

Synthesis of Gold Nanostructures for Optical Fiber Biosensors Towards the Detection of *Salmonella* Typhimurium

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Summary:

This work presents a proof-of-concept for the rapid detection of *Salmonella* Typhimurium for food safety applications. The sensing approach is based on localized surface plasmon resonance in tapered single-mode-multimode-single mode fibers functionalized with synthesized gold nanostructures. Gold nanoparticles and gold nanostars were successfully synthesized and optically characterized; with distinct plasmonic responses suitable for sensing applications. The preparation of optical fiber probe and functionalization with nanostructures and antibodies are currently in progress.

Keywords: gold nanoparticles, gold nanostars, LSPR, optical fiber, *Salmonella*

Background, Motivation and Objective

Salmonella Typhimurium is a major foodborne pathogen faced by the world. In fact, *S. Typhimurium* infections account for approximately 420,000 deaths annually, highlighting the urgent need for rapid and highly sensitive detection methods [1], [2]. The plate culture method remains the gold standard for identifying bacterial contamination. However, confirmation of contamination usually takes several hours to days, making it insufficient for meeting the rapid response demands of modern food industries. Several rapid methods have emerged, but they usually suffer from high cost or lower sensitivity. Optical fiber (OF)-based biosensors, particularly those utilizing localized surface plasmon resonance (LSPR), have shown promise as powerful platforms for real-time detection due to their high sensitivity, lower cost, and potential for portability [3], [4], [5]. In our study, we will be evaluating the performance of a tapered single-mode-multimode-single-mode (SMF-MMF-SMF) fibers functionalized with various synthesized nanostructures exhibiting LSPR: gold nanoparticles (Au NPs), gold nanostars (Au NSs), Au NP@ZrO₂, and Au NS@ZrO₂ core-shell particles. To enhance the biosensor's selectivity and specificity towards *S. Typhimurium*, monoclonal antibodies will be immobilized on the sensor surface. The study aims to fabricate an optical biosensor that is cost-effective, robust, and allows

for real-time detection to meet the current demands of the food industry.

Description of the New Method or System

In this work, a tapered SMF-MMF-SMF platform functionalized with gold nanostructures is proposed for bacterial detection in food. The novelty of the proof-of-concept lies in the integration and comparative evaluation of different gold-based nanostructure—Au NPs, Au NSs, Au NP@ZrO₂ core-shell particles, and Au NS@ZrO₂ core-shell particles—on the optical fiber platform. This approach would allow a systematic investigation of how nanostructure morphology influences both enhanced sensor performance and sensor stability in the presence of the target bacteria. This integrated design combines robustness, cost-effectiveness, and enhanced sensing performance, offering a promising approach for rapid, selective, and reliable pathogen detection in food safety applications.

Preliminary Results

Au NPs were synthesized using the Turkevich method. To strike the balance between the desired nanoparticle size ranging from 15-30 nm and keeping the precursor consumption at a minimum, optimization studies were done. The identified conditions were therefore 1.0 mM HAuCl₄ starting concentration, 1:5.1 HAuCl₄:citrate ratio, 15 min reaction time at 500 rpm stirring speed at a boiling temperature. This allowed the formation of spherical Au NPs with LSPR peak at 423 nm

(Fig. 1) and an average particle diameter of 18 ± 3 nm with a normal size distribution (Fig. 2). The same Au NPs were used as seeds for the synthesis of Au NPs through a surfactant-free approach. AgNO₃ was used to block high-energy facets of the Au NP seeds, allowing the specific migration of Au atoms from the growth solution onto the low-energy surface of the nanoparticle, which then form the branches [6]. Fig 3 shows the TEM micrograph of the synthesized Au NSs, with a characteristic LSPR peak at 822 nm. These results confirm the successful synthesis of gold nanostructures with desired optical properties, which will then be used for the functionalization of the optical fiber structure.

