Optimization Of A Surface Plasmon Resonance Sensor For Continuous Stress Monitoring

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Abstract

Wearable devices are drastically transforming the healthcare industry by enabling continuous, real-time monitoring of physiological and biochemical properties outside clinical settings. One particularly important application is the monitoring of stress; a significant factor linked to various chronic conditions such as depression and metabolic disorders. Continuous stress monitoring is crucial for its early detection and preventive health measures, which in turn lead to improved recovery and reduced healthcare costs.

In contrast to the more traditional optical sensors that can be bulky and include energy-consuming components, plasmonic sensors have emerged as a promising technology for integration into wearable devices due to their potential for miniaturization (Le et al., 2024). Plasmonic sensors, more specifically surface plasmon resonance (SPR) sensors, are based on plasmons that are collective oscillations of free electrons on a metal-dielectric interface. Plasmons are highly sensitive to the refractive index (RI) changes of the surrounding medium, caused by molecular interactions, and can therefore be exploited for biosensing. The RI change of a measured liquid sample results in a shift in the angle or wavelength of the reflected light, providing real-time information on analyte concentrations.

Fabrication of nanophotonic devices, such as plasmonic sensors, is often time-consuming and expensive. Computational modeling addresses these challenges by providing insights into sensor operation and therefore supporting efficient design and optimization.

In this work, we used the Wave Optics Module in COMSOL Multiphysics® to design and optimize gold grating-based SPR sensor chips for stress biomarker detection (Le et al., 2024; Ranta-Lassila et al., 2024). The simulations were performed on a single grating unit cell with periodic ports and Floquet boundary conditions to account for periodicity. The Brendel-Bormann model from the COMSOL Material Library was used for the gold grating, and a built-in, extremely fine, physics-controlled mesh was applied to ensure accurate results. The sensor chips were targeted for near-infrared (NIR) laser sources, around 780, 940, and 1550 nm. By comparing predicted sensitivity of SPR chips at different wavelengths, the sensor structure requiring lower laser power due to minimized light absorption in the sample is suggested. Lower power consumption improves thermal management, paving the way for more accurate and stable sensor performance (Fig. 1).

Reference

G. M. Hale and M. R. Querry, "Optical constants of water in the 200-nm to 200-micron wavelength region," Appl. Opt., 12, 555-563 (1973).

D. Le et al., "High-performance portable grating-based surface plasmon resonance sensor using a tunable laser at normal incidence," Photon. Res. 12, 947-958 (2024).

A. Ranta-Lassila et al., “Stress biomarker detection with a grating-coupled surface plasmon resonance sensor”, Opt. Eng. 63(11), 117103 (2024).

Figures used in the abstract

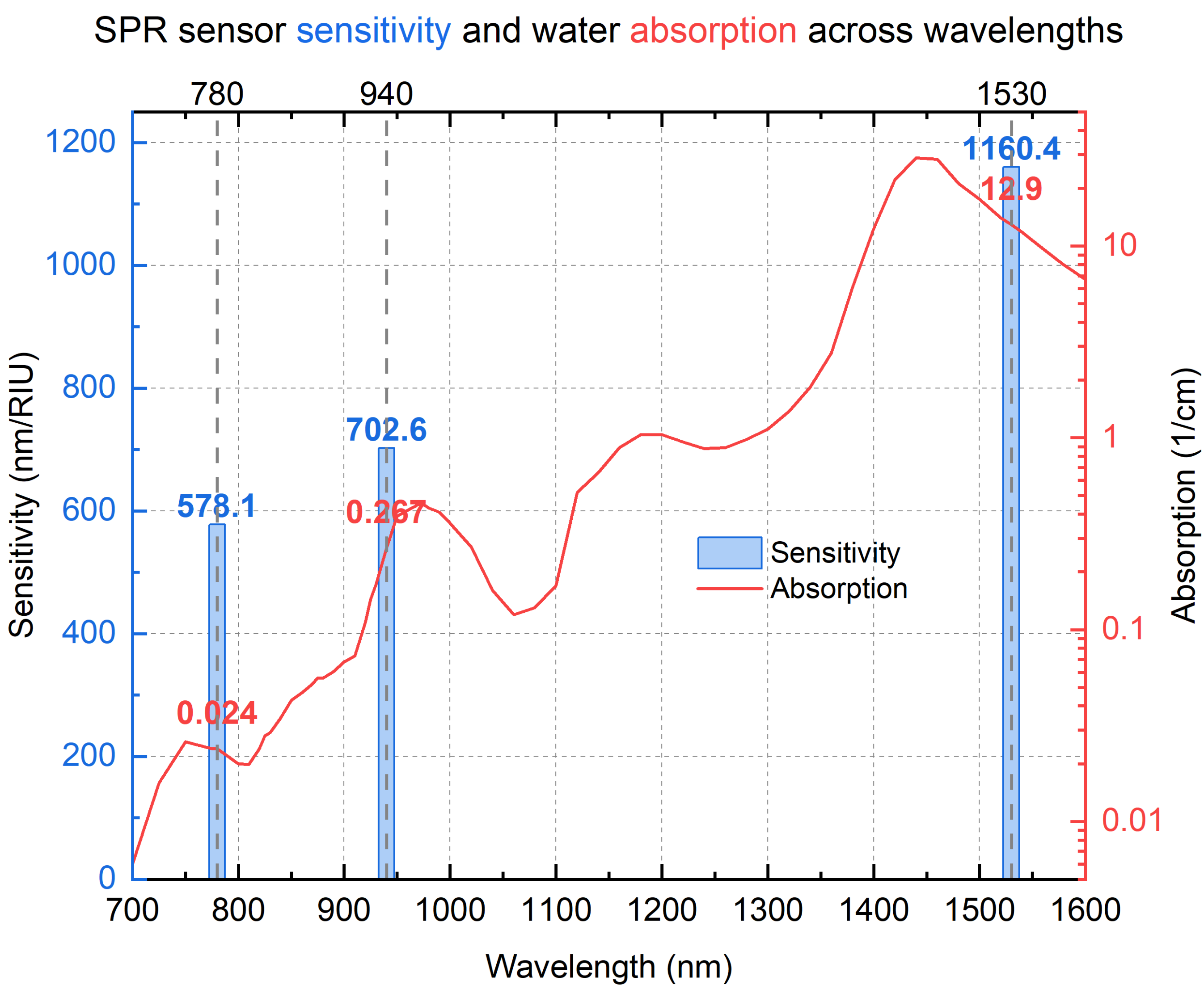

Figure 1 : Figure 1. Simulated sensitivity of the SPR sensors at 780 nm, 940 nm, and 1530 nm, shown alongside water absorption (Hale and Querry, 1973).