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# Study of "acoustic tweezer" chip for particles driving

*Zhao Weibing Zhu Xinhua Su Yan Wan Ying*

Nanjing University of Science and Technology, Nanjing 210094

**Abstract:** Surface Acoustic Wave (SAW) is one of the sound waves that travel parallel to the surface of an elastic material, and is capable of manipulating microparticles. This SAW device was named acoustic tweezers. Acoustic tweezers possess advantages of energy-efficiency, small size and easy-to-produce. Herein, we developed an acoustic tweezer chip to sort microparticles of different sizes. The chip consists of a pair of interdigital transducer (IDT) and a PDMS microfluidic channel. The IDTs generate the surface acoustic wave which acts on the particles in the microchannel. Finally the sorting of particles can be seen.

**Key words:** manipulating microparticles, acoustic tweezer, low energy consumption, interdigital transducer

## 1 Introduction

Acoustic tweezers, the system which use sound as tweezers, are so small and can be placed on a chip to manipulating micron or nanometer sized particles [1, 2]. The energy consumption of acoustic tweezers is less than 500 thousand times [3], which is much less than that of optical tweezers. Due to its small size, acoustic tweezers can be made by standard chip processing technology, so it has the possibility to be widely used.

Acoustic tweezers work through establishing a continuous surface acoustic wave. If the two sound sources are interrelated and each sound source produces the sound of same wavelength, then there will be a point which makes the related sounds cancel each other out, this point can be seen as the trough. Because sound waves have pressure, which can drive very small objects, so micro or nano particles move with the sound waves until the sound waves reach the trough, then the particles will fall to the trough and no longer move. If the sound comes from two parallel acoustic sources, the troughs will form a line or a series of lines. And if the sound source is perpendicular to each other, the troughs will form evenly spaced lines or columns like a chessboard. Also, these particles will also be pushed to places where the sound no longer moves.

Because of its versatility, low energy consumption, simple technology, miniaturization and so on, acoustic tweezers show obvious advantages. Acoustic tweezers will be used as a tool for (biological) tissue engineering, cell research, drug screening and so on.

## 2 Research on separation principle

The particles in the channel, as shown below, are affected by 4 forces, there are gravity, buoyancy, surface acoustic wave (SAW) and medium viscous force. In the vertical direction, gravity and buoyancy are balanced, so as to the motion of particles, we only need to consider the surface acoustic wave and viscous force in the horizontal direction.

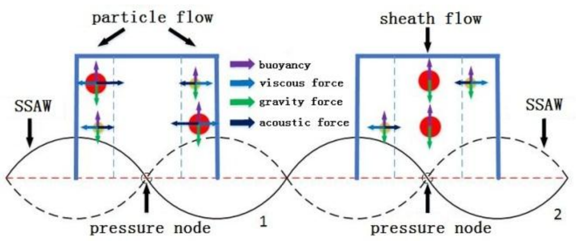


**Fig.1** Force analysis of particles in channel

The acoustic radiation force comes from the interaction between particles and sound waves; the expression of the acoustic radiation force of particles by the acoustic surface standing wave produced by interdigital transducer is given below [4-6]:

$$F_r = -\left(\frac{\pi p_0^2 V_p \beta_m}{2\lambda}\right)\phi(\beta,\rho)\sin(2kx) \tag{1}$$

$$\phi = \frac{5\rho_p - 2\rho_m}{2\rho_p + \rho_m} - \frac{\beta_p}{\beta_m} \tag{2}$$

Equation (1) is the calculation of surface acoustic wave($F_r$), therefore, without considering the environmental factors, the main factors affecting the surface acoustic wave($F_r$) are wavelength($\lambda$), particle volume($V_p$), $\phi$ function and sin(2kx). Obviously, the larger the wavelength($\lambda$) is, the smaller the surface acoustic wave ($F_r$) is. When the wavelength($\lambda$), particle and medium is constant, the surface acoustic wave depends on sin(2kx), k represents the wave vector, x is the distance between the particle and the node. According to the picture above, when the particles are between the antinode and the node of the wave, the farther the particles are from the wave node, the larger the surface acoustic wave ($F_r$) is, so as the other way. So the particles will move towards the pressure node under the effect of surface acoustic wave ($F_r$), after reaching the pressure node, the force of the particles will disappear, and then stop at the node position.

