



Role of Water Contact Angle in Biofunctionalized Gold Sensors for Glucose Detection Using K-SPR

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Abstract

Surface wettability, measured via water contact angle (WCA) assessments, is an essential parameter in evaluating sensor surfaces' characteristics in plasmonic biosensing, particularly in Kretschmann-based surface plasmon resonance (K-SPR). This study examines the influence of heptylamine plasma polymerization parameters on WCA measurement and correlates these surface alterations with the biosensor sensitivity. The results showed that increasing plasma deposition power from 10 W to 80 W increased WCA from 58° to 82°, transitioning the surface from hydrophilic to hydrophobic. At an optimal power of 30 W, the surface exhibited a WCA of 61.24° and a refractive index of sensitivity (RIS) of 60°/RIU. The correlation coefficient ($R^2 = 0.7584$) between plasma power and WCA confirms that controlled plasma treatment improves surface hydrophilicity and enables effective SPR-based glucose detection.

1. Introduction

Kretschmann-based surface plasmon resonance biosensors utilize surface chemistry for improved sensitivity and selectivity. Plasma polymerization of amine-rich precursors allows for adjustable wettability and reactive groups, enhancing sensitivity during SPR biosensing. Water contact angle (WCA) is the angle at which a liquid forms at the three-phase boundary. When the WCA is less than 90°, the solid surface is hydrophilic, and the lower the angle, the better the wettability. Conversely, when the WCA is more than 90°, the solid surface becomes hydrophobic, making it difficult to wet for bioreceptor immobilization [1]. This method offers a convenient metric for evaluating hydrophilicity alterations caused by plasma treatments, which directly influence analyte binding in plasmonic biosensing. Recent studies show plasma polymerization using amine-functional monomers improves sensor surface wettability and functionality, especially in SPR-based biosensors, where surface chemistry significantly influences detection sensitivity [2]. The K-SPR sensor, developed using plasma polymerization of heptylamine, was enhanced in surface performance and evaluated through WCA measurements and refractive index sensitivity properties.

2. Materials and Methodology

The K-SPR gold sensor slide was air-dried after 10 minutes of isopropanol and distilled water washing. The slide was placed on a copper platform before being installed in a glass chamber between two metal plates, as shown in Figure 1. Plasma polymerization begins by emptying the chamber to 6.6 Pa or less. Before activating the plasma-generating RF generator, ambient air enters the chamber at 25 Pa. Air plasma eliminates impurities from the chamber and the sample in 5 minutes. After evacuating the chamber to 6.6 Pa, 4 ml of heptylamine was added at 25 Pa to help release electrons and monomer fragmentation [3].

WCA measurements provide a metric for evaluating changes in hydrophilicity resulting from plasma treatments. The experiment employed variations in power, and the deposition time of 60 seconds was selected as it is brief yet conducive to cell adhesion and growth. This study employed the sessile drop technique [1]

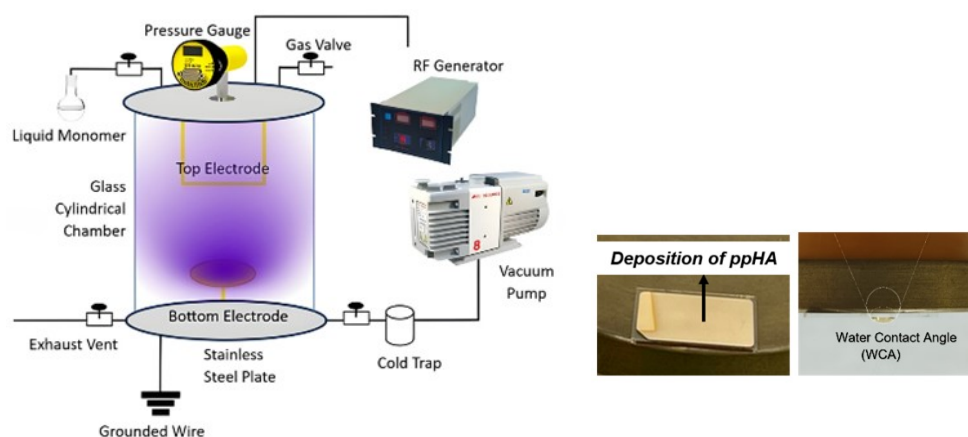


Figure 1. (a) Schematic of plasma polymerization of Heptylamine (ppHA) process and the water contact angle (WCA) measurement on Kretschmann-based surface plasmon resonance (K-SPR) gold sensor slide and (b) WCA on deposition of ppHA

to assess the water contact angle from two different sides with three repetitions and examined using ImageJ software.

