

Dependence of the Determination of Refractive Index Sensitivity of Plasmonic Sensors on the Calibration Method

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Summary:

Among label-free biosensors, plasmonic sensors are a growing area of interest for various applications. One of the most important and widespread parameters to characterize and compare them is bulk refractive index sensitivity (*RIS*). However, most of the researchers use different methods (solutions) to determine this value. In this work, various methods were tested on a single sensor element to investigate whether the different characterizing methods and used calibration solutions affect the obtained results.

Keywords: Localized surface plasmon resonance (LSPR), refractive index sensitivity (RIS), gold nanoparticles, microfluidics.

Background, Motivation and Objective

Localized surface plasmon resonance (LSPR) is a phenomenon that occurs when the incident light (i.e. electromagnetic radiation) interacts with the electron cloud of metallic nanoparticles, causing an oscillation of the electrons [1]. This happens at a specific frequency, the resonance frequency, which appears as an absorption peak in the optical spectrum.

The frequency – and thus wavelength – of the resonance is determined by numerous different factors, such as the size, shape, and material of the nanoparticles, as well as the refractive index of the surrounding medium. This last parameter is the one that enables the usage of nanoparticles as sensor elements: an increase in the concentration of the target molecule increases the refractive index, resulting in a shift of the absorbance peak that can be detected.[2]

The most common metric used to characterize these sensors is the refractive index sensitivity (*RIS*), which can be defined by eq. (1):

$$RIS = \frac{\Delta\lambda_p}{\Delta n} \quad (1)$$

where $\Delta\lambda_p$ is the shift of the spectral peak, and Δn is the change of the refractive index of the surrounding medium [1].

Different studies employ different methods to determine the sensitivity of their sensor. Most commonly, a dilution series of test solutions is used to measure the plasmonic response of the

nanoparticles in the function of a changing refractive index. The aim of this work was to investigate whether these various approaches and calibration solutions lead to the same result.

Description of the Method

The nanostructures used for the experiments are hexagonally arranged ellipsoidal gold nanoparticles. The fabrication process included the use of a porous alumina template, deposition, and then dewetting – as described in an earlier work [3].

Three different sets of solutions – sodium chloride, glucose and glycerol – were prepared and used for the experiments.

The optical spectroscopy measurements were performed using polydimethyl siloxane (PDMS) microfluidic cells.

Results

The raw data are presented in Fig. 1. Time is shown on the x-axis, whilst the changes in the peak's wavelength can be observed on the y-axis. These changes are caused by the different media (in order: air, water, NaCl: 5, 10, 15, 20, 25 w/w%, water, glycerol: 10, 20, 30, 40, 50, 60 w/w%, water, glucose: 10, 20, 30, 40 w/w%, water) surrounding the sensor in the microfluidic cell. As can be seen, solutions with increasing concentrations – and thus increasing refractive indices – resulted in increasing peak wavelengths.

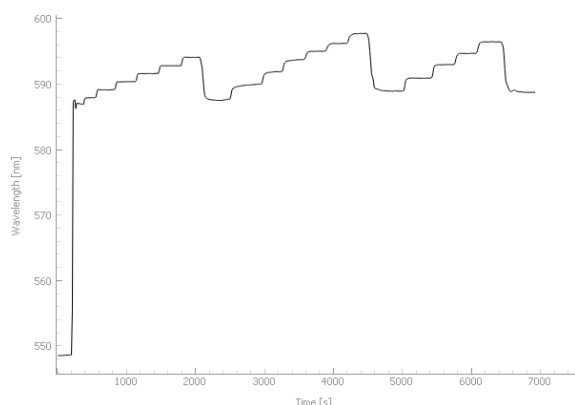


Fig. 1. Measurement results: shifts in peak wavelength vs time, caused by refractive index differences.

The results of the measurement are summarized in Table 1. After the evaluation of the obtained data, bulk refractive index sensitivities were calculated, taking into account the results of only one type of solution at a time.

Tab. 1: Refractive indices of the solutions and corresponding peak positions.

| | c [w/w%] | n [-] | Peak [nm] |
|-----------------|-------------|----------|--------------|
| Sodium chloride | 0 | 1.333 | 588.3 |
| | 5 | 1.342 | 589.6 |
| | 10 | 1.350 | 591.0 |
| | 15 | 1.359 | 592.4 |
| | 20 | 1.368 | 593.8 |
| | 25 | 1.378 | 595.3 |
| Glycerol | 0 | 1.333 | 587.7 |
| | 10 | 1.345 | 590.1 |
| | 20 | 1.357 | 592.4 |
| | 30 | 1.371 | 594.5 |
| | 40 | 1.384 | 596.1 |
| | 50 | 1.398 | 597.6 |
| | 60 | 1.413 | 599.5 |
| Glucose | 0 | 1.333 | 589.2 |
| | 10 | 1.348 | 591.4 |
| | 20 | 1.364 | 593.9 |
| | 30 | 1.381 | 596.0 |
| | 40 | 1.399 | 598.1 |

The bulk refractive index sensitivities for sodium chloride, glycerol and glucose were found to be 157.2 nm/RIU, 134.4 nm/RIU and 137.2 nm/RIU, respectively. This suggests that the RIS depends

not only on the specific sensor but also on the calibration solution used to determine its value. Further investigation is needed to better understand the reasons behind this phenomenon. In our work we will present detailed data obtained on various calibration scenarios aimed at systematically testing this behaviour, and an explanation for the observed differences will be given in the form of a model, that can be generally used for the reproducible and comparable calibration of plasmonic sensors.

References

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