GREEN-ENGINEERED 2D HYBRID MATERIALS WITH PLASMONIC NANOPARTICLES AND SMART POLYMERS: A MULTIPURPOSE PLATFORM FOR ENERGY, ENVIRONMENT AND HEALTH

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In this talk, I will present recent advances in the green synthesis of multifunctional two-dimensional (2D) hybrid materials developed to tackle urgent challenges in energy, environmental sustainability, and health. I will showcase case studies involving hybrid systems that integrate plasmonic nanoparticles—gold (Au), silver (Ag), and palladium (Pd)—with graphene oxide-based nanosheets and stimuli-responsive polymers, forming a versatile and scalable platform for a wide range of real-world applications.

These materials are synthesized using eco-friendly wet-chemical routes, such as employing glucose as a sustainable reducing agent and polyvinylpyrrolidone (PVP) as a stabilizer. This approach enables precise nanoparticle incorporation while maintaining the structural integrity and functional adaptability of the 2D framework. The incorporation of smart polymeric components allows the materials to respond dynamically to external stimuli—including light, pH, and temperature—activating behaviors such as tunable surface wettability and stimulus-triggered catalytic activity.

The functional properties of these hybrids have been extensively characterized using a comprehensive multitechnique approach, including X-ray photoelectron spectroscopy (XPS), Raman spectroscopy, UV-Vis and fluorescence spectroscopy, atomic force microscopy (AFM), transmission electron microscopy (TEM), and molecular dynamics simulations. These analyses reveal critical insights into how surface chemistry, nanoparticle distribution, and hybrid architecture influence overall performance.

Importantly, these materials exhibit multipurpose functionality. In the energy sector, they enable efficient photocatalytic hydrogen production under simulated solar irradiation. For the environment, they offer self-cleaning and pollutant-degrading surfaces that reduce maintenance and improve sustainability. In the field of health, their antimicrobial and bio-interactive properties open doors to applications in medical devices and protective surfaces.

Their robust, tunable design supports seamless integration into civil and chemical engineering applications, from smart coatings for infrastructure to active surfaces in environmental and biomedical contexts.

This work highlights how the intersection of green chemistry, nanotechnology, and materials engineering can yield scalable, high-impact solutions for a cleaner, healthier, and more sustainable future.