

# Development of a Photothermally-Activated Hybrid Sol-Gel Platform for Enzymatic Biosensing Applications

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Enzyme-based biosensors are promising tools for the detection of pollutants due to their specificity and environmentally friendly nature. Nonetheless, their practical performance is often limited by enzyme stability, reusability, and optimal operating conditions. Here, we present a hybrid sol-gel platform co-immobilizing laccase and gold nanoparticles (AuNPs) within a silica matrix, designed to integrate biocatalytic and photothermal functionalities for biosensing applications.

AuNPs were synthesized via the Turkevich method, stabilized with PVP, and embedded into the silica matrix during the sol-gel process. Laccase was co-immobilized in the same matrix, resulting in a monolithic material where both components coexist in a stable network.

Photothermal characterization demonstrated that embedded AuNPs effectively generated heat upon laser irradiation at 520 nm, producing a localized temperature increase without affecting the bulk solution. This thermal modulation was intended to enhance enzymatic activity transiently.

Enzymatic activity assays using ABTS as a model substrate confirmed that the immobilized enzyme retained catalytic function. Independent thermal stability analysis by fluorescence spectroscopy indicated a slight decrease compared to the free enzyme. Importantly, comparison between monoliths with and without AuNPs in the absence of laser irradiation revealed no significant difference in activity, indicating that the photothermal effect—activated exclusively under laser exposure—is responsible for the observed enhancement in catalytic performance.

Although target-specific analyte detection remains to be demonstrated, the platform shows potential as a modular system adaptable to various enzymes and applications. These findings highlight the promise of photothermally responsive sol-gel materials for biosensors capable of faster response times through controlled, localized heating.

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