Fabrication of Large Scale Nanofocusing Device Based on Negative Refraction Index Photonic Crystals

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Photonic crystals (PhCs) are an especially promising tool for the on-chip integration of silicon based ultra-compact nanophotonic circuits that manipulate the light signals. Typical design of a PhC devices exploits the photonic band gap, in general introducing some defect state to manages the gap property.

The negative refraction is another very exciting property of PhCs. The propagation in an opposite direction respect to the usual refraction laws allows new devices, such as the superlens that make possible a subwavelength definition in the far field domain [1] –[2].

In this work we present the fabrication of a photonic device for an unconventional application based on the negative refraction properties of PhC in combination with positive index region.

From one side the negative index allows an impedance matching, maximizing the coupling with external medium. The theoretical limitation of coupling efficiency, given by the numerical aperture, is overcome enhancing the evanescent component of the incident wave. This is possible creating resonance states on the surface, thanks to an accurate determination of the PhC termination [3].

Using a Silicon On Insulator (SOI) 200 nm thick silicon crystalline layer on 1μm thick oxide substrate [4], we spun 300 nm ZEP 520A e-beam positive Resist. We exposed the pattern shown in figure 1a and 1b by Vistec VB300 Electron Beam Lithography System and we transferred the pattern by ICP RIE by HBr recipe [5].

The pattern was transferred selectively on the silicon layer only. By using focused ion beam lithographic system, a big section just external of the PhC of about 200 μm x 300 μm of the oxide layer and of the silicon substrate was removed to allow the positioning of an optical fibre probe; from one side to illuminate the pattern and from the other side to receive the light.

Furthermore alternating properly dimensioned positive and negative index region produces a tightly confined guided light, as shown in the figure 2, where the beam FHWM is less than 1μm in correspondence of a free space wavelength equal to 1.55 μm. Figure 3 show a detail of the interface between the positive and negative index regions.

In order to investigate potentialities for practical applications, we analyze the robustness respect to small fabrication defects randomly distributed studying experimental performances of negative refraction devices over a large scale region (hundreds of microns)[6]. Some preliminary optical characterization will be discussed in the paper.

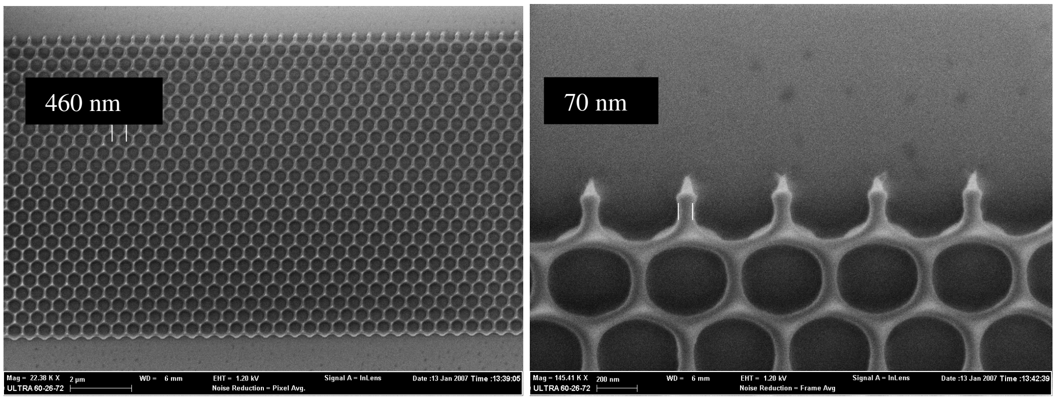

Figure 1. PhC structure with a negative refractive index at 1.5 m on SOI subtrate.

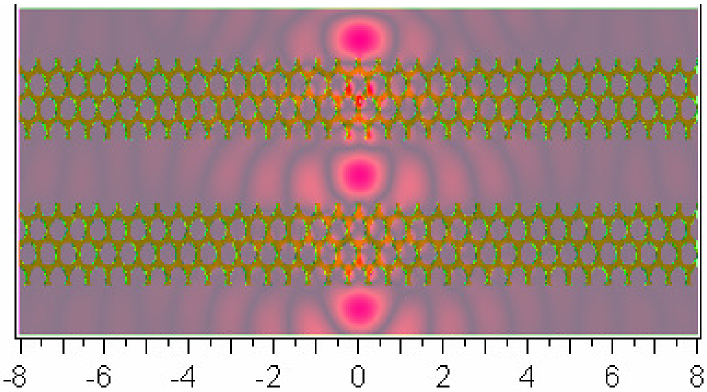

Figure 2. The electric field propagates in the vertical direction preserving a well confined transversal profile. Silicon holes PhC region, exhibiting n_{eff}= -1, green in the picture are alternated with positive index region n=1, purple in the picture.

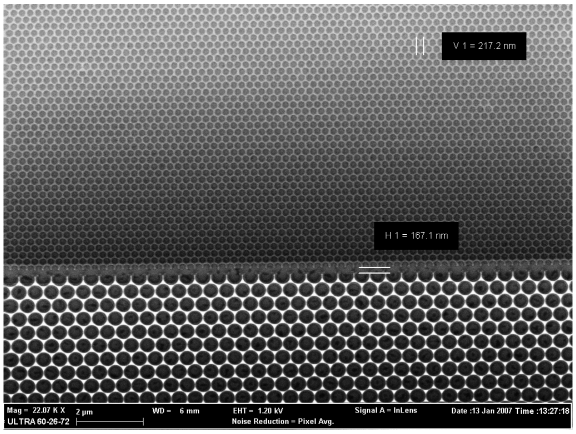

Figure 3. Detail of the interface between two PhC regions corresponding to positive (up) and negative (down) index regions at a wavelength 1.5 µm.

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