

Tuneable Interfaces in Single-Metal and Hybrid Nanoparticles: A Toolbox for Adaptive Sensing and Therapeutics

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Abstract

The chemical nature of surface ligands plays a pivotal role in tuning the structural, functional, and interfacial properties of colloidal nanoparticles (NPs), with direct implications for their application in sensing and nanomedicine. Particularly, the surface functionalization of metal nanoparticles (MNPs, gold (AuNPs), silver (AgNPs), palladium (PdNPs))[1–5] and covalent nanohybrids (titania-silver (TiO₂–Ag), and iron oxide-silver (FeO_x–Ag) systems)[6,7] through tailored thiol and silane chemistry enables the precise modulation of their physicochemical properties, highlighting the pivotal role of surface ligands in controlling interactions with analytes, drugs, and biological targets. The synthesis of MNPs through wet chemical reduction in the presence of hydrophilic thiols (sulfonated or aminated thiols) confers aqueous dispersibility, enabling electrostatic surface interactions and non-covalent immobilization strategies. The functionalization with hydrophobic or rigid dithiols forming covalent NP networks enhanced electrical properties of NPs and selective reversible/irreversible response in chemoresistive sensors depending on ligand rigidity and inter-particle distances. The appropriate combination of silane-thiol chemistry allowed the covalent assembly of AgNPs with TiO₂NPs or γ-Fe₂O₃NPs cores, forming synergistic nanoplatforms. These nanohybrids showed synergistic antibacterial effects via reactive oxygen species generation or enhanced germination activity in plants through metabolic modulation.

References

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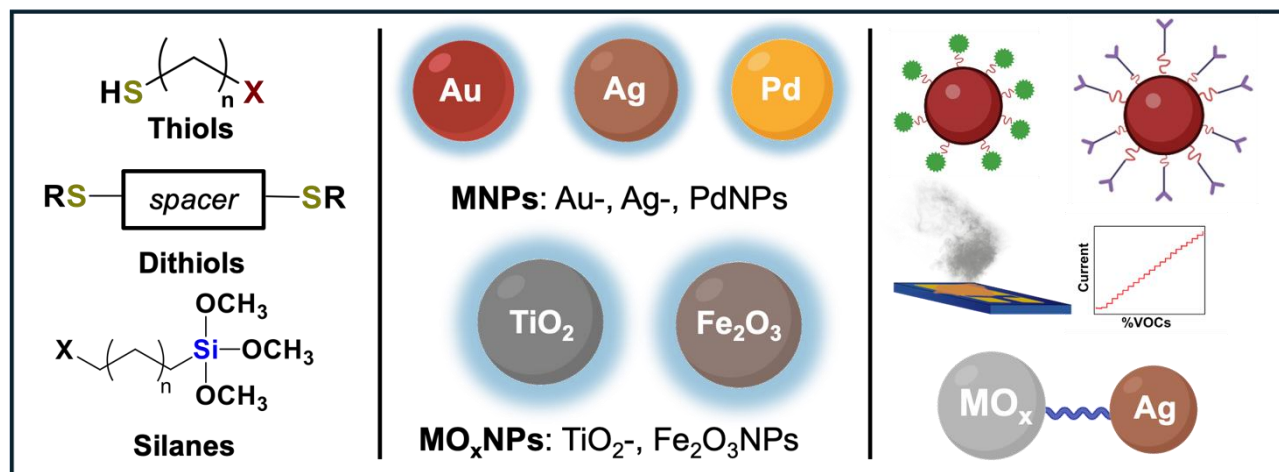


Figure 1: Schematic overview of functionalized nanoparticles and nanohybrids and their applications.