References

- [1] S. Kaushik, A. Pandey, U. K. Tiwari, and R. K. Sinha, "A label-free fiber optic biosensor for *Salmonella* Typhimurium detection," *Opt. Fiber Technol.*, vol. 46, pp. 95–103, Dec. 2018, doi: 10.1016/j.yofte.2018.09.012.
- [2] S. Wang *et al.*, "Nanostructure-Modified Optical Fiber Sensors for Detection of *Salmonella typhimurium* in Food," *ACS Appl. Nano Mater.*, p. acsanm.6c00082, Feb. 2026, doi: 10.1021/acsanm.6c00082.
- [3] Q. Zhang *et al.*, "Dual nanoparticle-enhanced biophotonic fiber sensor for highly sensitive and selective detection of *Pseudomonas aeruginosa* in food safety applications," *Sens. Actuators Rep.*, vol. 10, p. 100409, Dec. 2025, doi: 10.1016/j.snr.2025.100409.
- [4] X. Lang, "Chitosan-coated iron(III) oxide nanoparticles and tungsten disulfide quantum dots-immobilized Fiber-based WaveFlex Biosensor for *Staphylococcus Aureus* bacterial detection in real food samples," 2024.
- [5] A. Moslemi *et al.*, "Highly sensitive gold nanostar based optical fiber sensor with tunable plasmonic resonance," *Sens. Actuators Rep.*, vol. 9, p. 100326, Jun. 2025, doi: 10.1016/j.snr.2025.100326.
- [6] A. L. Siegel and G. A. Baker, "Bespoke nanostars: synthetic strategies, tactics, and uses of tailored branched gold nanoparticles," *Nanoscale Adv.*, vol. 3, no. 14, pp. 3980–4004, 2021, doi: 10.1039/D0NA01057J.

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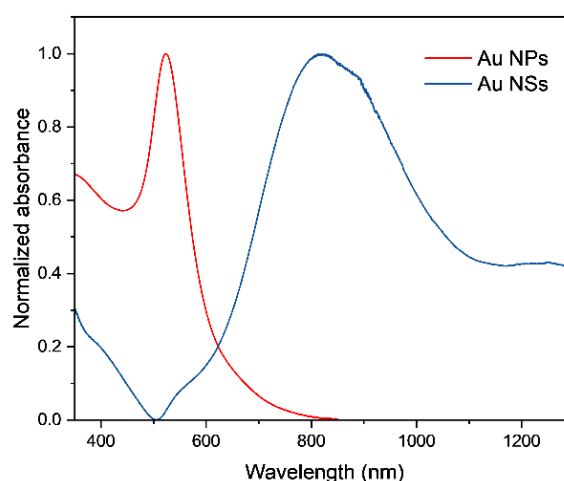


Fig. 1. UV-Vis-NIR absorbance spectra of Au NPs and Au NSs with corresponding LSPR peak at 423 nm and 822 nm, respectively.

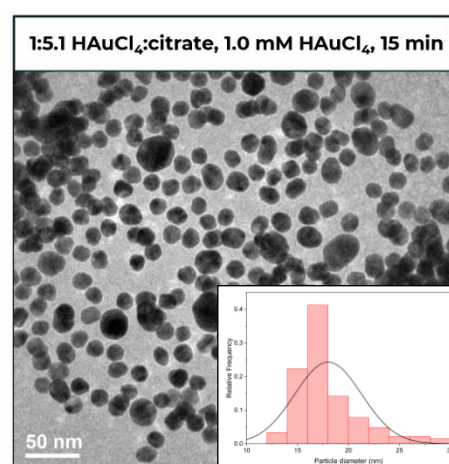


Fig. 2. TEM micrograph of Au NPs synthesized at the optimized precursor:reducing agent ratio, initial precursor concentration, and reaction time. Captured with 24k magnification and at 160 kV. (Inset: particle size distribution.)

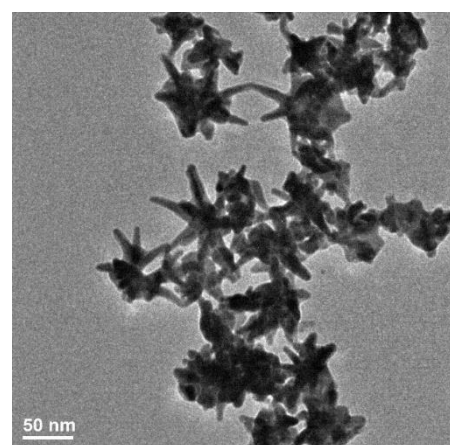


Fig. 3. TEM micrograph of Au NSs with well-defined branches. Captured with 24k magnification and at 160 kV