

One-dimensional photonic crystal for polarization-sensitive surface-enhanced spectroscopy

Erika Mogni^{1*}, Giovanni Pellegrini², Jorge Gil-Rostrá³, Francisco Yubero³, Giuseppina Simone^{1,4}, Stefan Fossati⁵, Jakub Dostálek^{5,6}, Rebeca Martínez-Vázquez⁷, Roberto Osellame⁷, Michele Celebrano¹, Marco Finazzi¹ and Paolo Biagioni¹.

¹Politecnico di Milano, Dipartimento di Fisica, 20133 Milano, Italy

²Università degli studi di Pavia, Dipartimento di Fisica, 27100 Pavia, Italy

³CSIC-Universidad de Sevilla, Instituto de Ciencia de Materiales de Sevilla, 41092 Sevilla, Spain

⁴Northwestern Polytechnical University, School of Mechanical Engineering, Xi'an Shaanxi, People's Republic of China

⁵AIT Austrian Institute of Technology GmbH, Biosensor Technologies, Tulln an der Donau, Austria

⁶Czech Academy of Sciences, FZU-Institute of Physics, Prague, Czech Republic

⁷Istituto di Fotonica e Nanotecnologie (IFN)-CNR, 20133 Milano, Italy

Abstract. We realize and experimentally characterize a novel platform for surface-enhanced sensing through Bloch Surface Waves (BSWs). We test a one-dimensional photonic crystal, with a high index inclusion in the top layer, that sustains surface modes with, in principle, arbitrary polarization. This is achieved through the coherent superposition of TE and TM dispersion relations of BSWs, which can also provide superchiral fields over a wide spectral range (down to the UV). The resulting platform paves the way to the implementation of polarization-resolved surface-enhanced techniques.

1 Introduction

Bloch Surface waves (BSWs) are supported by semi-infinite one-dimensional photonic crystals (1DPCs), where both the transverse electric (TE) and the transverse magnetic (TM) eigenmodes can be sustained. Thanks to the high sensitivity to the local refractive index, platforms supporting BSWs are widely used for sensing analytes which are selectively preconcentrated at the surface of such truncated photonic crystals [1-3]. Moreover, the resonant frequencies of the modes can be tuned by a proper design of the 1DPC, acting on the materials (i.e. the refractive index) and the thicknesses of the layers. A further step in surface-enhanced spectroscopies using BSWs would be the control over the polarization, which can be attained by engineering the overlap between the dispersion relations of the TE and TM modes. For example, the surface-enhanced study of oriented molecules anchored to the 1DPC surface could be realized through differential TE-TM reflectivity measurements, as customarily done in standard attenuated total internal reflection spectroscopy [4]. More specifically, the superposition of the TE and TM modes enables to amplify an optical response in linear and circular dichroism (CD) spectroscopies. CD, in particular, is gaining more and more importance due to the wide applications in chemistry, biology, medicine and pharmacology [5]. In general, CD signals are very weak if compared to those obtained in standard absorption spectroscopies, therefore novel “superchiral” approaches have been recently introduced to enhance the CD signal by engineering the optical chirality of the electromagnetic field with

nanostructured systems [6]. Both metallic and dielectric approaches are being used to obtain superchirality through the fabrication of nanostructures generating hot spots of enhanced optical chirality [7,8]. In this framework, we recently proposed a platform [2] that allows for the generation of superchiral surface waves. Here we fabricate a 1DPC that simplifies the previous design by reducing the number of layers while keeping similar polarization performance. We experimentally demonstrate the energy and momentum superposition of the TE and TM modes, paving the way to the employment of such a platform for surface-enhanced polarization-sensitive spectroscopies in the visible-UV range and, more generally, to the implementation of polarization-resolved surface-enhanced techniques.

