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Transportation Control of Microfluidic Particles using Mode Switching between Surface Acoustic Waves and Plate Waves

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1. Introduction

In the past decade, ultrasound acoustofluidics has received increasing interest for its application to serves as a tool for purely mechanical and label-free manipulation of particles and cells in MEMS and biological systems [1–3]. Ultrasound is regarded as one of candidates of the driving forces, in addition to the commonly learned electric, magnatic, optical forces, etc., for tailoring demanded lab-on-a-chip systems. The associated technology is also called acoustophoresis. Earily studies of acoustophoresis typically made use of bulk acoustic waves excited by piezoelectric transducers attached onto a micro-fluidic channel [4,5]. Constructive interference of the incident waves and reflected waves can build a standing acoustic wave field across the microfluidic channel for the particle manipulation [6]. However, such acoustofluidic devices suffer from the problem of incompatible acoustic impedence of commonly used buliding materials of the microfluidic channels for reflected waves.

In recent years, surface acoustic wave (SAW) has been demonstrated as a powerful alternative for bulk acoustic wave in constructing acoustofluidic devices for non-invasive manipulation of particles and cells. For example, SAW based acoustofluidic devices have been utilized to concentrate, separate, transport, enrich, and pattern particles or biological cells for various applications [6–9]. However, SAW based acoustofluidic devices rely on electrodes, which are known as interdigital tranducers (IDTs), properly fabricated on a piezoelectric substrate (e.g. $LiNbO_3$) for generating desired SAWs. Generation of SAWs with desired frequency (or wavelength), amplitude, and acoustic beam width is important for device functionalities. IDT design involves so many parameters to achieve the required properties. For example, different IDT pitches are used to generate SAWs with different wavelengths to build desired standing acoustic wave fields in microfluid.

In this work, we present a numerical study of transpotation control of microparticles achieved by mode switching between SAWs and plate acoustic waves (PAWs). The mode switching is based on the electrical excitation by the same IDTs at different input frequencies in a $LiNbO_3$ substrate of finite thickness.

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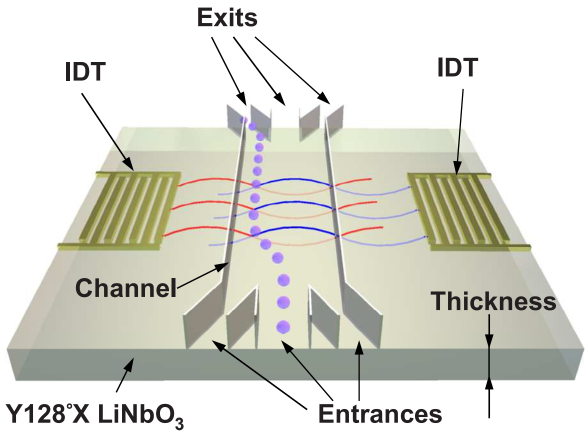

Fig. 1 Schematics of particle transportation into specific exit using a standing acoustic wave field generated by IDTs on both sides of the channel.

2. Method

Figure 1 shows the schematic illustration of the dual-mode acoustofluidic device including a microfluidic channel located between two IDTs patterned on a $LiNbO_3$ substrate of finite thickness. When excited by an AC signal, the IDTs convert an electric field into acoustic waves. As the IDTs are designed to have a specific pitch, we can control the input frequencies of the AC signal to particularly excite SAWs or PAWs. The excitation frequencies for SAWs and PAWs are respectively decided by the IDT pitch and substrate thickness. The excited SAW and PAW modes correspond to two different acoustic wavelengths, so that two different standing acoustic wave fields across the channel are formed to transport the particles toward different exits.

We use finite element analysis to simulate the acoustic wave fields and acoustic pressure fields and the coupling. A moving particle exposed to the standing acoustic wave field is subjected to a time-averaged acoustic radiation force and Rayleigh drag force and gravity. Considering all the acting forces in the Newton's second law, we can calculate the trajectory of the particle.

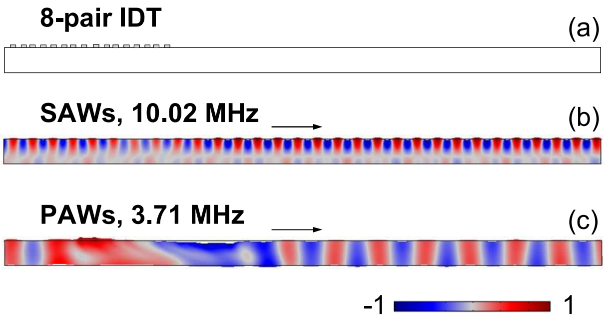

Fig. 2 Simulated results of exciting SAW and PAW fields by inputting AC signal to the 8-pair IDT at 10.02 and 3.71 MHz, respectively. The IDT pitch is 398 um.

