Design, fabrication and characterization of Bragg reflectors based on porous silicon monitored by photoacoustics

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Porous silicon (PSi) is a nanostructured material with diverse porous morphology, varied surface chemistry, and enormous surface area. PSi has been obtained commonly through electrochemical etching in hydrofluoric aqueous media. The optical response of PSi has been studied by photoluminescence, UV-VIS reflectance, ellipsometry, FTIR, among other characterization techniques, finding that the optical properties are tuneable as a function of the porosity percentage. But, the origin of their optical response is still in controversy. In that sense, it has been reported that the mechanism responsible for the total optical response is a complex mixture of surface chemistry and quantum confinement. The self-limited character of the porous silicon electrochemical reaction allows fabricating homogeneous films and heterostructures. Also, it is possible to custom porous silicon properties changing the growing parameters. This makes porous silicon in a candidate to develop optical devices such as porous distributed Bragg reflector and Fabry-Perot cavities. However, the physicochemical properties of porous silicon are critically dependent on the etching parameters and there are not theoretical models to predict PSi properties such as refractive index, absorption coefficient, thickness, porosity, and interfaces roughness [1]. Therefore, this work is focused on establishing a methodology based on photoacoustic (PA) to monitor the Bragg reflectors fabrication and a procedure to design and customize optical devices based on porous silicon. In this direction, it was determined and correlated some of the key points to be able to fabricate high-quality Bragg reflectors such as etching rate, porosity determination, a model to determine the refractive index of porous media by using photoacoustic and effective medium approximation. Also, simulation and design analyses of the optical multilayer system are discussed.

In this work we proposed to fabricate PSi heterostructures with applications in DBR's by controlling the porosity percentage during the formation of PSi films by photoacoustics (FA), with the aim of designing a monitoring and control method to predict and manipulate the refractive indices and the thickness of the layers to obtain PSi-based DBR's with specific spectral positions and bandwidths.

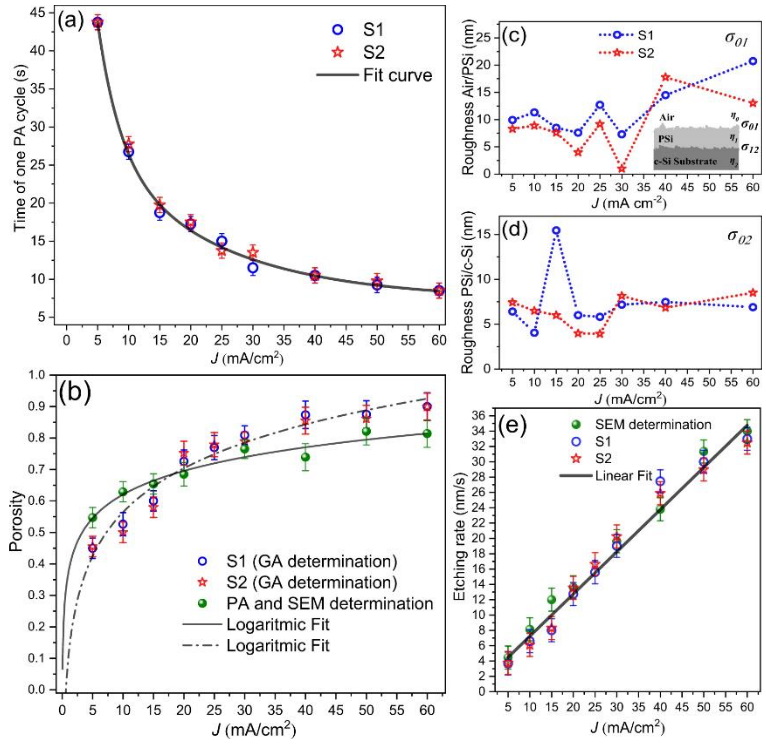

Fig. 1. Calibration series parameters. (a) PA time as a function of current density that exhibits an exponential decay behaviour. (b) Average porosity determined by genetic algorithms (GA) and PA-SEM, (c) and (d) interface roughness as a function of current density determined by GA fitting of UV-Vis spectrum. (e) Etching rate that exhibits linear behaviour.

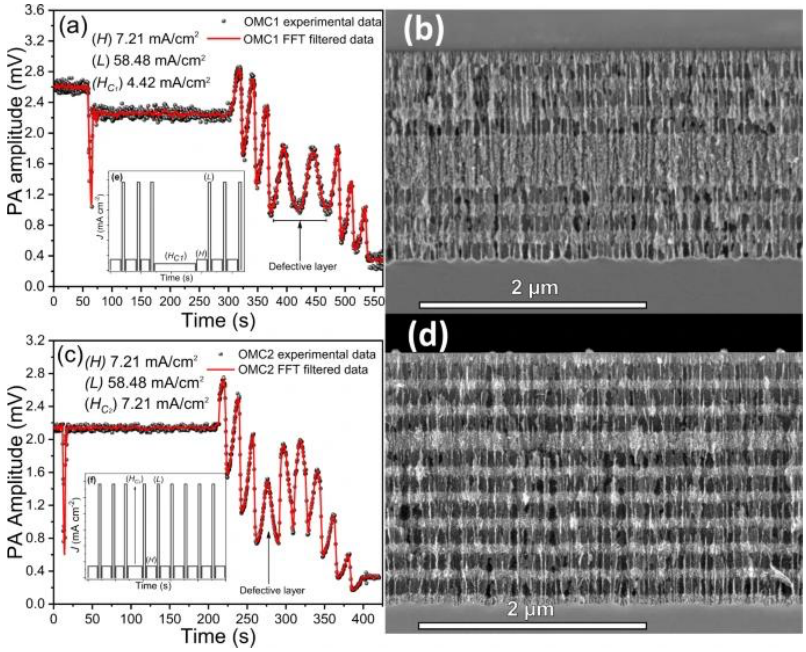

Fig. 2. PA amplitude during optical microcavity (OMC) fabrication. (a) OMC1, (c) OMC2, and its respective SEM cross-sectional images (b,d). Insets (e,f) correspond to the current profiles used for OMC1 and OMC2 fabrication respectively.

References

[1] C.F. Ramirez-Gutierrez, J.D. Castaño-Yepes, M.E. Rodriguez-Garcia, Modeling the photoacoustic signal during the porous silicon formation, Int. J. Appl. Phys., 121 (2017). https://doi.org/10.1063/1.4973940.