4 Electrochemically-prepared 2D and 3D photonic crystals

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4.1 Introduction

In the last ten years, photonic crystals have gained considerable interest due to their possibility to mold the flow of light [1]. Photonic crystals are physically based on Bragg reflections of electromagnetic waves. In simple terms, a 1D photonic crystal is a periodic stack of thin dielectric films with two different refractive indices n_1 and n_2. The two important geometrical parameters determining the wavelength of the photonic bandgap, are the lattice constant $a = d_1(n_1) + d_2(n_2)$ and the ratio of d_1 to a, where $d_{1,2}$ is the thickness of the layer with refractive index $n_{1,2}$. For a simple quarter-wavelength stack, the center wavelength λ of the 1D photonic stop band would be $\lambda = 2n_1d_1 + 2n_2d_2$. In the case of 2D photonic crystals, the concept is extended to either air holes in a dielectric medium or dielectric rods in air. Therefore, ordered porous dielectric materials like porous silicon or porous alumina are intrinsically 2D photonic crystals.

Electrochemically grown pores in metals and semiconductors have been studied for about 50 years [2, 3]. However, only in the last ten years intense research efforts have enabled the preparation of ordered pore arrays, with pore diameters in the range of a few nanometers to some tens of micrometers. The most studied materials are porous alumina and macroporous silicon and very recently porous III–V compounds. Porous alumina has been known for more than a century, but not before 1994 ordered arrays of porous alumina have been achieved [4]. This ordering was initially given by self–organization and the ordered domains were in the micron range. However, electron–beam lithography [5] and a new related technique of nano–indentation [6] allowed to prepare monodomain porous alumina structures with domain sizes limited only by the prepatterned area (some mm^2) and structure sizes in the nm–range.

Macroporous silicon has been pioneered in the early 1990s by V. Lehmann and H. Föll [7, 8]. Very regular pore arrays (pore size d: microns, domain size: up to wafer size) have been obtained by photolithographic prepatterning. These pores were called macropores[2] in contrast to microporous silicon, which is a sponge–like nanostructured material with photoluminescence properties that were intensively studied in the early 1990s [9]. Moreover, very

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[2]All pores are classified according to the IUPAC (Internat. Union for Pure and Applied Chemistry) – conventions unless otherwise indicated: microporous (equivalent to the often used term nanoporous): pore diameter $d < 5\ nm$, mesoporous: $d = 5 - 50\ nm$, macroporous: $d \geq 50\ nm$

Photonic Crystals: Advances in Design, Fabrication, and Characterization.
Edited by Kurt Busch, Stefan Lölkes, Ralf B. Wehrspohn, Helmut Föll

ISBN: 3-527-40432-5