3. Results and Discussion

Figure 2 shows the excited SAW and PAW fields using different input AC signal to the IDT. The IDT contains 8 pairs, and the pitch is 398 um. For exciting SAWs and PAWs, the input frequencies are 10.02 and 3.71 MHz, respectively. The assumed thickness of the Y128°X LiNbO3 substrate is 500 um. As a result, the corresponding wavelengths of SAWs and PAWs are 398 and 1000 um.

Figure 3 shows the acoustic pressure fields in the microfluidic channel as it is combined onto the LiNbO3 substrate. The channel is assumed to be made of PDMS and filled with water. The channel width and height are 150 and 25 um, respectively. It is observed that the acoustic pressure fields have pressure nodes at left and right-hand sides for the excitation of SAWs and PAWs, respectively. The result elaborates feasibility of building controllable acoustic pressure nodes by switching between two different acoustic modes (i.e., the SAW and PAW modes) via changing the input frequencies of the AC signal to the IDTs. Figure 3 also shows the simulated trajectories of the microparticles in the channel. Figure 3(c) shows the starting position of 8 um particles released around the middle region of the channel, and Fig. 3(d) show the trajectories and positions of the particles exposed to the standing acoustic fields developed by SAWs and PAWs for one second. The results show that the particles can be transported to left and right-hand exits when switching to SAWs and PAWs, respectively.

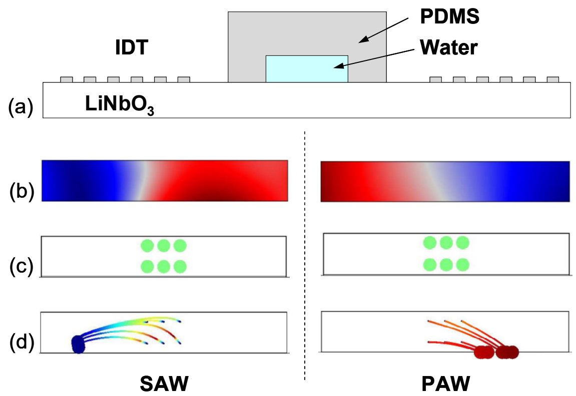

Fig. 3 (a) Cross-section of the acoustofluidic device. (b) Acoustic pressure fields in the channel by exciting SAWs and PAWs. (c) Starting position of the released particles. (d) Trajectories of the particles in the SAW and PAW induced acoustic pressure fields.

4. Conclusions

In this study, we proposed the transportation control of particles in a microfluidic channel using acoustic mode switching. We considered two IDTs and the microfluidic channel to be fabricated on a 500-um thick $LiNbO_3$ substrate where the SAW and PAW modes can be simultaneously supported to propagate and excited by the IDTs. We showed that by switching standing acoustic fields of SAWs and PAWs, two different acoustic pressure fields in the channel can be built to control the motion of the particles toward desired exits of the channel.

Acknowledgment

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References

1. J. Friend and L. Y. Yeo: Rev. Mod. Phys. **83** (2011) 647.
2. H. Bruus, J. Dual, J. Hawkes, M. Hill, T. Laurell, J. Nillson, S. Radel, S. Sadhal and M. Wiklund: Lab. Chip. **11** (2011) 3579.
3. H. Mulvana, S. Cochran, and M. Hill: Adv. Drug Delivery Rev. **65** (2013) 1600.
4. A. Nilsson, F. Petersson, H. Jonsson, and T. Laurell: Lab. Chip. **4** (2004) 131.
5. M. Koklu, A.C. Sabuncu, and A. Beskok: J. Colloid Interface Sci. **351** (2010) 407.
6. J. Shi, X. L. Mao, D. Ahmed, A. Colletti, and T. J. Huang: Lab. Chip. **8** (2008) 221.
7. Y. Ai, C. K. Sanders, and B. L. Marrone: Anal. Chem: **85** (2013) 9126.
8. J. Shi, D. Ahmed, X. Mao, S. C. S. Lin, A. Lawit, and T. J. Huang: Lab. Chip. **9** (2009) 2890.
9. Y. Chen, S. Li, Y. Gu, P. Li, X. Ding, L. Wang, J. P. McCoy, S.J. Levine, and T. J. Huang: Lab. Chip. **14** (2014) 924.