

Sensitivity Enhancement of LSPR Sensors on Flexible Glass Substrates through Bending-Induced Deformation

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Summary:

This study presents a flexible LSPR sensor based on gold nanoislands on a flexible glass substrate. Upon mechanical bending, the sensor exhibited a two-fold increase in refractive index sensitivity (from 96 to 205 nm/RIU), while maintaining stable extinction spectra. The enhancement may be attributed to reduced interparticle spacing and increased near-field coupling. This bending-induced effect provides a simple yet effective strategy for sensitivity tuning in wearable plasmonic sensors.

Keywords: LSPR, Au, Biosensing, Flexible, Wearable

Introduction

Localized surface plasmon resonance (LSPR) refers to the collective oscillation of conduction electrons in metallic nanoparticles when excited by incident light, typically occurs when the particle dimensions are smaller than the wavelength of light [1]. LSPR-based sensors can detect shifts in extinction or absorbance spectra upon analyte binding, allowing for label-free and real-time biosensing with high sensitivity [2]. Unlike conventional rigid glass or silicon wafers, flexible materials can conform to curved and dynamic surfaces, making them suitable for on-skin or in vivo biosensing, which is particularly valuable for wearable technologies, where sustained contact with soft biological surfaces is required [3]. Furthermore, flexible plasmonic substrates offer mechanical tunability, which may influence sensor performance or integrate with stretchable electronics. This study investigates the use of a flexible glass-based LSPR sensor and demonstrates the performance enhancement achieved through mechanical bending of the substrate.

Materials and Methods

A flexible glass with length/width/thickness as 3 cm/2 cm/50 μm was used for the substrate, an 8 nm of gold thin film was deposited on the flexible glass via thermal evaporation and followed by rapid thermal annealing (RTA) at 450 $^{\circ}\text{C}$ for 60 seconds, resulted in the formation of randomly distributed gold nano-islands as shown in Fig. 1(a). The LSPR characterization was carried out

using extinction spectra with measurement system as schematical plot shown in Fig. 1(b). Broadband illumination was provided by a halogen light source (HL-2000, Ocean Optics, U.S.), captured through a spectrometer (USB 4000, Ocean Optics, U.S.). The sensor was mounted on a motorized stage equipped with a custom-designed 3D-printed holder that enabled measurements under bending *configuration*. The substrate was deformed with a specified curvature to provide a mechanical stress condition.

For refractive index sensing, extinction spectra were performed with different refractive indices solutions, in the range of approximately 1.33 to 1.40. Multi-points measurements were conducted for bending *configuration* for determining error bars, proving the overall reliability of the results. All extinction spectra and LSPR peak positions were determined by Gaussian fitting using Origin software.

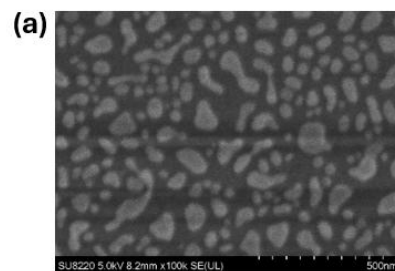


Fig. 2. (a) SEM images of Au nano-islands,

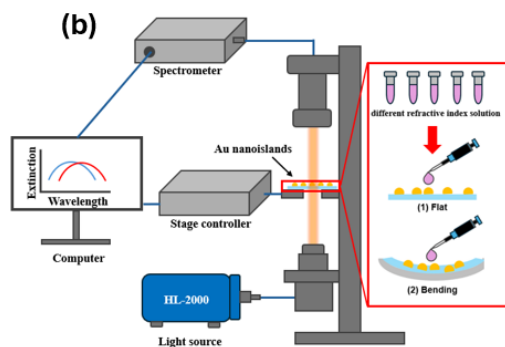


Fig. 2. (b) LSPR setup with flexible glass under flat and bending configurations.

Results and Discussion

The extinction spectra for flat and bending configuration showed negligible differences in the overall peak shape and position, indicates that the nano-islands maintained their structural integrity despite mechanical deformation. Such robustness is essential for potential integration into wearable or dynamic sensing systems [4].

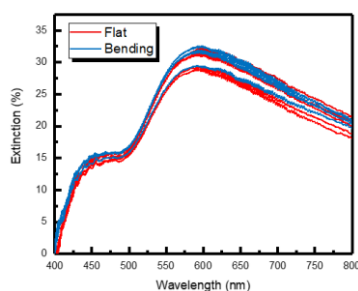


Fig. 3. Extinction spectra of flexible LSPR sensor under flat and bending configurations.

However, a notable distinction emerged when comparing refractive index sensitivity between the two conditions. The flat configuration has a sensitivity of approximately 96 nm/RIU. In contrast, the bending configuration showed a significantly higher sensitivity of about 205 nm/RIU, which is more than two-fold increase in sensitivity suggests that mechanical bending introduces beneficial changes at the nanoscale level.

The observed enhancement in sensitivity is likely due to several mechanisms. First, Bending may reduce nano-island spacing then enhance plasmonic coupling, leading to stronger near-field effects and improved sensitivity [5]. Substrate curvature could also modulate light scattering or alter resonance conditions slightly, contribute to heightened refractive index responsiveness.

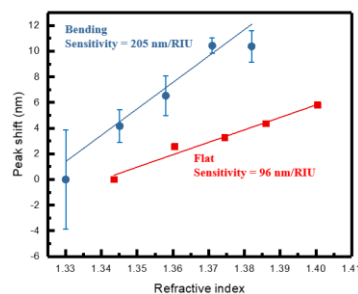


Fig. 4. Refractive index sensitivity of the LSPR sensor under (a) flat and (b) bending configurations, showing sensitivities of 96 nm/RIU and 205 nm/RIU, respectively.

Conclusion

This study demonstrates that LSPR sensors fabricated on the flexible glass substrate with an enhanced sensitivity through mechanical bending. While the extinction spectra remain stable across deformation states, the refractive index sensitivity increases from 96 nm/RIU to 205 nm/RIU. Nonetheless, adhesion issues were observed as repeated measurements after bending introduced variability. Future efforts should improve nanoisland stability via adhesion layers or embedding, and enhance packaging to protect the sensing layer, enabling robust, flexible plasmonic sensors.

References

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