Smart microfluidic channels with integrated ultrasonic transducers

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Abstract- *Using recent development in the fields of ultrasonic MEMS devices, we propose to integrate ultrasonic sensors and actuators in bio-fluidic channels. The integration of ultrasonic transducers in small channels enables many applications that have heretofore been in the domain of large-scale ultrasonic sensors and actuators. Silicon micromachined ultrasonic capacitor transducers (CMUTs) and Zinc Oxide based piezoelectric transducers will be investigated for use in applications such as: flow measurement, fluid pump, pressure, density, viscosity, and other mechanical properties.*

Project Summary

We have integrated capacitive micromachined ultrasonic transducers and piezoelectric transducers with microfluidic channels. Using these transducers we have demonstrated the measurement of temperature, binary fluid composition and pressure (viscosity) in microfluidic channels. The essence of all the above measurements is the time of flight monitoring of an ultrasonic pulse in fluidic channels. In the simplest arrangement, a transducer is placed on one of the walls of the channel. The transducer excited by the short electrical pulses generates acoustic waves into the liquid filling the channel. One can easily measure the delay time between the ultrasonic reflections from the opposing walls of the channel. The acoustic velocity is given by dividing the acoustic path length by the time of flight. Channel height is usually known very accurately. If not, it can also be determined by using a calibration liquid with a known velocity. Sound velocity of the liquid varies with the temperature, composition of the liquid and pressure. Therefore, by measuring the sound velocity, one can monitor the above-mentioned liquid properties. Especially, there is a growing need for accurate temperature measurement in microfluidic channels. Precisely controlling and monitoring temperature in micro-channels is crucial to monitor the reaction rates between two or more chemicals. Many bio-medical procedures such as the Polymerase Chain Reaction (PCR) among others, involve the cycling of temperatures. Ultrasonic temperature measurement method enables controlling of temperature with 0.1-degree accuracy. In addition to above mentioned measurement capabilities, ultrasound can also be used for actuation of liquids in micro channels. When an ultrasonic harmonic field is generated in a fluid, second order radiation pressure builds up in the direction of the propagation. This pressure pushes the liquid away from the transducer. Using this, one can build very efficient mixers in a micro channel. Mixing of different chemicals is very important for many biologic agents. The characteristic laminar flow that occurs in micron-scale channels makes mixing of two fluids a very challenging operation. This can be a serious problem in systems that require the interaction between two or more fluids. Many mixers, both active and passive, have been demonstrated utilizing different methods. Moving small inert beads inside the fluid and applying alternating electric fields (electrokinetic mixing) are two such methods. We use ultrasonic radiation pressure for mixing of different liquids. Furthermore, the routing of fluids is even more challenging due to the small scales involved. MEMS switches with moving components show a high failure rate and deteriorate in performance with time. The acoustic implementation of a microfluidic switch gives reliable and stable switching as it does not have moving components. The acoustic implementation of both micro-mixers and micro-switches share many benefits such as ease of design and fabrication, having no moving components, being non-invasive and being easy to integrate in many existing systems. It should also be noted that the transducer could be located both inside and outside the channel giving an additional degree of flexibility in its fabrication.