Controlling the optical properties of macroporous silicon structures

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Photonic crystals are artificial materials with a periodic variation in the index of refraction which leads to the formation of forbidden optical bands (the so-called photonic band gaps, PBG) [1]. Significant efforts have been undertaken in order to fabricate micro- and nano-structures that meet the requirements for 3D photonic crystals, such as periodicity in all three dimensions, high dielectric contrast and very good uniformity in large scales. Macroporous silicon [2], produced by electrochemical etching of silicon in HF solutions, has proved to meet these requirements and has become an excellent material for the development of 2D and 3D photonic crystals. An example of a macroporous silicon structure can be seen in Fig. 1.

A prominent feature of the electrochemical etching technique is its flexibility in 3D sculpturing of silicon. Since the distribution of the pores in the plane can be defined by a lithographic process and the periodicity along the pore axis can be controlled independently, a great variety of pore geometries and distributions can be designed to meet specific optical behaviors [3]. Consequently the dispersion relation may be modified by changing the shape of pore diameter modulation. The freedom in adjusting the pore diameter, makes it easier the incorporation of planar defects, whose dimensions and thus spectral positions, can be designed beforehand.

In this work we report on the fabrication and optical characterization of 3D macroporous silicon structures. FT-IR spectrometry measurements of the reflectivity and transmitivity along the pore axis reveal PBG, which are also confirmed by simulations of band dispersion, as seen in Fig. 2. We study the influence of pore modulation on the band gap properties (spectral width and position). In addition, thermal emission is inhibited in the band gap region which allows us to tailor the emission spectrum of the material.

We study the optical properties of three-dimensional structures obtained by post-etching treatments of the macroporous arrays. Adjacent pores can be widened [4] and become connected thus providing 3D structures with very high porosities and new photonic crystal geometries.

References

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Figures

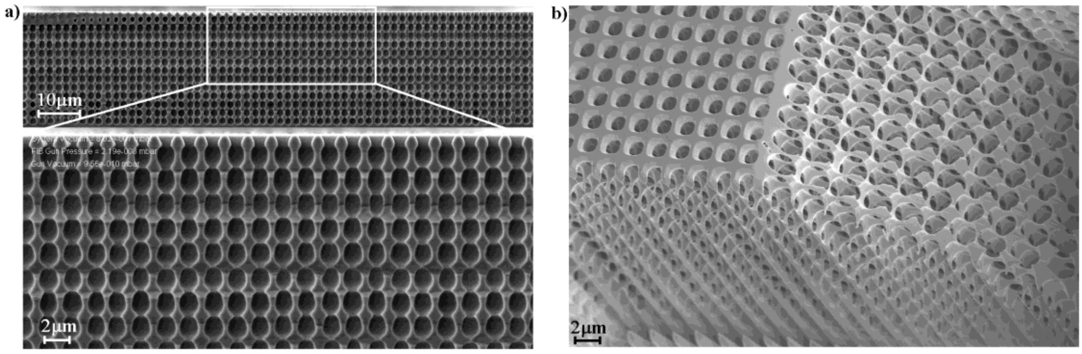

Fig. 1. SEM pictures of macroporous silicon samples with modulated pores. Periodicities are 2μm in all three dimensions. (a) Large-scale stable structures can be performed. (b) Post-processing allows the definition of new geometries and shapes.

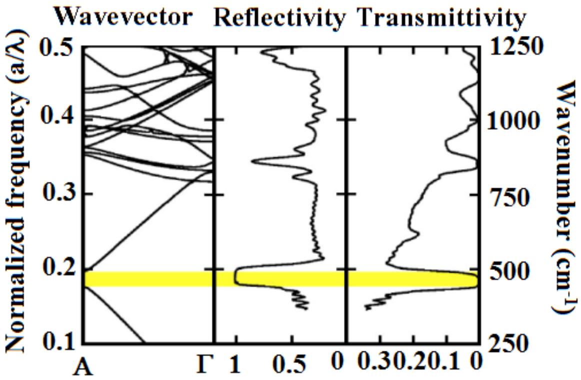

Fig. 2. Simulated dispersion relation of macroprous silicon sample in the pore direction. FT-IR measurements have been carried out with a 4μm-periodicity structure. PBG (shaded in yellow) reveals as a spectral region with 100% reflectivity and 0% transmitivity.