Surface-Enhanced Raman Spectroscopy (SERS) and Photo-Induced Enhanced Raman Spectroscopy (PIERS) may not be household terms, but they hold the key to unlocking a world of scientific possibilities. These techniques are revolutionizing our ability to understand and manipulate the molecular world, from probing chemical reactions to monitoring health and environmental safety even at the level of a single molecule.

SERS harnesses the remarkable properties of noble metal nanoparticles and their interaction with laser light, leading to the improvement of molecular detection. While attempts have been made to use other materials, such as dielectrics, to boost Raman signals, the noble metals have consistently outperformed them. A breakthrough has come in the form of hybrid materials that combine semiconductor-nanoparticle connections. These hybrids benefit from both the plasmonic properties of nanoparticles and the interesting electronic properties of the semiconductors, the combination of which results in even higher SERS signal values. PIERS takes this a step further by elevating the SERS signal through electron migration between the semiconductors and metal nanoparticles when a hybrid composite is exposed to light. These hot electrons can be transferred to molecules on the metal surface, initiating plasmon-driven chemical reactions.

The goal of the project is to utilize SERS and PIERS spectroscopy as molecular tools for exploring the photocatalytic and depollution efficiency of hybrid nanomaterials. Three objectives guide our research. First, we assess the impact of chemical and morphological features of nanostructured semiconductors and metal nanoparticles on SERS and PIERS amplification. We focus our attention on substrates offering to engineer precise shapes and sizes and ensuring reproducible Raman scattering. A comprehensive understanding of SERS and PIERS mechanisms generating charge carriers is essential for long-term and reproducible Raman signals. This goal involves the engineering of hybrid materials with narrow band gaps to control charge transfer processes. In the final phase of the project. Our approach employs in situ time-resolved and mapping techniques to study kinetics and spatial distribution.

This project will lead to a significant advance in spectroscopy based on plasmonic effects. It has the potential to increase the efficiency, stability, and versatility of photocatalytic nanomaterials and to quickly evaluate their applicability.