

Performance Comparison of Thiophene Derivative Films for SPR-Based Creatinine Detection

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Abstract

This study presents a comparative SPR analysis of tetrahydrothiophene (THT) and benzo[b]thiophene-2-carboxaldehyde (BTCA) as sensing layers for creatinine detection. Using an SPR setup, both materials exhibited concentration-dependent spectral shifts. The BTCA-based sensor demonstrated higher sensitivity (3.3557 nm/(mg/dL)), better linearity ($R^2 = 0.9636$), and lower detection limits than THT, attributed to stronger molecular interactions, including hydrogen bonding and dipole-dipole effects. These results confirm BTCA's superior plasmonic response, supporting its potential as a label-free sensing material for creatinine detection in clinical diagnostics.

1. Introduction

Surface plasmon resonance (SPR) occurs when polarized light hits a metal-dielectric interface at a specific angle, exciting surface electrons (plasmons) on the metal layer, typically gold. This generates a resonance condition that is sensitive to changes in the local refractive index, allowing for real-time monitoring of biomolecular interactions. When an analyte like creatinine binds to the sensor surface, it alters the refractive index, causing a measurable shift in the resonance wavelength. This study uses a wavelength-interrogated SPR platform with two sulfur-containing compounds, THT and BTCA, as sensing layers. Their electron-rich sulfur atoms and polar functional groups enhance non-covalent interactions with creatinine, improving surface binding and plasmonic response [1]. This approach enables receptor-free, cost-effective sensing with tunable sensitivity and practical potential for clinical diagnostics.

2. Method

Figure 1 shows the SPR setup using the Kretschmann configuration. Gold-coated microscope slides (24 mm × 24 mm) were prepared by sputtering a 50 nm gold layer using a current of 60 mA, with a sputtering rate of 9 nm/min, repeated five times to ensure uniform thickness. Two thiophene-based sensing materials—benzo[b]thiophene-2-carboxaldehyde (BTCA) and tetrahydrothiophene (THT)—were deposited onto the gold surface by dropcasting 600 μ L of each compound, followed by drying at 137–235 deg C. for 10–20 minutes. SPR measurements were conducted with the SF11 prism, where the reflectivity response to creatinine concentrations (0.2–1.2 mg/dL) was recorded. Resonance wavelength shifts were analyzed to develop calibration curves, determine sensor sensitivity, and calculate detection limits for both BTCA- and THT-based SPR films.

3. Results and Discussions

This study presents the reflectance spectra analysis of SPR sensors utilizing THT and BTCA for creatinine detection. In the THT-based sensor, reflectance spectra (Figure 2(a)) show resonance dips shifting from 435

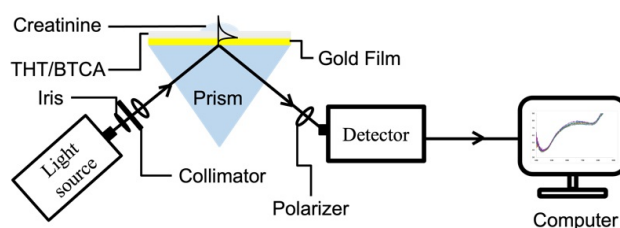


Figure 1. Schematic diagram of SPR setup for creatinine detection.

to 445 nm with increasing creatinine concentrations (0–1.2 mg/dL), indicating a redshift. Based on Figure 3, two-phase linear response is observed (blue line): a steep slope at low concentrations (0–0.4 mg/dL) with a sensitivity of 3.385 nm/(mg/dL) and $R^2 = 0.8708$, and a more gradual gradient beyond 0.4 mg/dL with reduced sensitivity (0.565 nm/(mg/dL), $R^2 = 0.9231$), attributed to binding site saturation. Calculated limits of detection (LOD) and quantification (LOQ) were 0.57 mg/dL and 1.72 mg/dL at low concentrations, and 1.4 mg/dL and 4.32 mg/dL at higher concentrations, respectively.

