Fabrication and Optical Properties of ZnO-nanowire-induced nanocavities in grooved SiN photonic crystals

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Semiconductor nanowires positioned in grooved Si photonic crystals (PhCs) have recently been shown to be a promising and versatile platform to achieve high-Q nanocavities in the infra-red range [1]. We here show that this approach can be extended to shorter wavelengths, using grooved SiN PhCs and ZnO single nanowires (NW) (Fig 1 (a)), a configuration that would be of interest for the realization of near-UV nanolasing and more. According to three dimensional finite-difference time-domain (3D-FDTD) calculations, such NW-induced cavities with a 3-μm-long and 90-nm wide NW can present a fundamental mode with a quality factor Q = 18000 and a mode volume $V = 5.52(\lambda/n_r^{NW})^3$ in the near-UV range (Fig 1 (b)). We implement this design by first fabricating free-standing two-dimensional (2D) PhC line-defect waveguides in a 100-nm-thick SiN slab obtained by plasma-enhanced chemical vapor deposition on a silicon substrate. A 90-nm-wide groove is then defined in the waveguide and ZnO NWs are dispersed on the surface of the patterned SiN. Individual NWs are finally positioned inside the grooved PhC by atomic force microscope nanomanipulation (Fig 1 (c)). As predicted by 3D-FDTD, room-temperature μPL of bare ZnO NWs do not present any spectral feature indicating the presence of photonic Fabry-Pérot modes, whereas NWs positioned in grooved PhCs exhibit NW-induced nanocavity resonances in the near-UV range (Fig 1 (d)). We show that the optical properties of such resonant modes are in fair agreement with 3D-FDTD calculations and we report on quality factors as high as $Q = 1.4 \times 10^3$ at $\lambda = 397nm$, which is a promising first step toward the use of ZnO-NW-induced nanocavities for the realization of nanolasers.

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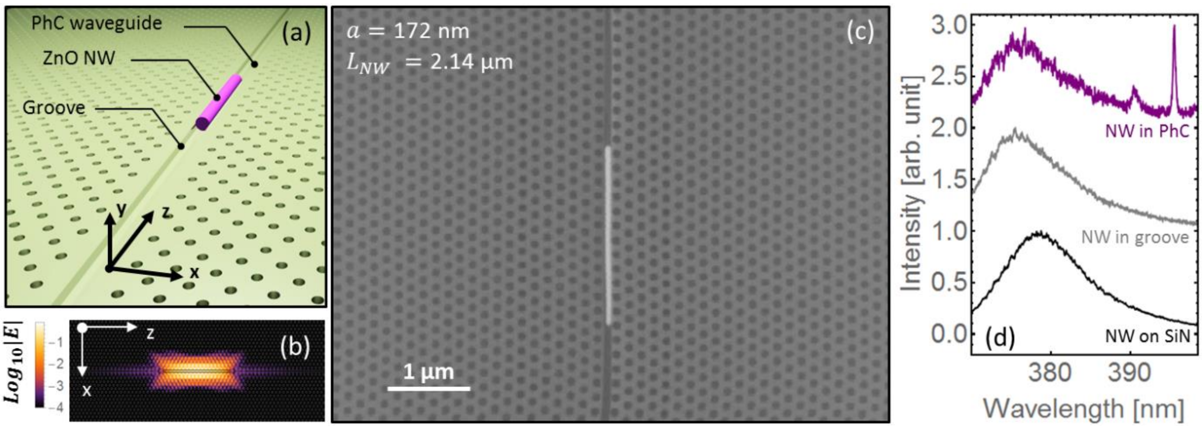

Figure 1. (a) Schematics of a ZnO-NW-induced PhC nanocavity. (b) 3D-FDTD fundamental mode calculation of a ZnO-NW-induced PhC cavity. (c) Scanning electron microscope of a single 2.14-μm-long ZnO NW inserted in a grooved SiN PhC of lattice constant a = 172 nm. (d) Room-temperature μPL intensity of the single NW displayed in (c) (purple line), of a single NW inserted in a groove with no PhC (gray line) and of a single NW on unpatterned SiN (black line).