Luminescent probes of structural phase transitions in optical materials occurring under extreme conditions of high pressure and temperature

1. Goals of the project

The aim of the research is to develop a new, non-destructive and cheap method for detecting structural phase transitions in luminescent materials under extreme conditions of high temperature and high pressure. The materials will exhibit luminescent properties thanks to the incorporation of an dopant of Ln^{3+} ions into their structure, *e.g.* Eu^{3+}, Sm^{3+}, Pr^{3+} or Ho^{3+} exhibiting characteristic emission spectra, showing changed spectroscopic properties depending on the surroundings, *i.e.*, the crystal structure of the doped material. Polymorphic materials with the same composition but different physicochemical and photophysical properties will be obtained. Changes in the luminescent properties of materials in varied physical conditions will be examined, which will be correlated with changes in the internal structure of the materials, *e.g.*, phase transitions in extreme conditions of high pressure and high temperature. Additionally, thanks to the use of a high pressure hydraulic press (up to 10 GPa), it will be possible to obtain larger amounts of materials with previously unknown luminescent properties. Simultaneous compression and heating of materials in a diamond anvil cell will enable the production of new, advanced materials. The last goal of the project will be to obtain new luminescent sensors of physical conditions - high pressure and high temperature.

2. Research realized in the project

The project consists of six stages of research taking into account: **(I)** Preparation of luminescent materials with a defined structure and composition, which will include an in-depth analysis of structural and luminescent properties in ambient conditions; **(II)** Preparation of luminescent materials showing polymorphism, with the same elemental composition, but different structural and luminescent properties; **(III)** Investigation of the structural properties of materials under high pressure conditions using structural X-ray diffractometry and Raman spectroscopy to determine structural changes in materials; **(IV)** Investigation of luminescence properties of materials under high pressure conditions, in order to correlate changes in luminescent properties with structural changes; **(V)** Investigation of the structural properties of materials under high temperature conditions using structural X-ray diffractometry and Raman spectroscopy to determine the structural changes of materials under high temperature conditions; **(VI)** Investigation of luminescence properties of materials under high temperature conditions in order to combine changes in luminescent properties with structural changes of materials under extreme temperature conditions.

The structures and properties of materials with both reversible and irreversible transformations in extreme conditions will be examined. New materials resulting from defined irreversible transformations in extreme conditions will be additionally obtained in larger quantities thanks to a muffle furnace and a high pressure hydraulic press for detailed physicochemical and photophysical analysis in ambient conditions. Materials with reversible phase transition will be used to develop new optical thermometers and manometers.

3. The reasons for the research subject

Current methods of structural transformations are based on structural X-ray diffractometry or Raman spectroscopy, which are methods that require expensive and advanced research equipment. The development of new spectroscopic methods for determining phase transitions will significantly facilitate research into new materials. The research undertaken in the project will contribute to the development of new materials with extraordinary physicochemical and optical properties. The project will also have an impact on the development of luminescent thermometry and manometry, which are rapidly developing fields of materials science.