3C-SiC Phononic Waveguide for Manipulating Mechanical Wave Propagation

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Phononic crystals (PnCs) are artificial crystal structures that consist of periodic arrays of mass and elastic spring components, analogous to the arrangement of atoms and bonds in crystal lattices. PnCs offer mechanical wave transmission along the structure in passbands and strong rejection in their stop bands and bandgaps.[1] We report on the design, fabrication, simulation, and experimental demonstration of the first one-dimensional (1D) PnC waveguide (WG) based on a periodic array of 3C-SiC coupled micromechanical resonators. The SiC PnC WG is fabricated by using a single-crystal 3C-SiC layer grown on a Si wafer via atmospheric pressure chemical vapor deposition (APCVD). To fabricate a SiC PnC WG, the ~370nm 3C-SiC layer is patterned by using the NanoBuilder system to precisely control focused ion beam (FIB) milling. We find that the NanoBuilder system enables us to pattern very small features while maintaining the overall periodicity of the PnC. Compared to the PnC WG fabricated by FIB process without using NanoBuilder (Fig. 1a), the pattern generated by using the NanoBuilder system (Fig. 1b) is much closer to its design. Besides, the NanoBuilder tool offers minimal modification of unpatterned area (Fig. 1b), while the typical FIB process leads to considerable contrast changes in the SEM image near the FIB patterns (Fig. 1a). Following the FIB, the exposed Si is then etched in an HNA (hydrofluoric acid, nitric acid, DI water 1:2:1) solution to make suspended SiC structures. Mechanical wave propagation in the 3C-SiC PnC WG is characterized via a two-laser interferometry system. The design of PnCs consists of 50 cells (Fig. 1b), exhibiting flexural wave propagation in high frequency (HF). Along with finite element method simulations that reveal phonon dispersion (Fig. 1c) and transmission characteristics (Fig. 1d), experimental results in the frequency domain (Fig. 1e) provide deterministic characteristics of the 3C-SiC PnC WG including stop band and 2nd passbands, and bandgap where the wave propagation is strongly prohibited. Further, temporal measurement in the time domain (Fig. 1f-i) reveals dynamics of mechanical wave propagation including group velocity (up to v~370m/s), transmission loss (~2dB/mm). The new key features in a 1D SiC PnC WG will facilitate constructing all-mechanical circuits for sensing, signal processing, and communication in harsh environments. Also, our work opens a new avenue toward building a platform that can bride information in classic and quantum regimes for emerging quantum signal processing applications.

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[1] D. Hatanaka, I. Mahboob, K. Onomitsu, H. Yamaguchi, *Nat. Nanotech.* **9**, 520–524 (2014).

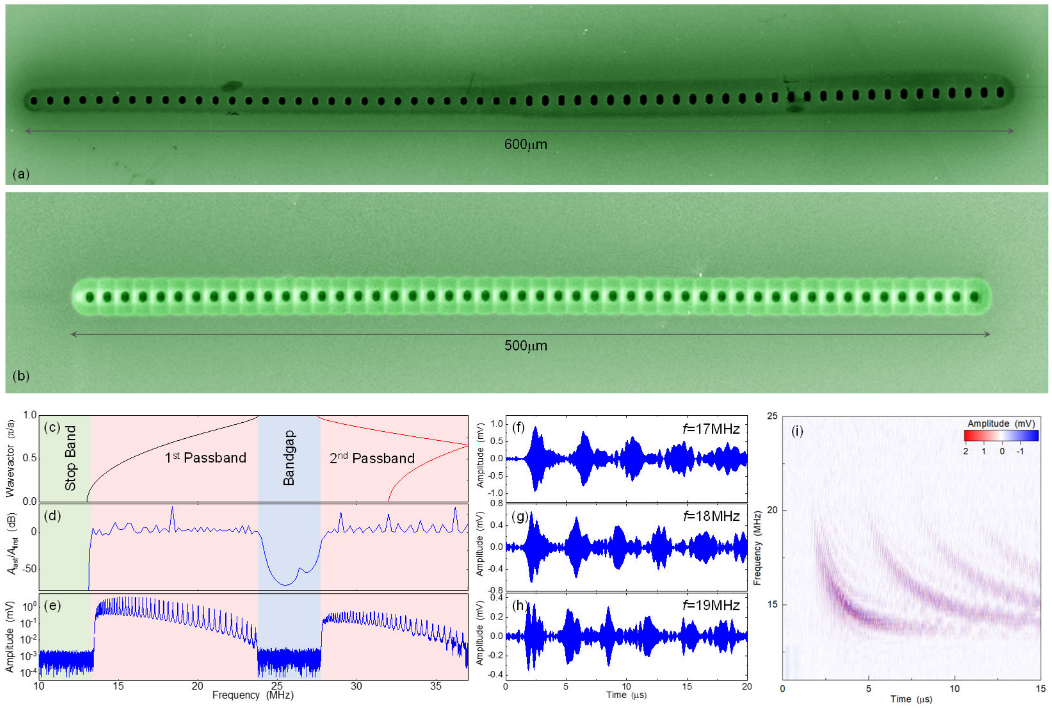

Fig. 1. Performance of a SiC PnC WG. SEM images of PnC WG fabricated by (a) typical FIB process and (b) NanoBuilder FIB tool. Simulated (c) dispersion and (d) amplitude ratio between the first and last cell. (e) Measured characteristics of the device. Green, red and blue colors represent stop band, passband and bandgap, respectively. Temporal dynamics of phononic wave propagation at (f) f=17MHz, (g) 18MHz, and (h) 19MHz. (i) The 2D color map represents the measured time-domain amplitude responses by sweeping the excitation frequency.