3. Results and Discussion

Figure 2(a) presents the water contact angle (WCA) measurements across six replicates for each plasma deposition power, showing consistent and repeatable trends with minimal deviation, which validates the reliability of the experimental data. Figure 2(b) indicates the WCA increased from 58° at 10 W to 82° at 70 W, indicating a transition from hydrophilic to hydrophobic surface properties. However, it plateaued or declined after 70 W, possibly due to over-deposition or surface roughness. Reducing deposition power, specifically 10 W to 30 W, leads to a more hydrophilic surface, which is beneficial for sensor applications. Moreover, a linear trend ($R^2 = 0.7584$) shows a positive correlation between plasma power and WCA. The fitted trendline $y = 3.1811x + 55.969$ suggests a $\sim 3.18^\circ$ increase in WCA for every 10 W increase in power, allowing precise control of surface wettability.

Figure 3 shows changes in K-SPR resonance angles and dip depth due to surface modifications in air and PBS on a K-SPR Au sensor slide and functionalized ppHA at 785 nm optical wavelength. K-SPR measurements confirmed these changes, with bare gold surfaces showing a distinct dip at 43° in air and 66° in PBS due to increased refractive index. ppHA-deposited gold surfaces showed a broadening dip at 50° and a red-shift to 70° in PBS.

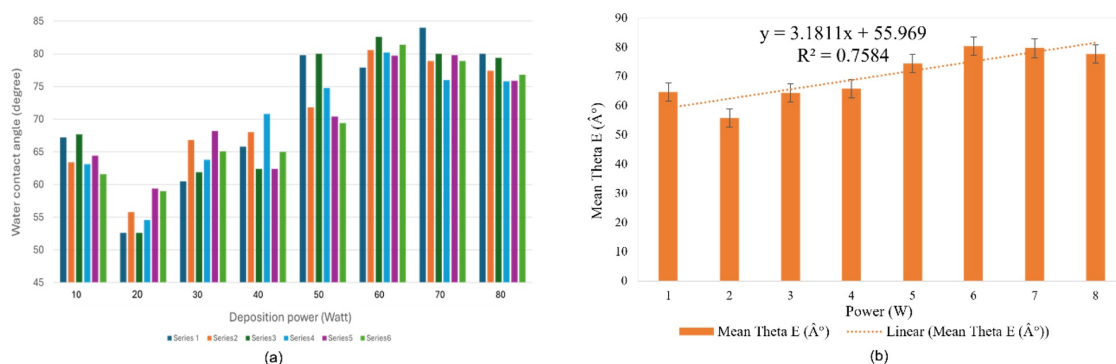


Figure 2. WCA across plasma deposition powers (10-80W) with 5 replicates and the correlation between deposition power and water contact angle for ppHA-coated surfaces.

While the addition of the ppHA layer improves hydrophilicity and supports biomolecule binding, it also introduces an optical layer that can partially reduce the penetration depth of the plasmonic field. This results in a slight reduction in RIS from 69°/RIU (bare gold) to 60°/RIU (ppHA) which created a trade-off.

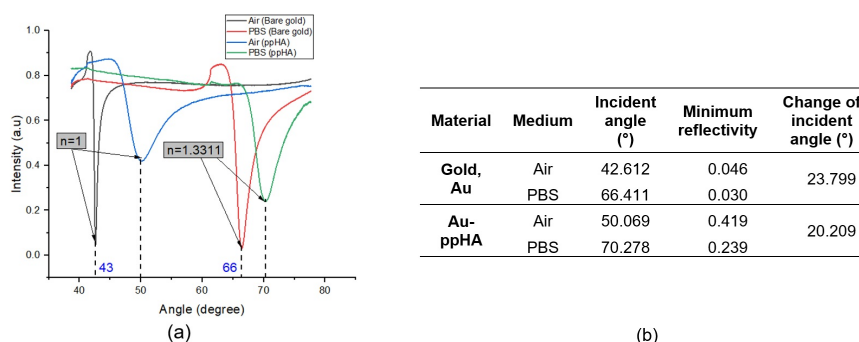


Figure 3. SPR reflectivity curves and resonance angle shifts of bare and ppHA-coated gold sensors in air and PBS.

4. Conclusion

This study shows that the plasma polymerization of heptylamine (ppHA) can increase the surface functionality of gold-based SPR biosensors. By tuning plasma deposition power, water contact angle (WCA) measurements revealed that surfaces become increasingly hydrophobic above 40 W, whereas optimal hydrophilicity was achieved at 30 W. Water contact angle (WCA) measurements confirmed improved hydrophilicity, while refractive index sensitivity (RIS) analysis demonstrated a strong optical response of $60^\circ/\text{RIU}$. These improvements support more effective bioreceptor immobilization and contribute to the overall sensitivity and reliability of SPR-based biosensing.

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