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Benchmarking the Gas Sensitivity of LSPR Sensors With a New Parameter

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Summary:

A new parameter is introduced to benchmark the gas sensitivity of plasmonic sensors. This parameter takes into account both the surface sensitivity and the plasmon decay of the used nanoparticles and considers adsorbed gas layers on the sensor surface. Its applicability was tested with a novel plasmonic sensor based on ellipsoidal gold nanoparticles arranged in tightly packed hexagonal lattices, exposed to the exchange of different inorganic gases. The controversy often present when comparing the response of plasmonic sensors tested in liquids and gases is resolved by using this new parameter.

Keywords: Localized Surface Plasmon Resonance; Refractive Index; Gas Sensing; Modelling adsorption interfaces; Gas Sensitivity

Background, Motivation an Objective

The interpretation of the gas sensing performance of localized surface plasmon resonance (LSPR) based sensors is not trivial. The most widely used approach in the literature is using the bulk refractive index sensitivity (*RIS*), calculated by dividing the measured plasmon resonance peak shift ($\Delta\lambda_p$) with the refractive index difference of the exchanged gases (Δn_b), as in eq. (1). [1].

$$RIS = \frac{\Delta\lambda_p}{\Delta n_b} \tag{1}$$

In this approach, the gases are characterized by their bulk refractive index (n_b) only, without considering gas layers adsorbed on the surface of the used nanoparticles or the effect of the plasmon field's decay. The problem with this approach is that the resulting *RIS* values calculated by exchanging gases are usually an order of magnitude higher than those calculated by calibrating the LSPR sensor with liquids of known refractive index.

Description of the New Method or System

In order to resolve these apparent discrepancies between LSPR sensitivity calibrations in liquids and gases, and for the proper evaluation of the gas sensing performance of these sensors a new model was introduced that takes into account both the surface sensitivity and the plasmon decay of the nanoparticles to evaluate the measured LSPR response considering adsorbed gas layers with a $\Delta n_l(t)$ function, where t is the thickness of the adsorbed gas layer. Based on this model, a new benchmarking function, termed as gas sensitivity *GS*(*t*) is introduced, as defined in eq. (2). *GS*(*t*) characterizes the gas sensing performance of a plasmonic sensor and – as will be demonstrated – is independent of the type and pressure of the tested gases.

$$GS(t) = \frac{\Delta\lambda_p - RIS\Delta n_b}{\Delta n_l(t)} \tag{2}$$

Results

To demonstrate the applicability of this parameter, a novel plasmonic sensor based on ellipsoidal gold nanoparticles arranged in tightly packed hexagonal lattices [2] was tested by switching the gas atmosphere between inorganic gases, namely He/Ar and Ar/CO_2, at constant pressure and room temperature. The nanoparticle arrangement of one of the tested plasmonic sensors is shown in Fig. 1.

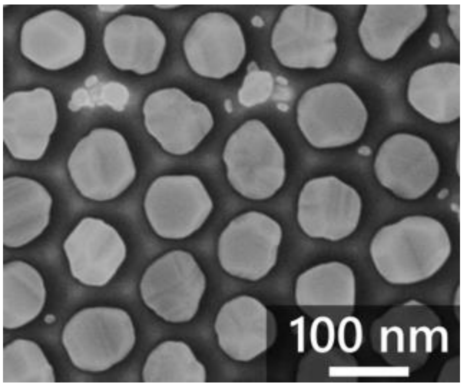

Fig. 1. Scanning electron microscopy image of the tested gold nanoparticle arrangement [3].

Based on the response of the sensors upon gas exchange, numerical modeling and simulations were done to determine the plasmon decay length of the particles and to calculate the $\Delta n_l(t)$ functions for the different gases. Based on these, the gas sensitivity functions ($GS(t)$) were also obtained for the tested conditions, as shown in Fig. 2.

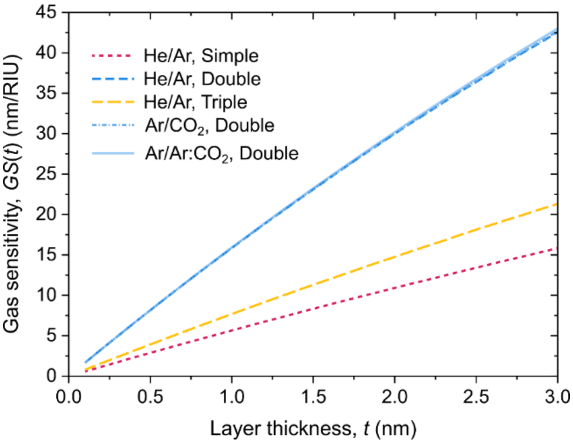

Fig. 2. Gas sensitivity functions GS(t) for the three tested nanoparticle arrangements calculated for different gas exchanges. The ‘simple, double, triple’ phrases stand for the different particle arrangements, with increasing particle density [3].

As can be seen in Fig. 1, for a given sensor type, the calculated gas sensitivity functions were independent from the type of gases or the measurement conditions.

In the presentation we will demonstrate that the proposed sensitivity model provides a unified explanation for the sensors' response, consistent with their behavior both in the tested liquids and gases and also, that the derivative of the gas sensitivity function, namely d$GS(t)$/dt, can be conveniently used as a single parameter for benchmarking purposes.

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