Title of Abstract: Piezoelectric Actuation for Microfluidic Mixing Applications

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Introduction: Lab-on-a-chip is rapidly growing platform technology for microscale analysis and diagnostic applications. However, the microscale flow is mostly laminar which limits mixing to diffusion and hinders successful implementation of many assays. Some researchers have used complex geometry channel to increase the area over which diffusion occurs. However, this method is limited by fabrication complexity and longer time durations. Piezoelectric materials can convert one type of energy to another and can be used both as sensors or actuators. In the latter form, they convert electric charge into physical motion and thus are excellent candidates for microfluidic mixing applications. The summer research project described herein focuses on a special class of piezoelectric actuators that are made of polymers, specifically Polyvinylidene Fluoride (PVdF). The flexibility and ease of handling of PVdF actuators make them ideal for 'soft' microfluidic devices.

Materials and Methods: The piezoelectric actuators were driven by a connected-bridge circuit [1] that provided the amplified oscillating signal needed to produce necessary vibrations in the material. Both ceramic (PZT) and polymer (PVdF – Precision Acoustics Dorchester, UK) were used in the experiments. Three experiments were conducted to characterize the actuation parameters. First, finding the resonant frequency that causes the highest vibration in the materials. Dissolution times for similar sized salt crystals were recorded at various frequencies under a microscope. Second, measuring the displacement of piezoelectric vibration. The PVdF material was held in a cantilever beam formation. With one end fixed, the movement of the beam tip was measured under a microscope and image analysis program (Kinovea) was used to determine the displacement. Lastly, determining the efficacy of mixing in closed PDMS microfluidic channels. Red and blue dyes were entered into a y-shaped PDMS channel and the flow and mixing properties were observed with and without piezoelectric actuation.

Results and Discussion: The results of the dissolving duration experiments indicate a positive effect of using the piezoelectric actuators for mixing application. The average time of salt dissolving was 122 sec without mixing which reduced to 75.9 sec with the mixer actuating at a drive frequency of 5.4 kHz. The relative displacement of the actuator varied with frequency with the best results obtained between 5-10 kHz for the PZT actuator. The maximum displacement of 7μm was found for the PVdF cantilever beam at 27 Hz. For the flow in the PDMS microchannels, the width of one of the flow streams increased by roughly 10μm as the fluid passed over the vibrating piezo disc and returned to original width beyond the disc. This indicates that the acoustic vibrations generated by the PZT actuator were affecting the flow inside the PDMS channels. However, more experiments need to be done to fully characterize this effect and to optimize the flow and actuation drive parameters to enhance the mixing effects.

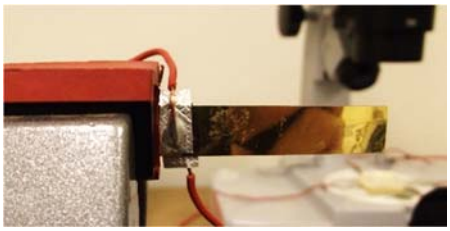

Figure 1: The displacement of the PVdF strip was measured in the shown configuration. Conductive adhesive tape was used for electrical connection to the two sides of the actuator. The displacement was measured using a digital microscope. In order to reduce the motion of the strip due to air current, the whole setup was placed inside a cardboard box (not shown).

Conclusion:
Piezoelectric actuation is a good solution for mixing in microfluidic channels. Polymer based piezoelectric actuators are flexible and therefore more suitable for soft microfluidic devices. The mixing effect with the PZT disc outside the microchannel was implemented and was shown to affect the flow inside the channel. However, several parameters need to be optimized for best mixing results. Future work will focus on incorporating the PVdF strip inside the microchannel.

Reference
[1] Robinson, S., Power Elect. Tech., 2006, 32 (4), pg 40.