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Editorial

Special Issue on Optical Sensors and Gauges Based on Plasmonic Resonance

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A surface plasmon is a plasmon that propagates through a surface; i.e., it is an electromagnetic wave from the interaction of an electromagnetic wave with the oscillations of free electrons on the surface of a metal, which propagates at the separation interface of a metal (Drude model) [1].

There are two types of plasmons, the polariton surface plasmon that has the form of an electromagnetic wave, which propagates through the interface of a metal-dielectric surface [2], and the localized polariton surface plasmon, which is comprised of localized electron oscillations in metallic nanoparticles that are found inside a dielectric [3].

From the Lycurgus Cup in 272-337 AD [4], through the wonderful stained glass of Romanesque and Gothic churches and cathedrals [5] to the most modern sensors, plasmons have always been present in the life of human beings, although we did not know about them.

The first to obtain the mathematical expression of a plasmon was Gustav Mie in 1908 [6]. Humanity had to wait almost 70 years until work with particles began in the 1980s, resulting in one of the first articles on plasmonic sensors to be published in the world [7]. It has been a hard task; physicists and engineers have had to work together, first to formalize the equations of plasmons and evanescent waves at dielectric-metal interfaces and second to build structures that would make it possible to obtain these plasmons. Later, these scientists, working together with biologists, medical doctors, chemists, etc. paved the way for the creation of plasmonic sensors gradually designed to measure all kinds of variables, not just physical ones. The last step has been the design and manufacture of new materials, metal alloys, or the doping of materials to replace metals and dielectrics and achieve better resolutions and sensitivities [8].

Considering the structure of the sensor, the only configurations are Otto (prism-metal-dielectric) [9] and Kretschmann (prism-dielectric-metal) [10]. In terms of sensor design, there are intensity, wavelength, and angle interrogation sensors. Although they may all have the same sensitivity and resolution, sensors based on intensity interrogation have the advantage of not having moving parts, so there is no mechanical wear and tear, and they will have a long useful life [11].

Do plasmonic sensors really measure the amount of substance in a certain medium, for example, do they measure salinity, sucrose concentration, the presence of CO, etc.? The answer is no. These sensors measure differences in the refractive index of the medium, and from here, we can relate, for example, the concentration of sucrose in a medium to the refractive index. Measuring the refractive index (or changes in refractive indices) is what makes them better, more general and universal, since they do not analyze a specific substance but rather a property.

They are nanophotonic sensors, so their tiny size allows them to be integrated with more sensors to build an array and be able to detect different substances, materials, etc. without more than multiplexing in time or space the input and output optical power [12] or integrating them into more complex sensors capable of measuring more than one parameter at the same time [13]. The applications of these sensors are not only in the field of physics; they are also being used very successfully in chemistry, biology, medicine, etc. In the latter

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case, as they are made of biocompatible materials, they can be introduced into the patient's body (if necessary) without putting humans (or animals) at risk.

This Special Issue aims to collect and present cutting-edge research on all plasmonic sensor technologies to contribute to the research, design, development, and applications with articles that demonstrate the most recent advances in plasmonic sensors with new scientific knowledge, designs, and their practical applications.

A total of seven papers in various fields of SPR sensors are presented in this Special Issue.

In the article by Cardoso M.P. et al. [14] a Tunable plasmonic resonance sensor using a metamaterial film on a D-shaped photonic crystal fiber for refractive index measurements is proposed. These meta-materials are sub-wavelength cells of metallic nanorods arranged in a dielectric background, and exhibit bulk properties that are useful for controlling and manipulating surface plasmon resonances.

Pérez-Ocón et al. [11] present the design of two sensors, one for the continuous measurement of sucrose concentration with sensitivities of 11.9–5.7 RIU^{-1} and resolutions of the order of 10^{-4} RIU; this sensor is capable of measuring sucrose concentrations of up to 78 BRIX, that no plasmonic sensor has so far been capable of measuring. The other sensor [15] measures CO_2 concentrations with a resolution of 10^{-5} RIU. This new sensor, due to its sensitivity and resolution, along with its diminutive size, could be integrated into an electronic nose and used on spacecraft, the International Space Station, or even commercial flights. Both sensors have some of the highest sensitivities and resolutions to date in this type of plasmonic sensor.

An important fact about SPR sensors is how temperature affects the measurements. Temperature changes the wavelength at which surface plasmon resonance occurs. On the other hand, it is evident that an increase or decrease in temperature affects the propagation of radiation in optical fibers. The study by Su. N et al. [16] shows a novel dual wavelength method to evaluate the effect of temperature on fiber optic SPR sensors in real time.

As an example of a sensor used in medicine, we have the sensor by Sankiewicz, A. et al. [17]. These researchers have applied plasmon biosensors based on surface plasmon resonance imaging (SPRi) to detect the 20S proteasome protein and ubiquitin carboxy-terminal hydrolase L1 (UCH-L1) in the blood serum and urine of patients with TCC (narrow cell carcinoma) of transition and to be able to make an early diagnosis of bladder cancer.

The contamination of phenolic compounds in the natural environment is a toxic response that induces severe impact on plants, animals, and human health. Ly, N.H. et al. [18] have made an updated review of the recent developments and trends of new plasmon resonance nanomaterials, which are assisted by various optical sensors, including colorimetry, fluorescence, localized surface plasmon resonance (LSPR), and plasmon-enhanced Raman spectroscopy. These advanced and powerful analytical tools exhibit potential application for ultra-high sensitivity, selectivity, and rapid detection of phenol and its derivatives.

The article by Rodrigues et al. [19] presents an exhaustive review of gas sensors based on the localized surface plasmon resonance (LSPR) phenomenon, including LSPR theory, the synthesis of nanoparticle-embedded oxide thin films, and strategies to improve the sensitivity of these optical sensors, supported by simulations of electromagnetic properties.

The submission for this Special Issue is now closed, but the SPR sensors are still current, research does not stop and technology takes advantage of all the scientific advances on new materials and plasmons to face the new challenges that science, technology and society, demand. We are continuing to work on this.

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