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Editorial

Recent Development of Resonance-Based Optical Sensors and Biosensors

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Optical sensors and biosensors have attracted significant research effort due to their unique features compared to their electronic counterparts, as well as their potential to provide fast, reliable, in situ or in vivo real-time detection of physical parameters, chemical compounds or elements, and biomolecules [1,2]. The integration of those devices with micro/nanotechnology has given not only the opportunity to develop highly sensitive, selective, repeatable and reproducible photonic devices, but also to underpin novel sensing/biosensing schemes for their use in real life applications [3–5]. In particular, fiber optic devices allow the exploitation of the fascinating and peculiar light management at unprecedented and remarkable levels, which the other optical technologies can hardly attain [6–8]. In all cases, the interaction of light travelling within the photonic device with the surrounding environment generates surface waves (for instance, evanescent waves, Bloch waves, surface plasmon polaritons, waves related to lossy/leaky mode or derived from guided mode, etc.) that are able to assess every change occurring in the surrounding medium [9,10]. Micro/nanotechnology, together with nanoparticles, nano films or nanostructure in general, permit one to tailor such surface waves with outstanding spectral resolution, precision and accuracy, thus envisaging high performance and high technological-level optical platforms [11–13]. Clearly, the modeling and optical characterization of the nanostructures play a crucial role, especially in chemical sensing and biosensing, and hence several studies have been reported so far [14]. Finally, the recent literature accounts for some intriguing examples of optical sensing platform where molecules of clinical interest for diagnostics have been effectively and quantitatively detected [15–20].

Here, attention is paid to those devices that are characterized by the presence of a resonant band or simply resonance (i.e., attenuation dip or adsorption peak) in their transmission or reflection spectrum due to a particular coupling of light within the photonic device. The detection mechanism basically relies on a wavelength (λ, nm) or intensity (T, dB) demodulation scheme. Both approaches have advantages and disadvantages depending on the final application. As far as the sensing mechanism is concerned, it basically relies on the optical measurement of the refractive index (RI) changes occurring in the surrounding environment. In this sense, it turns out to be decisive to discriminate between volume or bulk RI sensing and surface or add-layer RI sensing [21]. Since the performance of the photonic sensing platforms is highly dependent on the capability of the surface waves to penetrate the surrounding medium in terms of penetration depth, the previous concept deserves to be emphasized. In volume RI sensing, the surface wave interacts with all the surrounding medium for the entire field extent. Conversely, in surface RI sensing, the interaction of interest occurs between the functionalized sensing layer and a portion of the surface wave, with the thickness of the biosensing layer (tens of nm) generally much less than the penetration depth of the surface wave (hundreds of nm). In this last case, encompassing chemical sensing and biosensing, it becomes essential to assess the residual wavelength shift or intensity change of the resonance related to the interactions between the sensing layer and the analyte under investigation [9,21].

The Special Issue

This Special Issue is focused on the unique and novel implementations of optical sensors and biosensors that allow them to perform measurements in challenging physical, chemical, and biomedical applications. Potential topics include, but are not limited to, recent developments in the following areas: design/development/optimization of optical sensors, biosensors and optical detection platforms in general; application of an optical system to measure physical parameters, chemical compounds or elements, or biomolecules; measurement of multiple parameters with a single device; real-time, resonance-based sensing/biosensing; fiber-optics devices and optical micro-/nano-resonators; and novel photonic devices or methodologies in optical sensing/biosensing.

Until now, two articles have been published within this SI. Ran et al. [22] propose a pH sensor that leverages the microfiber Bragg grating with an ultra-compact size. Using the electrostatic self-assembly layer-by-layer technique, the functional film consisting of sodium alginate is immobilized on the fiber surface. Consequently, the alteration of aqueous pH could be quantitatively indicated by the wavelength shift of the grating resonance via the RI changes of the sensing film due to the water absorption or expulsion. The temperature compensation (as cross-sensitivity) can be carried out by recording two reflections simultaneously. Furthermore, the modeling and simulation results predict the pivotal parameters of the configuration for sensitivity enhancement. The proposed proof-of-concept enriches the toolbox of pH sensor for the need for detection in extremely small spaces, such as living cells or the biological tissues.

Berneschi et al. [23] review optical fiber micro/nano tips (OFTs), defined as tapered fibers with a waist diameter ranging from a few microns to tens of nanometers and different tip angles. The field of applications ranges from physical and chemical/biochemical sensing—also at the intracellular levels—to the development of near-field probes for microscope imaging and optical interrogation systems, up to optical devices for trapping and manipulating microparticles (optical tweezers). Clearly, the ability to fabricate OFTs by tailoring some of their features according to the requirements determined by the specific application becomes crucial. The review encompasses a short overview of the main fabrication methods used to realize OFTs and then some of their intriguing applications, such as the development of label-based chemical/biochemical sensors and the implementation of SNOM probes for interrogating optical devices, including whispering gallery mode microcavities.

In conclusion, this Special Issue explores new insights in resonance-based optical sensors and biosensors as powerful and effective photonic platforms for applications in physical sensing, chemical sensing and biosensing towards the development of real life tools.

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