Surface acoustic wave microfluidics: micro-particle patterning to biosensors

The era of huge electronic circuits ended when such circuits got integrated into tiny chips, dramatically reducing size and at same time increasing the efficiency. A similar trend is observed in bio- and chemical engineering: analyses and syntheses involving fluids, which originally could be one only on large scales, can be performed in microscale thanks to the developments in the field, microfluidics (1, 2). Microfluidic devices or so called lab-on-a-chip devices carry liquids typically in volumes of micro- or nano-litres through microchannels or on specially designed open surfaces. The liquid is carried as continuous flow or as tiny droplets. Microfluidic technology offers higher accuracy and efficiency to processes compared to those in the bulk scale. Therefore, it is widely applied in interdisciplinary fields such as diagnostics, biomedical and chemical engineering. Microfluidics can contribute towards facilitating point-of-care diagnostics especially developing- and low-income countries in a very affordable way. Various minimally complex microfluidic tests are available commercially (e.g. glucose test, pregnancy test etc.), other advanced applications including DNA sequencing (such as Base4 or Illumina) make use of microfluidic technology and numerous other applications are being developed.

In microfluidics, the fluid of interest can be chemicals or biological samples. One of the methods to manipulate fluids in microfluidics is using acoustics, namely using surface acoustic waves (SAW). SAW are waves that propagate on the surface of elastic materials (3). It is generated by electrically actuating piezoelectric surfaces. Numerous biological and chemical applications are demonstrated using SAW in microfluidics (3, 4, 5). These applications are based on the fact that excitation of fluid with SAW generates three effects: (i) streaming flows; (ii) standing pressure waves inside the fluid; (iii) standing capillary waves if a free interface (liquid-air) is present such as in a droplet.

Unfortunately, only a little is known about the mechanism of origin of the capillary waves in SAW excited droplets. The high frequency (typically MHz) acoustic waves result in the generation of subharmonic (kHz) capillary excitations. Such subharmonic excitations in droplets cannot be explained as often expected by subharmonic Faraday waves (6) since several experimental results contradict it (5, 7).

The standing pressure waves formed due to SAW can be exploited to trap, sort and manipulate microparticles and biological cells in liquid (3, 4, 5). This acoustic trapping process is influenced by the capillary oscillations when a free interface (liquid-air) is present, for example in a droplet. The effects of the interaction of the pressure waves and capillary waves are not well understood. This understanding is required for precise manipulation of the microparticles acoustically.

The ability to manipulate and pattern particles at precise locations acoustically will be utilized in making engineered surfaces. It becomes possible when evaporation of the liquid is performed with controlled particle assembly (5, 8, 9). Another important proposed application is highly sensitive and efficient biosensors point of acre diagnostics.

In this proposed project, I address two main aspects of acoustics: first, understanding the effects of capillary waves in precise patterning of particles with SAW; and the second, developing biosensors based on the capability of precise acoustic control of flow and particle pattering.

References

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