



Optical sensors based on lossy-mode resonances

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ABSTRACT

Lossy-mode resonance (LMR)-based optical sensing technology has emerged in the last two decades as a nanotechnological platform with very interesting and promising properties. LMR complements the metallic materials typically used in surface plasmon resonance (SPR)-based sensors, with metallic oxides and polymers. In addition, it enables one to tune the position of the resonance in the optical spectrum, to excite the resonance with both transverse electric (TE) and transverse magnetic (TM) polarized light, and to generate multiple resonances. The domains of application are numerous: as sensors for detection of refractive indices voltage, pH, humidity, chemical species, and antigens, as well as biosensors. This review will discuss the bases of this relatively new technology and will show the main contributions that have permitted the optimization of its performance to the point that the question arises as to whether LMR-based optical sensors could become the sensing platform of the near future.

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1. Introduction

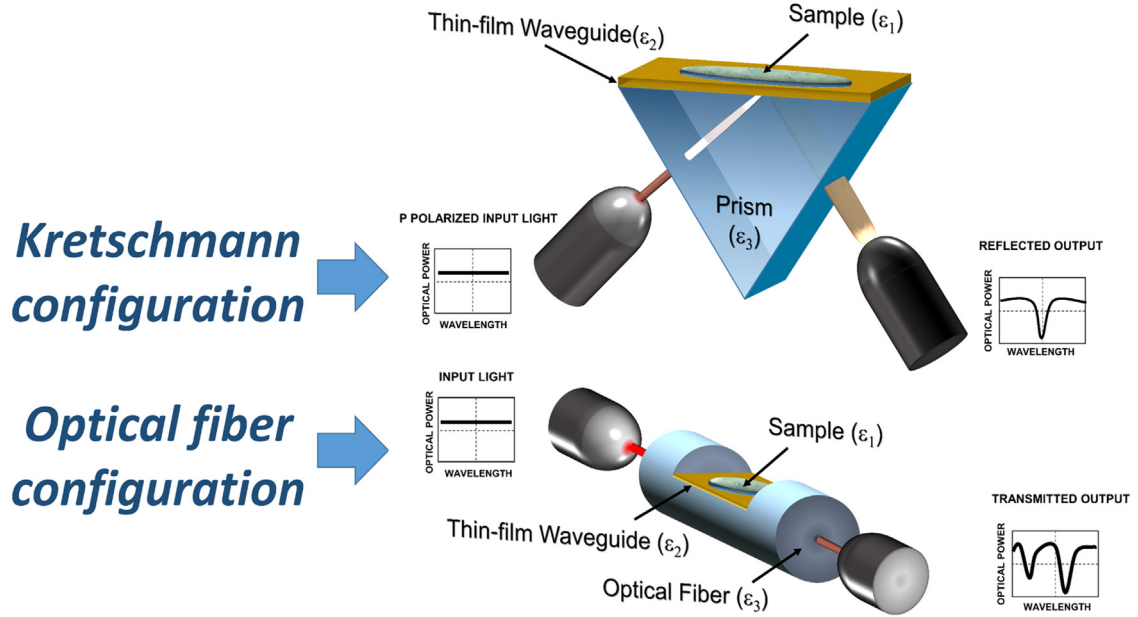
In recent years, the deposition of thin films has permitted the development of numerous applications in important domains such as optical communications, optical microscopy, and photovoltaics [1,2]. In the field of sensor research, the development of the first surface plasmon polariton resonance-based sensor in 1982 was a scientific breakthrough [3]. It used the Kretschmann-Raether con-

figuration [4] (see Fig. 1(a)), which basically consists of an optical prism on which a 56-nm-thick silver coating had been deposited. This setup permits surface plasmon polaritons to be generated at the metal-dielectric interfaces and to couple light at specific wavelength ranges. For this reason, this phenomenon is called surface plasmon polariton resonance or, for the sake of simplicity, surface plasmon resonance (SPR). The position of the resonance in the spectrum is very sensitive to the thin-film thickness and to the surrounding medium. If a layer sensitive to biological or chemical species is set on top of the metallic layer, then a biosensor or a chemical sensor is obtained [5]. In view of these interesting properties,

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(a) Setups for LMR and SPR generation



(b) LMR and SPR generation conditions

TYPE OF RESONANCE	$\hat{\epsilon}$ CONDITIONS	n, k CONDITIONS $\forall n > 0, k > 0$
SPR Surface Plasmon Resonance	$\epsilon'_2 < 0$ $ \epsilon'_2 > \epsilon''_2 $ $ \epsilon'_2 > \epsilon'_3 $	$k_2 > (\sqrt{2} + 1)n_2$ $k_2^2 - n_2^2 > 1.45^2$
LMR Lossy Mode Resonance	$\epsilon'_2 > 0$ $ \epsilon'_2 > \epsilon''_2 $ $ \epsilon'_2 > \epsilon'_3 $	$k_2 < (\sqrt{2} - 1)n_2$ $n_2^2 - k_2^2 > 1.45^2$

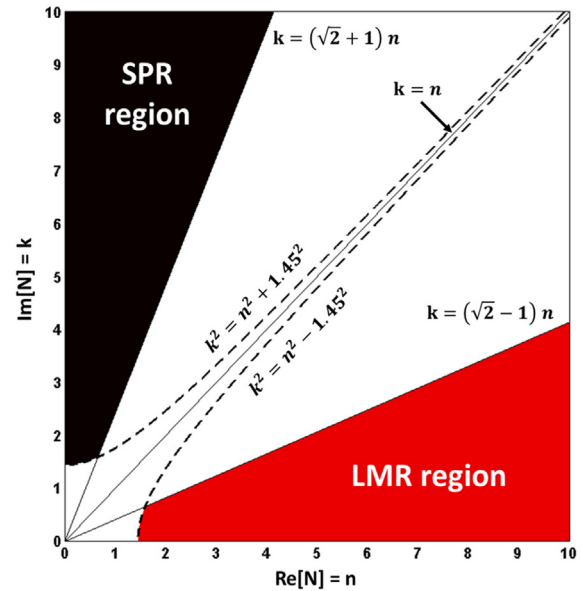


Fig. 1. (a) Generation of LMR and SPR with a nanocoated optical prism (Kretschmann configuration) and a nanocoated D-shaped optical fiber. (b) Conditions for LMR and SPR generation in both configurations.

the number of publications has increased exponentially, especially for detecting chemical and biological species [6,7], and there are some companies exploiting these devices especially for biosensing (Biacore <http://www.biacore.com>, Bionavis <http://www.bionavis.com>, and Xantec Bioanalytics <http://www.xantec.com/>).

Unfortunately, the sensitivity limit for SPR sensors seems to have been attained [8]. However, there is still another phenomenon that can be obtained with the Kretschmann configuration. In the

same year as the first SPR sensor was developed, it was proved using a dielectric waveguide with a semiconductor waveguide clad that attenuation maxima in the transmission spectrum could be obtained for specific thickness values of cladding [9].

On this basis it was proved later that it is possible to obtain a sensor for humidity, water, and alcohol vapor, or even n-heptane and iso-octane vapors, by using an anisotropic polymer deposited on a waveguide [10–12]. The basic principle of the measurements was

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