To different particles in the same position, the surface acoustic wave ($F_r$) depends on the particle volume ($V_p$) and $\phi$ function. Equation (2) is the calculation of $\phi$ function, where $\rho_p$ and $\rho_m$ correspond to density of the particles and density of medium, $\beta_p$ and $\beta_m$ correspond to compressibility of particles and compressibility of medium. So in the same medium, when the compressibility of different particles is very small, the volume of particles($V_p$) determines the surface acoustic wave($F_r$).

Equation (3) is the calculation of viscous force ($F_v$) [7], so for particles of different sizes, viscous force ($F_v$) depends on the radius of the particle(r).

$$F_v = -6\pi\eta r v \tag{3}$$

So when the particle size increases, the increase of surface acoustic wave ($F_r$) will be more than the increase of viscous force ($F_v$). In other words, the larger the particle, the larger the resultant force of $F_r$ and $F_v$, and then particles move faster and more clearly. So the larger particles move faster than the smaller ones, which cause the separation of large and small particles.

## 3 The design of interdigital transducer

The chip includes interdigital transducer and PDMS microchannel, select the appropriate substrate, the PDMS microchannel is processed in the middle of the substrate and the interdigital transducers are processed on both sides.

### 3.1 Interdigital transducer(IDT)

In the whole system, interdigital transducers convert electrical energy into acoustic energy, and then acoustic energy is used to drive particles. In the design of interdigital transducers, we consider the following conditions. First of all, the interdigital transducers produce surface acoustic wave standing wave[8], to achieve SAW with a high coupling coefficient, we choose Y+128° X-propagation lithium niobate ($LiNbO_3$) wafer (500 mm thick) as the substrate. For the design of interdigital transducers, acoustic wave length should be 300um, so the width and pitch of the IDTs were 75 mm and 150 mm[9]. The acoustic aperture is 16mm, there are 20 pairs of IDT, and the distance between one pair of IDTs is 8mm. As shown in the following picture:

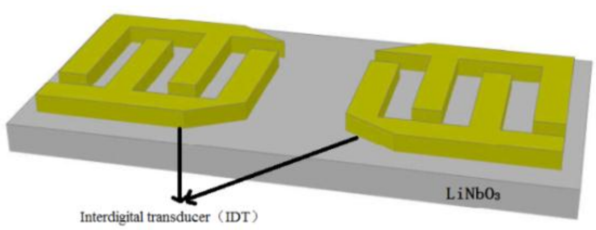

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**Fig.2** Structure of IDTs

The relation between acoustic wave frequency and wave velocity is as follows:

$$f = \frac{v}{\lambda} \quad (4)$$

So our signal frequency is set at 12.6 MHz.

### 3.2 PDMS microchannel

In the design of microchannel, considering the particles move to the pressure node or antinode under the action of SAW, we set the width of the microchannel half a wavelength (150um), so we can guarantee the separation position.


**Fig.3** Structure of microchannel

1,2,3 is the entrance，1 and 3 are injected the sheath fluid, the inlet 2 is injected liquid with particles, so when the liquid enters the channel together, it forms the laminar flow as shown in the figure below:

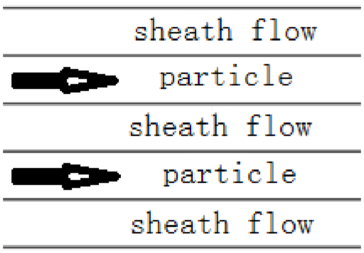


**Fig.4** the laminar flow

### 3.3 Connection of inlets and outlets of micro channel

We choose polytetrafluoroethylene (PTFE) tubes to connect inlets and outlets. The inner diameter of the tube is 0.3mm and the external diameter is 0.6mm. We insert the tubes into PDMS and spread PMDS prepolymer on the connection, then dry it. This ensures the strength of the connection, avoids leakage and other phenomena. The model is as follows:

