Design of nanowire-induced nanocavities in grooved SiN photonic crystals for the ultra-violet and visible range

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Semiconductor nanowires positioned in grooved Si photonic crystals have recently been shown to be a promising and versatile platform to achieve high-Q nanocavities in the infra-red range [1]. Using finite-difference time-domain calculations, we show that this approach can be extended to shorter wavelengths, using grooved SiN photonic crystals and single nanowires based on semiconductors emitting in the ultra-violet and visible range e.g. diamond, ZnO or GaN (refractive index $n_r^{NW} = 2.4$). We discuss how the quality factor and mode volume of such nanocavities are influenced by various design parameters such as photonic crystal dimensionality and geometry, groove dimensions as well as NW geometry and position. We find that with realistic design parameters, quality factors as high as 18000 can be obtained in grooved two-dimensional photonic crystal line-defect waveguides with a mode volume $V = 5.52(\lambda/n_r^{NW})^3$ (Figure 1). In grooved nanobeam photonic crystals, quality factors can even reach 51000 with a significantly smaller mode volume $V = 1.45(\lambda/n_r^{NW})^3$ (Figure 1).

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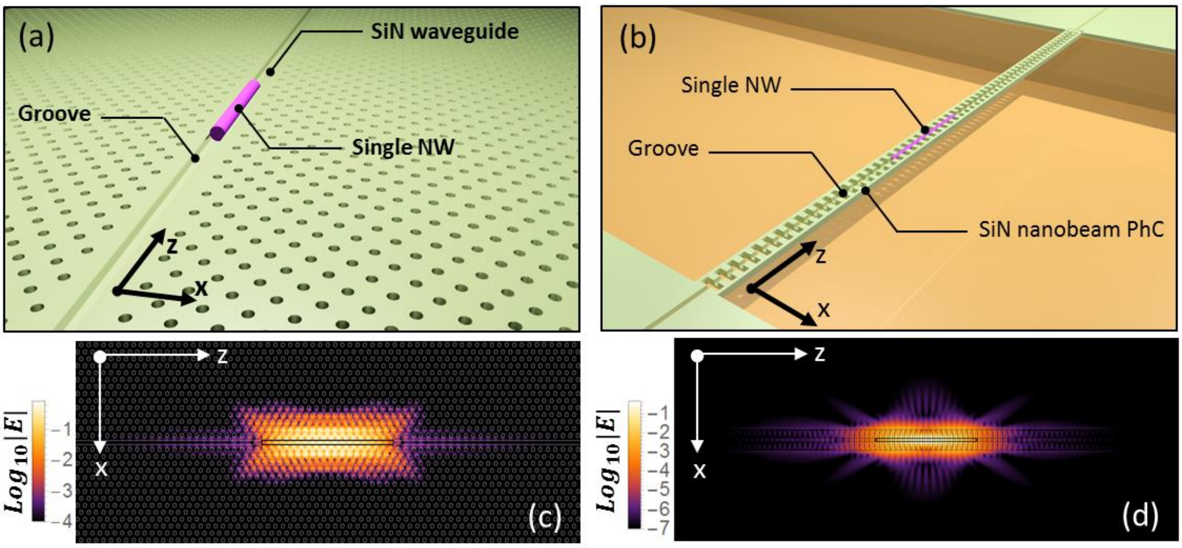

Figure 1. Schematics of a single nanowire positioned in (a) a grooved SiN two-dimensional photonic crystal line-defect waveguide and (b) a grooved SiN nanobeam photonic crystal. (c) Mode profile of the nanocavity represented in (a) for a 3-μm long nanowire with a 90-nm diameter, a slab thickness t = 100 nm and a lattice constant a = 170 nm. The resonant mode wavelength is 393 nm, close to a ZnO nanowire emission, the quality factor is Q = 18000 and the mode volume is $V = 5.52(\lambda/n_r^{NW})^3$. (d) Mode profile of the nanocavity represented in (b) for the same nanowire, a nanobeam thickness t = 100 nm, a nanobeam lattice constant a = 150 nm, and a nanobeam width w = 600 nm. The resonant mode wavelength is 380 nm, the quality factor is Q = 51000 and the mode volume is $V = 1.45(\lambda/n_r^{NW})^3$.

[1] M. D. Birowosuto *et al.*, Nature Materials **13**, 279 (2014).