, analyzing, and presenting the data
- writing of scientific papers and delivering the results at the conferences
- understanding and description of the observed phenomena.