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# Phonic Crystal Disturbed Surface Acoustic Waves for Microparticle Concentration and Separation inside a Sessile Droplet

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## 1. Introduction

Acoustofluidic actuation of a microfluid has increasing applications in microparticle and bio-cell manipulation [1–3]. Acoustic manipulation of these micro-objects suspended in a microfluid is useful in separation, concentration, and mixing for biological, physical, and chemical diagnosis applications. The developed acoustofluidic devices can be classified into sessile droplet-based and microchannel-based platforms, while the former is typically simpler in fabrication and application in several functions [4]. Meanwhile, the generation of an effective acoustic wave field to interact with the microfluid is crucial for realizing the manipulating functionalities. The interdigitated tranducers (IDTs) attached to surface of a piezoelectric substrate can produce an dersired frequency of surface acoustic waves (SAWs) within a wide available range (10–1000 MHz). However, for a sessile droplet-based acoustofluidic plateform, tailoring the SAW field excited by usual IDTs turns into more important to the functionality of particle manipulation without the microchannels [5]. In a sessile droplet, SAWs can produce strong acoustic streaming flow (ASF) and acoustic radiation force (ARF) to actuate suspended micro-objects. Without confinement of the fluidic domain by microchannel, however, the ASF and ARF fields would not always be suitable for specific manipulation functionalities. Therefore, other innovative means to tailor the ASF and ARF fields for a sessile droplet are required.

In this paper, we present an experimental study on manipulating the microparticels suspended inside a sessile droplet using SAW field disturbed by phononic crystals (PCs) excited by usual IDTs. The disturbed SAW field result in ASF and ARF fields inside the sessile droplets distinct from those without disturbance of SAWs by PCs. As a result, concentration and separation of microparticles are achieved.

## 2. Methods

**Figure 1** shows the schematics of the SAW acoustofluidic platform with PCs for manipulating microparticles inside a sessile droplet. A pair of IDTs is placed on left-hand and right-hand sides of

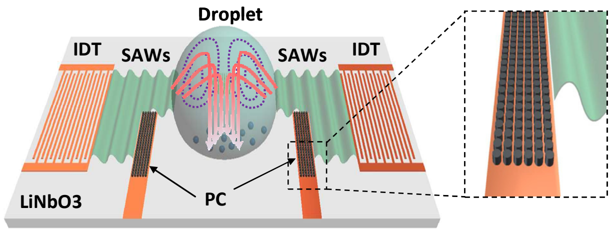


Fig. 1 Schematic of the SAW based acoustofluidic platform with PCs for manipulating microparticles inside a sessile droplet.

the sessile droplet, and two PC arrays are grown symmetrically in between the IDT and droplet that extend partial range of the SAW beam width to disturb the SAWs. The employed feature of the PCs is the phononic band gap that can effectively reduce SAW transmission intensity. The disturbed SAWs incident into the droplet induce two strong acoustic streaming vortex in the top half and symmetric with respect to the central line of the droplet. The two symmetric vortices also drive a current flow toward the bottom half of the droplet accompanying the traveling acoustic waves reflected by the droplet’s spherical boundary. In addition, the interference of the two SAW beams also constructs a significant attenuated standing acoustic pressure inside the top half of the sessile droplet. The attenuated standing acoustic pressure and traveling acoustic waves can exert ARF on the microparticles. Particularly, the effectiveness of the ARF exerted by the traveling acoustic waves depends considerably on the particle size.

The acoustofluidic platform was fabricated on a piezoelectric substrate (128°YX LiNbO3) of 500 μm thickness, and IDTs are patterned on top with Cu film using an e-beam evaporation process. PCs were grown after the IDT process using a micro electroplating process [6]. In the experiments, a camera (Canon 70D) with a macro lens (Canon EF 100mm f/2.8L Macro) was used to record the images of the microparticle motions inside the sessile droplets positioned on top of the substrate. The SAWs were excited through the IDTs by an AC signal produced and amplified by an RF signal generator (N5181A, Keysight) and power amplifier (ZHL–1-2W, MiniCircuits). The experimental setup

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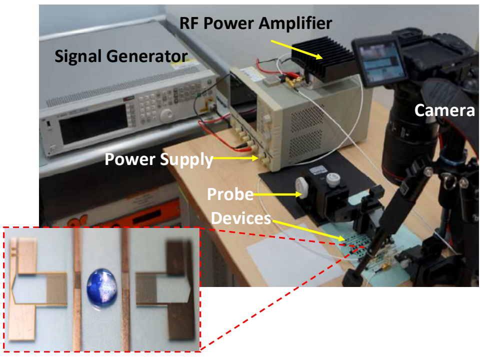


Fig. 2 The experimental setup and a realized device.

and a realized device are shown in **Fig. 2**. The substrate surface was coated with a hydrophobic layer to increase the contact angle to about 90°.