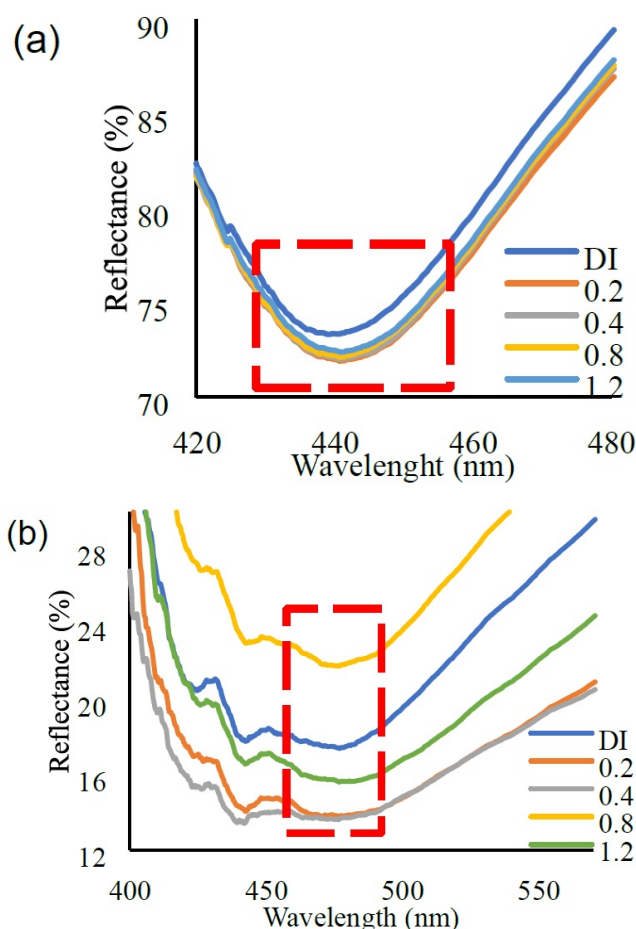


Figure 2. (a) Reflectance spectra of THT (435–445 nm) and (b) BTCA (460–490 nm) SPR sensors with increasing creatinine levels.

For the BTCA-based sensor, spectra exhibit resonance dips within 460–490 nm (Figure 2(b)). A non-monotonic trend (orange line) is noted where lower concentrations (0.2–0.4 mg/dL) show blueshifts, potentially due to initial adsorption disrupting the interfacial environment where early weak interactions may disturb the surface hydration layer or displace loosely bound molecules, briefly lowering the local refractive index before stable binding occurs [2]. In Figure 2(b), SPR intensity variations are likely caused by fluctuations in the light's



polarization, which can result from instability in the light source, optical components, or the overall setup [3]. Higher concentrations (0.8–1.2 mg/dL) consistently induce redshifts, reflecting increased surface interactions.

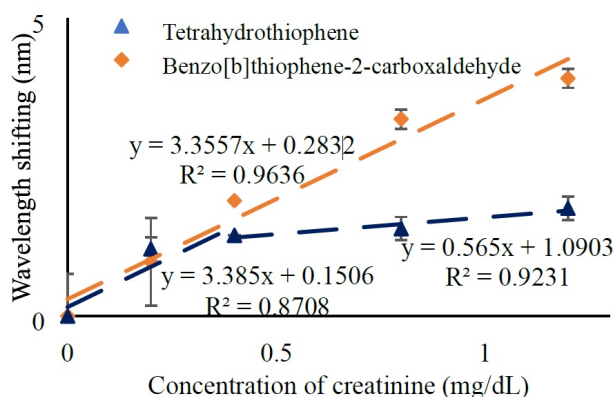


Figure 3. Linear correlation between creatinine concentration and wavelength shift.

The standard calibration curve shows a strong linearity ($R^2 = 0.9636$) with a high sensitivity of 3.3557 nm/(mg/dL), and LOD and LOQ values of 0.56 mg/dL and 1.70 mg/dL, respectively. Both sensors show label-free, concentration-dependent plasmonic shifts linked to molecular interactions. The THT sensor has dual-phase sensitivity, while the BTCA sensor performs better with more consistent linearity and stronger interactions with creatinine, including hydrogen bonding [4]. BTCA's polar carbonyl group and aromatic thiophene ring enhance dipole-dipole interactions and potential $\pi - \pi$ stacking, resulting in greater refractive index changes and higher sensitivity in SPR detection compared to THT [5].

4. Conclusion

The SPR platform effectively distinguished between THT and BTCA for creatinine detection. While both showed concentration-dependent resonance shifts, BTCA outperformed THT due to stronger molecular interactions, resulting in higher sensitivity and a more linear response. Its enhanced plasmonic response, driven by hydrogen bonding and dipole interactions, underscores its potential for detecting creatinine in biological fluids such as serum or urine, paving the way for non-invasive kidney function diagnostics.

Acknowledgments

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