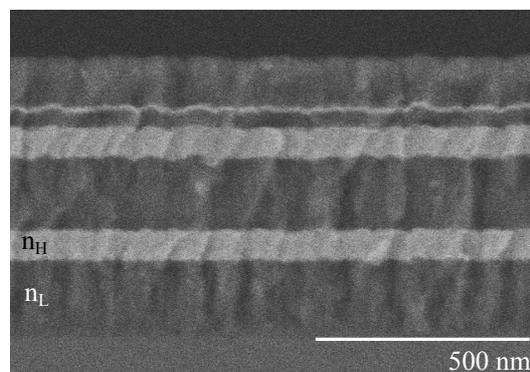


Figure 1. Cross section SEM micrograph of the manufactured 1DPC

* Corresponding author: erika.mogni@polimi.it

2 Materials and methods

The platform consists in a 1DPC grown by reactive magnetron sputtering and made by 2 periods of alternating compact layers of SiO₂ (low refractive index) and Ta₂O₅ (high refractive index) with different thicknesses, terminated with an additional low-index layer incorporating a high refractive index inclusion as shown in the cross-section SEM image in Figure 1. The characterization of the optical response of the sensing platform was done in water using a fluidic cell realized using a polymeric double-side tape with the fluidic chamber cut by femtosecond laser micromachining. The top layer is a fused silica slide that contains the housing to plug the fluidic tubes.

3 Results and discussion

For the experimental demonstration of the superposition of the TE and TM modes, reflectance measurements are performed on the 1DPC with the fluidic chamber filled with water. The resulting dispersion relations are reported in the experimental reflectivity maps of Figure 2 for TE and TM illumination (panels a and b, respectively), together with representative angular plots at specific wavelengths (panels c and d), confirming the close overlap of the two modes in good agreement with simulations. Upon increasing the wavelength, the excitation angle of the modes decreases, approaching the onset of total internal reflection. Moreover, it can be observed that, while the TE mode is narrow and sharp, the TM mode is broader and weaker but still recognizable, allowing us to experimentally confirm the mode superposition. The overlapping of the dispersion relations offers the possibility of facile generating of an arbitrary polarization of the surface modes in order to pave the way to the implementation of polarization-resolved surface-enhanced techniques. This can be achieved by the simultaneous coupling to both TE and TM modes with controlled relative phase and amplitude.

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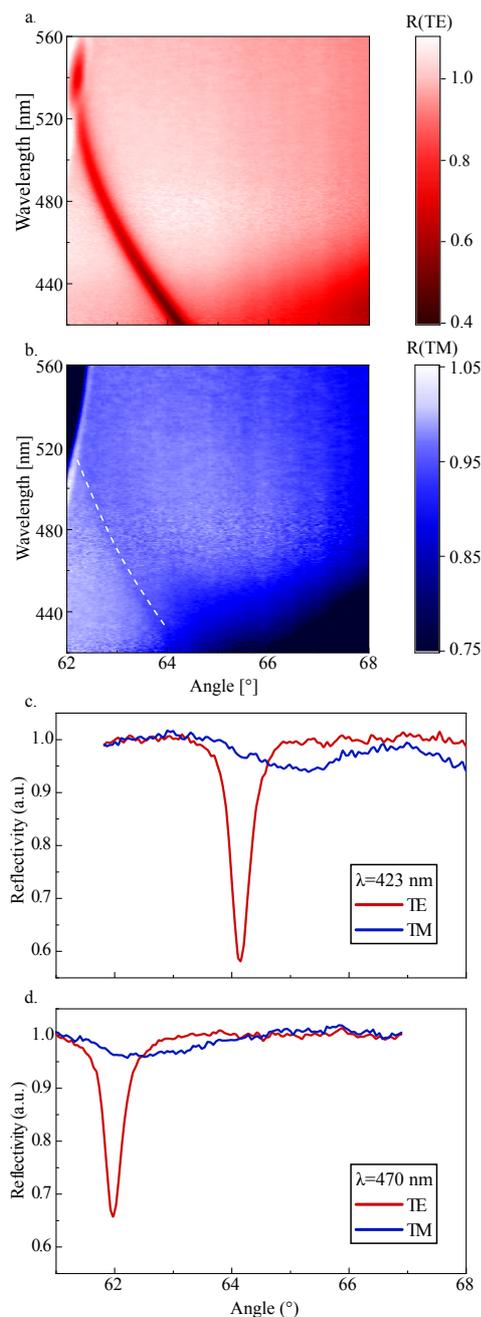


Figure 2. Experimental reflectivity (R) maps for a) TE illumination and b) TM illumination when the surface of the 1DPC is immersed in water. The dispersive TE and TM modes are visible as dips in the reflectivity maps. Experimental angular plot for a wavelength equal to c) 423 nm and d) 470 nm.

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