Nanoporous silicon photonic structures for the development of ultrasensitive biosensors

R. Caroselli, S. Ponce-Alcántara, A. Griol, L. Bellieres, J. García-Rupérez*

Nanophotonics Technology Center, Universitat Politècnica de València, 46022 Valencia, Spain
* jaigarru@upvnet.upv.es

Abstract

We present the development of a high index contrast nanoporous silicon platform to be used for the creation of ultrasensitive nanophotonic biosensing structures. In this work, we aim at mimicking the configuration of SOI (Silicon on Insulator) platform, where a thin high index top silicon layer sitting on a low index silicon oxide lower cladding is used in order to provide a high confinement of the light within the photonic structures created in the top silicon layer.

A limiting factor in the sensitivity of traditional planar photonic sensing structures based on a high index contrast configuration is the fact that only the evanescent field propagating outside of the photonic structure is used for sensing purposes, while the majority of the optical field distribution associated with the guided mode is within the structure itself. On the other hand, there is an increasing interest on the use of porous silicon for the development of sensing structures, since this platform provides a higher surface/volume ratio as well as the possibility of infiltrating the target analytes directly into the pores in order to obtain an increased sensitivity.

With these ideas in mind, we have worked on the optimization of a porous silicon bilayer with a refractive index profile similar to that of a SOI wafer in order to be able to have a high confinement of the light and a much reduced size of the photonic structures, while significantly increasing the sensitivity. In order to be able to obtain a high refractive index of the top layer, where the photonic sensing structures will be created, reduced size pores (with diameters lower than 8 nm) have been created. The optimization of the fabrication process for obtaining this nanoporous bilayer configuration has mainly involved the analysis of the effects of the hydrofluoric acid concentration, the current density applied, the wafer resistivity and the process time. Furthermore, the reduction of the stress between the layers has also been studied, resulting in mechanically more stable structures. By using the Bruggeman's model [1], we have estimated the refractive index of the nanoporous silicon layers after optimizing the electrochemical fabrication process, achieving values of 3.23 and 1.78 for the optical layer and the lower cladding respectively. E-beam lithography has then been used to create the photonic structures onto this nanoporous silicon platform, successfully being able to transfer the designed layout to the top high index porous silicon layer.

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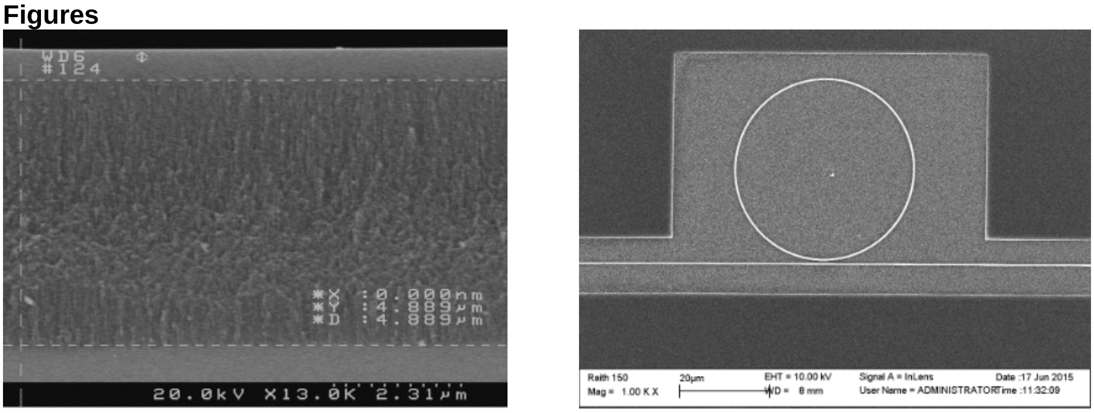
References

[1] W.M. Merrill, et al., IEEE Trans. Antennas Propag, **47** (1999) 142-148.

Figures



SEM images of (left) the nanoporous silicon bilayer and (right) a ring resonator created onto this platform using e-beam lithography.