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Ph.D. DISSERTATION DEFENSE

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Degree: Doctor of Philosophy
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Title: Functional and Catalytic Metal Nanoparticles

Chairperson: Dr. Junfeng Liang, Department of Chemistry and Chemical Biology, School of Engineering & Sciences

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ABSTRACT

Metal nanoparticles (MNPs) as a major nanomaterials category possess completely different properties compared to bulk materials and ion forms, which inherit and expand the possibilities from their original elemental counterparts. MNPs exhibit excellent optical, electrical, and catalytic properties, benefiting from mature synthetic and conjugation methods, as well as their high surface area-to-volume ratios. They also demonstrate unique magnetic, thermal, and quantum confinement effects. This diverse range of tunable properties allows metal nanoparticles to be intensively utilized in diagnosis, catalysis, drug delivery, biomedical applications, etc. Modification of particle surfaces and coordination with other nanomaterials can further optimize their capabilities and advantageous characteristics, enabling application-driven design and engineering.

Gold nanoparticles (AuNPs) have been widely investigated as surface modifiers inspired by great physical and chemical properties. However, the complexity of morphology control, coating process, and high expense remain severe limitations. Here, functionalized AuNPs with great dispersity and stability were designed and synthesized. Reactivity of functionalized AuNPs in response to stimuli like pH, oxidation, and light was studied and utilized to control AuNP aggregation in solutions and coatings on solid surfaces. Such adhesive and easily manipulated AuNPs provide a facile and time-saving technology for wide biomedical and sensing applications.

Unlike AuNPs, iron nanoparticles are commonly applied to environmental and clinical areas due to their unique reactivity towards hydrogen peroxide (H_2O_2) synthesis and decomposition. Through a mild hydrolysis method, we synthesized nano-sized β-FeOOH and assembled them on polydopamine coated surfaces to mimic peroxidase-mediated reactive oxygen species (ROS) production. Besides the catalytic mechanism studies, Unlike other iron-based catalyst, this β-FeOOH based system works at room temperature without the needs of UV and sunlight activation. The potential applications of the new system in chemical pollutant removal and biofouling controls were explored.