High performance lithium niobate surface acoustic wave transducers exceeding 10 GHz resonant frequency

X. Chen[1,*], M. A. Mohammad[1,*], J. W. Conway[2], B. Liu[1], Y. Yang[1], T.-L. Ren[1,†]

[1]*Institute of Microelectronics & Tsinghua National Laboratory for Information Science and Technology (TNList), Tsinghua University, Beijing 100084, China*
[2]*Stanford Nanofabrication Facility, Stanford University, Stanford, California 94305*
**These authors contributed equally* †E-mail: *RenTL@tsinghua.edu.cn*

Surface acoustic wave (SAW) interdigitated transducers (IDTs) are an essential component of numerous communication and electronics devices. In addition, a plethora of sensors make use of SAW IDTs for sensing temperature, gases, biological molecules, and acceleration, etc. Recently, there has been renewed interest in using SAW devices for short range, high speed communications. The structure of a two-port SAW device is shown in Fig. 1a-1b. The resonant frequency of the IDT is determined by the material (a peizoelectric crystal/film) and the IDT period (λ). A smaller λ generates a higher resonant frequency enabling faster data transfer rates, improved selectivity for sensors, and opens a window for advanced research in opto-acoustics [1]. Additionally, a high quality (*Q*-) factor and low insertion loss (*IL*) must be achieved. Lithium niobate ($LiNbO_3$) is an established piezoelectric material used for SAW devices with a high electromechanical coupling factor (K^2_{eff}), low losses, and high stability. Using $LiNbO_3$ an up to 8.6 GHz frequency has been reported; however, with a very high -60 dB *IL* [2]. In this work, we report a systematic study of super high frequency regime $LiNbO_3$ SAW transducers with significantly lower *IL*s, high K^2_{eff}, high *Q*-factors and a highest frequency exceeding 10 GHz (see Fig. 2c). Electron beam lithography (Raith 150^{TWO}) was used to pattern various IDTs with linewidth/period(λ) ranging from 80/320 nm to 200/800 nm (Fig. 1c-1f). Development and testing of even smaller λ's is underway. The non-conductive nature of $LiNbO_3$, the SAW structure, and the design constraints complicate the fabrication. However, these challenges have been overcome by using a conductive top-coating (ESPACER) and careful dose optimization through process window investigations resulting in improved performance. The IDTs are formed using a 30/12 nm Au/Ti layer lifted-off after patterning of a 200 nm thick PMMA 950k layer. Fig. 2 shows selected measurement results for 80/320 nm and 100/400 nm vertically (V-type) and horizontally (H-type) oriented devices. Generally V-type devices provide a higher frequency, lower *IL* and better K^2_{eff} at the cost of a lower *Q*-factor. H-type devices exhibit a greater number of resonant modes and have higher *Q*-factors. In addition to studying the orientation of the IDTs with respect to the crystal planes, the effect of the SAW pad design, IDT design, and $LiNbO_3$ substrate type on the frequency characteristics were also studied (to be presented in detail). This is the first report of >10 GHz $LiNbO_3$ SAW devices. We expect to push the operational limits even higher – Fig. 3 presents a 40/240 nm SAW IDT with an expected frequency exceeding 14 GHz.

[1] S. Ayalew and M. Li, Nature Communications **5**, 5402 (2014).
[2] N.-H. Chen *et al.*, J. Micromech. Microeng. **21**, 045021 (2011).

Acknowledgments: This work was supported by National Natural Science Foundation (61434001), 973 Program(2015CB352100), National Key Project of Science and Technology (2011ZX02403-002), and Special Fund for Agroscientic Research in the Public Interest (201303107) of China.

