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Abstract of Main Thesis

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Title of Thesis: Study on Strain Sensing Effect in Silicon Photonic Crystal Nanocavities

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This thesis presents the theoretical and experimental investigations of the strain sensing effect of two dimensional (2D) photonic crystal (PhC) nanocavities for high-resolution mechanical sensing applications. When there is a strain applying in the PhC cavtiy, the refractive index of material and geometry of the air hole lattice are changed, leading to changes in the resonant wavelength of the cavity. Unlike prior studies on the field of PhC based mechanical sensors, in which only theoretical investigations were reported, in this study, both theoretical and experimental studies are performed.

To demonstrate the strain sensing effect, fundamental PhC nanocavities are designed and investigated. Two types of cavity are formed by modifying air holes size and shape (hole-modified cavity), and by changing holes positions (hole-shifted cavity). The PhC in this study is based on triangular lattice with lattice constants and air hole radius are 460 nm and 138 nm for hole-modified cavity, and 450 nm and 150 nm for hole-shifted cavity, respectively. These cavities are optimized to provide highest quality factors, and therefore, enhance the measurement resolution.

In theoretical investigation, changes in the geometry of the PhC due to strains were simulated by using finite element method (FEM). The strain sensing effects were evaluated for both longitudinal strain (the strain parallels to the direction of light propagation), and transverse strain (the strain perpendiculars to the direction of light propagation). By using finite difference time domain (FDTD) simulation, the linear relationship between the applied strain and the shift of the resonant wavelength of the nanocavity was obtained. Furthermore, the anisotropic property of the sensing effect was achieved. Changes of the refractive index of material due to strain are also discussed.

In experimental investigation, the PhC nanocavities were fabricated on silicon-on-insulator (SOI) wafer rely on electron beam lithography (EBL), plasma etching and cleaving process. Property of the fabricated cavities was characterized by using an end-fire coupling light transmission measurement setup. We have achieved a hole-shifted PhC nanocavity with Q-factor up to 4500. Tensile strains were applied to this PhC cavity through the cantilever structure by loading of standard weights at its free end. The strain sensing effect was evaluated by measuring the shift of resonant wavelength of the nanocavities. The experimental results of strain sensing based on 2D PhC nanocavities have been obtained, and it agreed well with simulation results.

As a conclusion, this study has shown the good prospect and issues of applying PhC nanocavities in high resolution strain sensing applications.