Surface-Enhanced Raman Spectroscopy (SERS) is an extremely effective analytical technique known for its high sensitivity and specificity. It finds applications in various scientific fields, including studying chemical reaction mechanisms and identifying and quantifying biological and chemical substances. Specially prepared substrates based on metallic nanostructures are increasingly used as biosensors, for instance, in biochemical, medical, and environmental analyses such as pesticide detection.

Photo-induced Enhanced Raman Spectroscopy (PIERS) is an advancement of the SERS technique, invented in 2016. It involves using a well-designed substrate, a nanoplatform composed of semiconductor materials with metal nanoparticles, pre-activated with UV light to achieve additional electromagnetic and chemical enhancements. As a result, the signal measured in the PIERS technique is enhanced by at least an order of magnitude compared to SERS. Therefore, PIERS has the potential to become one of the most sensitive analytical techniques, enabling the detection of single molecules.

Unfortunately, the scientific literature still lacks detailed information regarding the mechanisms behind PIERS enhancement. The optimal structure of the substrate, the thickness of the semiconductor layer, and the plasmonic properties related to the presence of metallic nanostructures for achieving optimal PIERS enhancement remain unclear. Additionally, no systematic studies have been conducted to describe the relationship between the intensity and wavelength of the UV light used for substrate photoactivation, the level of PIERS enhancement achieved, and the duration of its decay.

This project focuses on the design, preparation, and characterization of innovative, reusable nanoplatforms for both photo-induced enhanced Raman spectroscopy and surface-enhanced Raman spectroscopy as analytical sensors. These nanoplatforms will be based on a thin layer of titanium dioxide and noble metal nanoparticles, primarily silver, deposited through a photocatalytic deposition process. This production method for PIERS/SERS nanoplatforms is relatively fast and cost-effective compared to advanced technologies.

One of the main objectives of this project is to correlate the structural and physicochemical properties of the prepared nanoplatforms with their ability to enhance signals based on the PIERS and SERS phenomena. Furthermore, the suitability of the PIERS technique for ultra-sensitive detection of various molecules, particularly environmental pollutants like pesticides, drugs, and explosives, will be determined by evaluating the detection limit of these substances. The project will also determine the optimal thickness of the semiconductor layer that ensures the highest possible signal amplification in the PIERS technique. Systematic studies of nanoplatforms with different plasmonic properties will elucidate the conditions under which effective charge separation between TiO_2 and silver nanoparticles occurs under UV light. These properties include nanoparticle size, coverage of the oxide surface with metallic nanostructures, and the maximum of their localized plasmon resonance. These factors significantly influence charge accumulation within the nanoparticles and the duration of PIERS enhancement after the photoactivation process. Ultimately, based on the project's results, a model explaining the PIERS effect will be proposed, deepening the understanding of the technique by linking the efficiency of generating free charge carriers under UV radiation with the nanoplatform architecture and electron flow between metallic nanoparticles and the semiconductor, including their analytical sensor capabilities.

The described studies will have a profound impact on the development of research in the correlation between the structural and morphological features of nanomaterials and their spectroscopic properties. The project's economic and social effects will involve the development of innovative, reusable SERS/PIERS nanoplatforms for ultra-sensitive detection of selected chemical and biological substances.