# Optical Detection of Ultrasound by using Polymer Filled Silicon High Contrast Grating directly Integrated on Fiber Tip

Cheng Zhang, Tao Ling and L. Jay Guo*

*Department of Electrical Engineering and Computer Science, C-PHOM,*
*The University of Michigan, Ann Arbor, Michigan 48109, USA*
**guo@umich.edu*

Direct integrating acoustic detectors on fiber tips could enable various applications, such as intravascular photoacoustic/ultrasound imaging, remote strain monitoring and point-of-interest ultrasound inspection. In this work, we developed a fabrication process to realize a polymer filled silicon high contrast grating (HCG) structure directly on an optical fiber tip as a novel acoustic detector.

In HCG, sharp resonances are formed by multimode interference inside the sub-wavelength silicon layer, which are related to the grating material's properties, nano-grating dimensions as well as the refractive index of surrounding mediums[1]. Incident acoustic pressure wave modulates the polymer refractive index filled in the grating trenches via the elastic-optic effect[2], and shifts HCG resonance frequency. Thus a HCG filled with polymer becomes an effective acoustic wave detector by recording the reflected light intensity variation which is a direct replica of the incident ultrasound waveform.

We have developed a novel process to fabricate and transfer the HCG structure onto fiber tips with preserved functionalities and performance. The HCG fabrication starts with E-beam lithography and RIE to define grating pattern on the top silicon layer of a SOI wafer (Fig.1a). Then SU-8 polymer is filled into the grating trenches by an imprinting process (Fig. 1b). This functional HCG membrane is transferred onto fiber tip with the help of a sacrificial release layer. A microscope image of the final acoustic fiber probe is shown in Fig. 1c. A probe light is incident through the fiber and the measured reflection spectrum is plotted in Fig. 1d. The optical Q-factor of the resonance is ~3000. The acoustic response of the nano-probe is measured by using an ultrasound transducer as source (Fig. 2). For imaging application, the acoustic waveforms recorded by the acoustic fiber probe are used for subsequent image reconstruction.

1. C. J. Chang-Hasnain and W. Yang, *Adv. Opt. Photon.* **4**(3), 379-440 (2012)
2. A. Maxwell, S.-W. Huang, T. Ling, J.-S. Kim, S. Ashkenazi, and L. J. Guo, *IEEE J. Special Topics in Quantum Electron.*, **14**, 191-197 (2008)

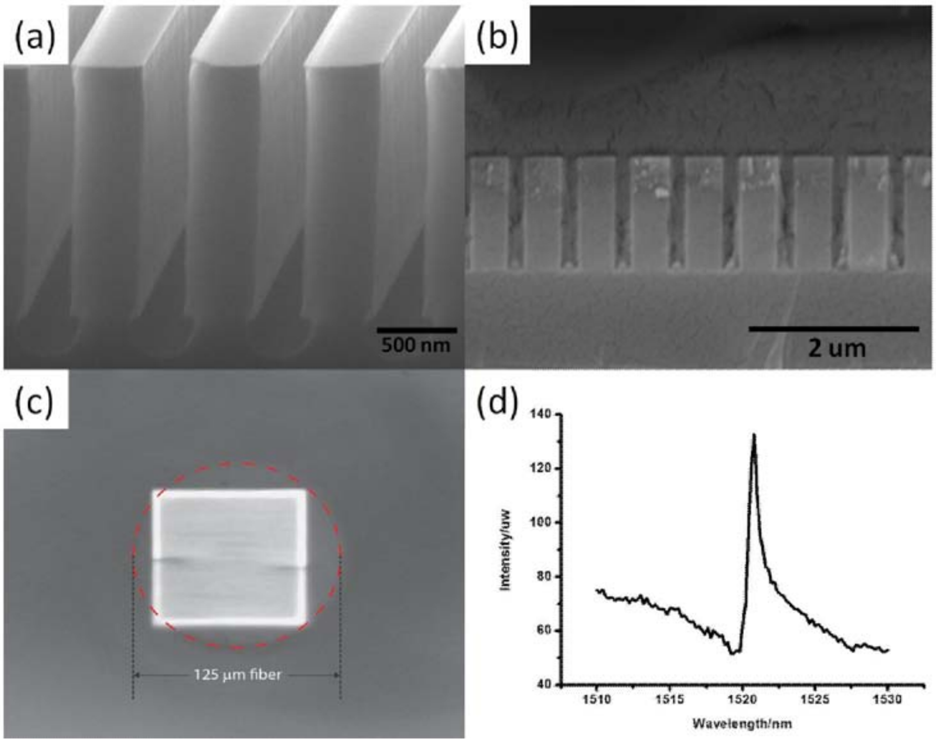


Figure 1: (a) SEM image of HCG. (b) SEM image of HCG filled with SU-8. (c) Microscope image of the fiber acoustic nano-probe. (d) Measured reflection power spectrum of the device, with Q-factor around 3000.

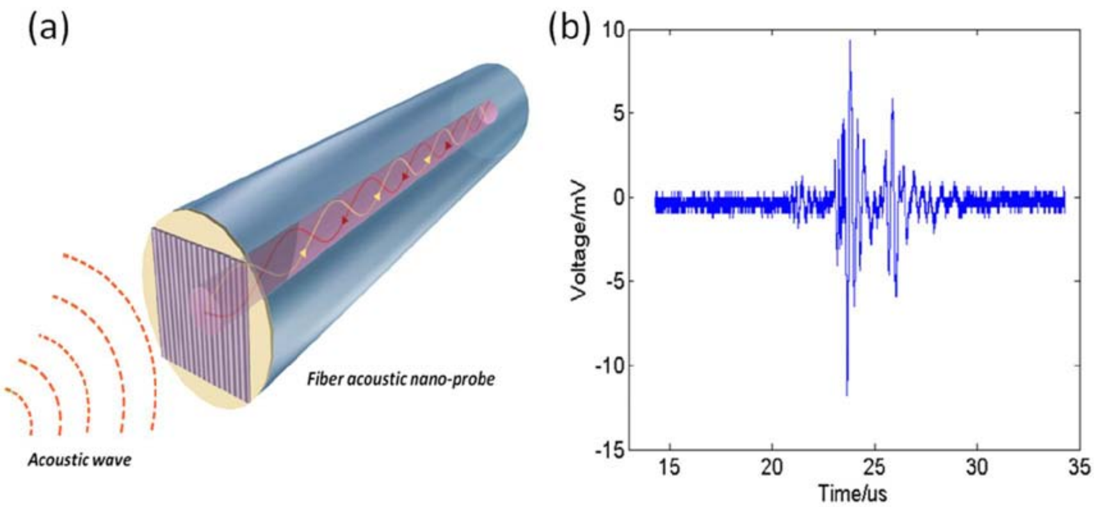


Figure 2: (a) A schematic of characterizing the nano-probe for ultrasound detection. (b) Recorded ultrasound waveform by the nano-probe integrated on the fiber tip.