## 3. Results and Discussion

We first designed the phononic band gap of our Ni pillar PCs by a finite-element method (FEM) with a conventional numerical algorithm. The PC's lattice constant is 60 μm, the pillar diameter is 50 μm, and the pillar height is 10 μm. A SAW band gap ranges from 26 to 31.1 MHz is achieved with the design. **Figure 3** shows the calculated results of 30-MHz SAW stopped by the PCs. Measurement of the S21 signal using a network analyzer (Agilent E5061B) for the SAWs passing the PCs confirmed a 13 dB descend in SAW intensity.

**Figure 4** shows the manipulating results of suspended microparticles, via SAWs of 30 MHz in frequency and 19.2 V in input voltage, inside a sessile droplet of 6.0 μL. The particle sizes included 2 μm and 20 μm in diameter. Figure 4(a) shows the concentration of 2-μm polystyrene (PS) particles by the SAWs without PCs. The particles concentrate into a quadruple pattern. Figure 4(b) shows the concentration of 2-μm polystyrene (PS) particles by the SAWs with PCs. Differently, the 2-μm particles concentrate into a pile at the top end of the droplet. The concentration mechanism is strong ASF and ARF simultaneously localized inside the top half of the droplet. Figure 4(c) shows the concentration of 20-μm polystyrene (PS) particles by the SAWs with

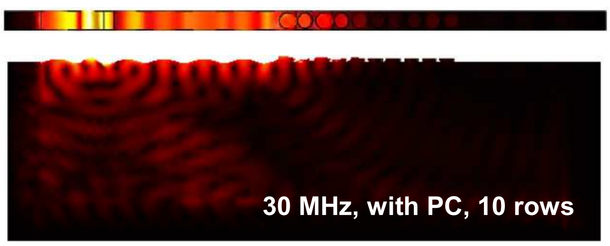


Fig. 3 Calculated results of 30-MHz SAW stopped by the PCs.

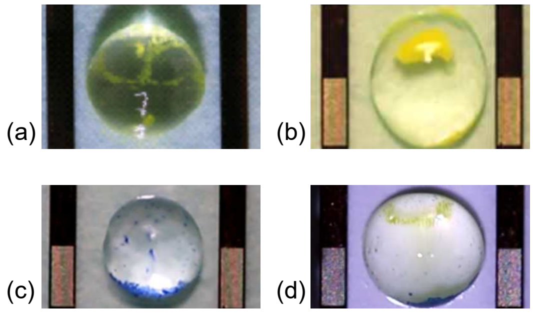


Fig. 4 SAW manipulation results. (a) 2-μm particles, without PCs. (b) 2-μm particles, with PCs. (c) 20-μm particles, with PCs. (d) Mix of 2- and 20-μm particles, with PCs.

PCs. Alternatively, the 20-μm particles concentrate into a pile at the bottom end of the droplet. The larger size of the particles were driven by the current flow toward the bottom half of the droplet and subjected to considerable ARF by the reflected traveling acoustic waves. Although 2-μm particles can be driven by the current flow toward the bottom half; however, ARF is too small to drive the 2-μm particles to the bottom end. Mixing the 2 and 20-μm microparticles inside one sessile droplet, Fig. 4(d) shows the separation of the microparticles of two different sizes by the PC disturbed SAW field.

## 4. Conclusions

We have experimentally studied microparticle concentration and separation inside a sessile droplet using SAWs disturbed by PCs with a frequency of 30 MHz. Microparticles of 2 and 20-μm in diameter can be concentrated at different sides of the sessile droplet by a PC disturbed SAWs to induce a strong ASF and impart a direct ARF on the microparticles. Separation of 2 and 20-μm mix microparticles was also achieved.

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