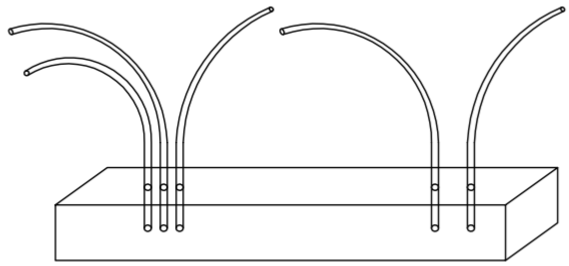

**Fig.5** Connection of inlets and outlets of microchannel

## 4 Results and discussion

### 4.1 Simulation of microchannel

Through the front design, we basically determine the structure of the micro channel. But considering the flow of the fluid outlet, we need to get concrete results through simulation. So, in order to ensure the normal flow of outlets, we carried out the streamline simulation on export by COMSOL. We set the width of the middle channel 60um, bilateral symmetrical, 45 degrees tilt angles. The result of the simulation is as follows:

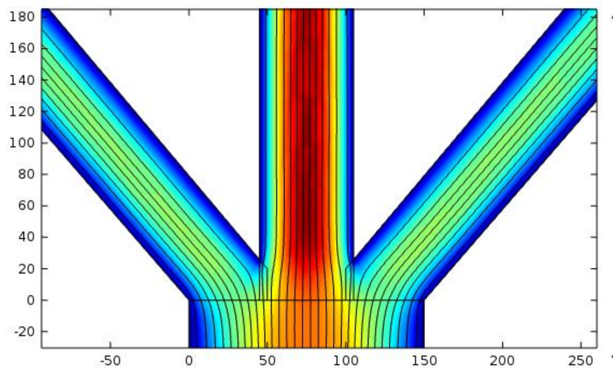


**Fig.6** Simulation of outlet streamlines

It can be seen from the figure, there are 9 streamlines on both sides of the channel, 12 streamlines in the midde channel. For the design of the channel, on the one hand, this result can ensure the normal outlet liquid of the middle channel, on the other hand, it can also let fluid production of exports of both sides not be too much.

### 4.2 experiment of particle manipulation

In the experiment, we inject liquid by injection pump. As to particles, we choose fluorescent polystyrene microspheres with diameter of 5um and non-fluorescent polystyrene microspheres with diameter of 1um, the concentration was 1mg/ml. In order to prevent clusters of particles, we use TWEEN-20 for the pretreatment of polystyrene microspheres. We use deionized water as the sheath and set the rate of flow 2.5ul/min. In the experiment, we clearly see the movement of fluorescent particles in the chip by fluorescence microscope. Also, we observed that fluorescent particles can be separated from non-fluorescent particles under the drive of acoustic tweezers.

## 5 Summary

Based on the unique advantages of acoustic tweezers, a particle sorting chip is designed in this paper. It produces surface acoustic wave by applying the pumping signal to IDTs, then we can observe the separation of particles by different diameters under the force of SAW. The experiment proves that fluorescent polystyrene microspheres with diameter of 5um and non-fluorescent polystyrene microspheres with diameter of 1um can separate from each other. This design is expected to be used in biomedical research.

## References

1. N. Mu, The advent of Multifunctional micro acoustic tweezers[J], Technology development of enterprise:2, 2009, 16 (11): 55-55.
2. J. Xiao, Multifunctional micro acoustic tweezers[J], Technology and market, 2009, 16(11):88-89.
3. C. R. P. Courtney, C. E. M. Demore, H. Wu, et al, Independent trapping and manipulation of microparticles using dexterous acoustic tweezers[J], Applied Physics Letters, 2014, 104(15):492-660.
4. X. Ding, P. Li, S. C. Lin, et al, Surface acoustic wave microfluidics.[J], Lab on A Chip, 2013, 13(18):3626-3649.
5. G. H. Du, Z. M. Zhu, X. F. Gong, Basic of Acoustics[M], Nanjing University Press, 2012.
6. J. C. Cheng, Principle of Acoustics[M], Science Press, 2012.
7. J. Shi, H. Huang, Z. Stratton, et al, Continuous particle separation in a microfluidic channel via standing surface acoustic waves (SSAW)[J], Lab on A Chip, 2009, 9(23):3354-3359.
8. W. Zhou, Experimental Study on Mechanical Properties in Acoustic Streaming[D], Nanjing University, 2016.
9. J. F. Ping, Z. C. Le, Research and Design of Surface Acoustic Wave Interdigital Transducer[J], Application of Photoelectric Technology, 2011, 26(4):49-52.