Third generation surface acoustic wave devices for active microfluidics

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Background, Motivation and Objective

Active microfluidic setups deploying surface acoustic wave (SAW) actuators have been proven to be beneficial for various tasks in modern labs including fluid mixing, manipulation and sorting of immersed particles and cells as well as for aerosol generation. For optimal design and operation of such devices, thorough knowledge of excited acoustic wavefields and resultant spatial fluid motion is important on one side while on the other side challenging comprehensive numerical simulations of involved effects have to be carried out. In this contribution, investigations on four cases of SAW-based actuators used for different microfluidic purposes are presented and discussed.

Statement of Contribution/Methods

For a straight microfluidic channel, three-dimensional fluid motion as a result of incident SAW is investigated in terms both FEM simulation and 3D streaming measurement. Our FEM simulation based on a novel streaming force approach and taking into account the real surface wave profile allows a relatively fast and easy access to resultant streaming with results being in good quantitative agreement with experimental data.

Aiming for lab-on-a-chip systems with a need for precisely controlled 2D manipulation of bio-particles, SAW wavefields of different types and with complex patterns have to be excited. Here, the popular 128°Y-cut of $LiNbO_3$ is thoroughly investigated. Different configurations for realizing travelling as well as standing wave fields with respect to one and two dimensions are discussed in detail.

For SAW-based aerosol generation, a highly interesting application for inhalation therapy, liquid chromatography and microprinting, a compact aerosol generator was realized. This device for the first time combines precisely placed, on-chip lithographically structured microchannels together with SAW transducers. The achievable droplet size-distribution and its dependency on input power, wavelength and fluid flow rate were investigated.

Finally, new kinds of SAW-fluid interaction are discussed. While microfluidic surface wave actuators usually deploy Rayleigh-type SAW with significant out-of-plane surface displacements, our investigations show that also originally shear horizontal polarized (SH) SAW modes can be used for microfluidic actuation if converted into a vertical polarized mode by an appropriate scattering structure inside the microscale vessel. Moreover, in case of highly-coupling piezoelectric substrates the electric field accompanying the SAW is also capable of accelerating the acoustic streaming effect.

Results/Discussion

Different cases of SAW-based actuators ranging from channel-based microfluidics over aerosol generation to new interaction effects have been investigated. Hereby, new methods for simulation have been used supplemented by different advanced microacoustic measurement techniques.