Harnessing Nanomaterials in Advanced Gas Sensing Technology

One of the greatest challenges of today's world is the growing air pollution, which contributes to cardiovascular diseases, respiratory issues, cancer, and environmental degradation. As a result, there is an increasing demand for technologies capable of detecting air pollutants in a precise and repeatable way. This project aims to meet this demand by utilizing the unique properties of nanomaterials, specifically transition metal carbides (TMCs) and MXenes, to develop advanced gas sensors. TMCs and MXenes are next-generation nanomaterials that possess high electrical conductivity, excellent chemical stability, and a large surface area. These properties make them ideal for detecting gases such as NO_2, CO_2, and VOCs. Although MXenes show potential in this area, their long-term stability, particularly in humid conditions, remains an issue. This problem is directly linked to the material preparation methods. The goal of this project is to investigate and develop synthesis techniques that eliminate these problems. We plan to use chemical vapor deposition (CVD) to produce pure, defect-free TMC nanocrystals.

Innovation in this project comes not only from synthesizing new materials but also from developing the active layers in gas sensors. As part of the project, we will test standalone TMC nanocrystals and their combination with other nanomaterials, such as graphene oxide and graphene. Our main objective is to improve the long-term stability and selectivity of MXenes by synthesizing new phases and compositions of their non-functionalized counterparts, while gaining a better understanding of synthesis and detection mechanisms. Sensors based on TMCs, MXenes, and hybrids with other nanomaterials can have applications in many fields:

- **Environmental Monitoring**: detecting pollutants in highly industrialized and urbanized areas.
- **Industrial Safety**: rapid detection of leaks and hazardous substances to enhance workplace safety.
- **Healthcare**: sensors in the form of smartwatches and smartbands that detect low concentrations of substances in exhaled air, aiding the diagnosis and treatment of conditions like diabetes.
- **Military Technologies**: rapid detection of chemical and biological threats to enhance the defense of military and civilian population.

Our planned research is built on solid methodological foundations, utilizing advanced analytical techniques such as electron microscopy and Raman spectroscopy. These will be applied during the optimization of synthesis processes to obtain the most efficient product, whether from chemical vapor deposition or chemical synthesis.

This project, by deepening our knowledge of the properties and applications of advanced nanomaterials like TMCs, aligns with the European Union's policy on developing new materials for energy applications and detection technologies. The potential impact of these studies goes beyond academic considerations and scientific curiosity, carrying with it the hope of tangible discoveries that address modern societal challenges. The project will not only contribute to the development of materials engineering but will also strive to tackle global issues facing the world today.