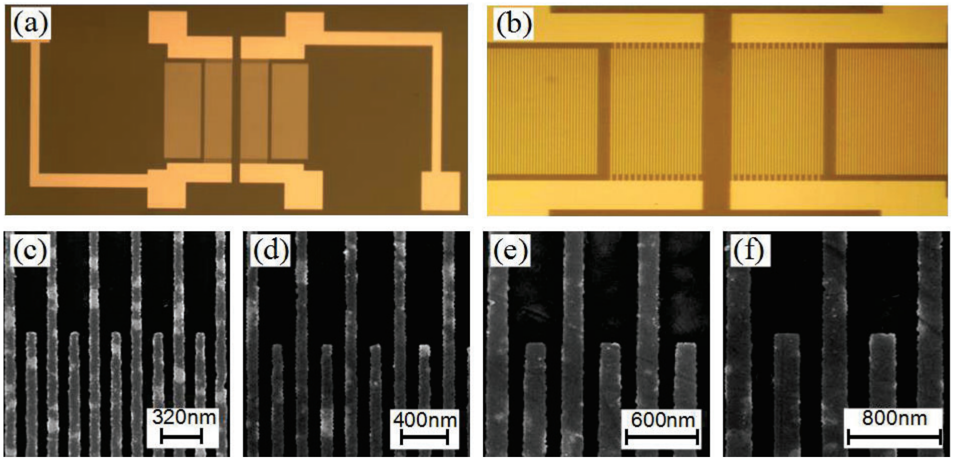

Fig. 1. (a) Structure of a SAW device, with (b) inner IDTs and outer reflectors. SEM images of (c) 320 nm, (d) 400 nm, (e) 600 nm, and (f) 800 nm period IDTs.

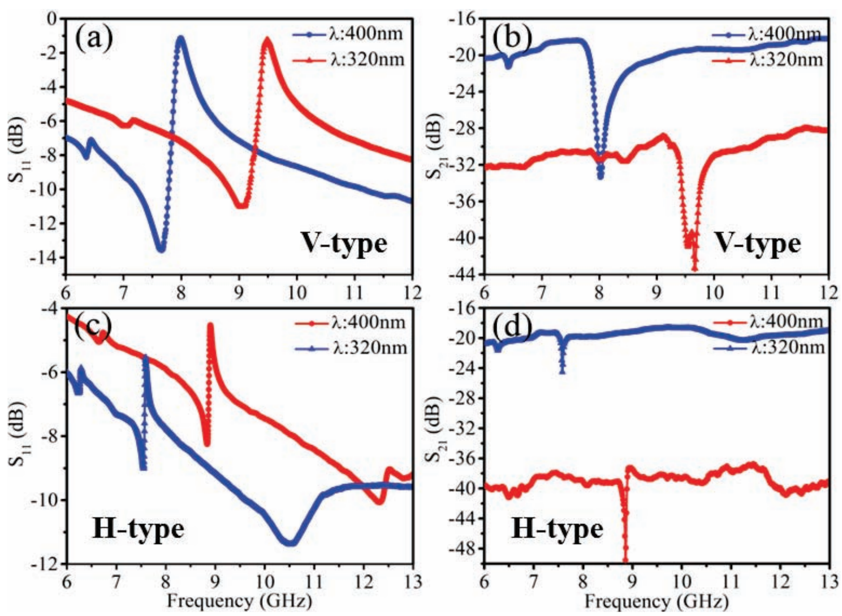

Fig. 2. Reflection (S_{11}) and transmission (S_{21}) parameters for (a,b) vertically and (c,d) horizontally oriented 400 nm and 320 nm period SAW devices on 128° Y-cut $LiNbO_3$.

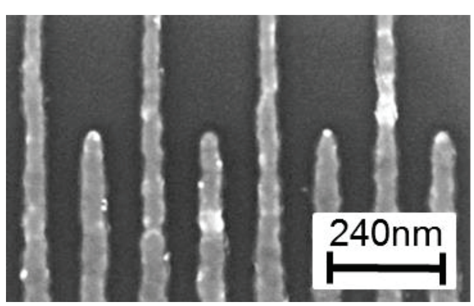

Fig. 3. A 240 nm period (≥40 nm linewidth) IDT on $LiNbO_3$ (testing underway).