# Fabrication and Characterization of Bubble-Driven Micromixers

**Matthew Rolleston, Advisor: Dr. Lynn Fuller**

Rochester Institute of Technology, Department of Electrical and Microelectronic Engineering, Rochester NY 14623

RIT Kate Gleason College of Engineering

MicroE Microelectronic Engineering

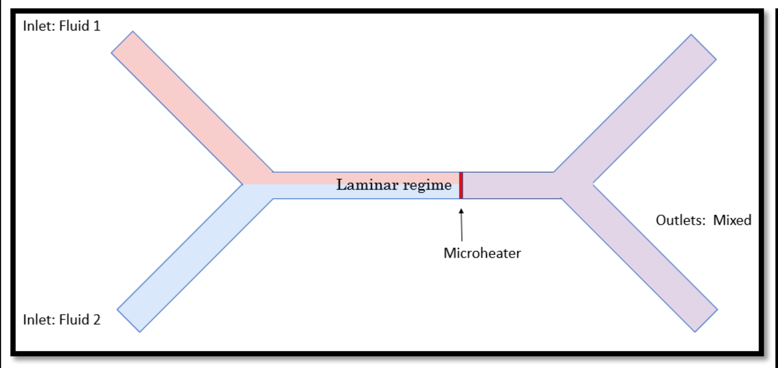
## I. Project Objectives

**Goal: To demonstrate that MEMS microheaters can be used as micromixers.**

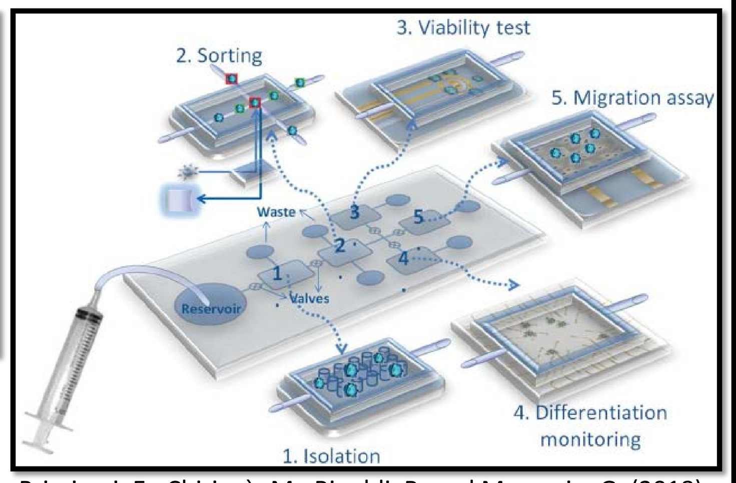
- Design and fabricate a MEMS microheater.
- Demonstrate the pulsatory mixing effects of the microheater.
- Provide evidence that mixing is caused by a drive bubble.

## II. Motivation

- The precise manipulation of fluids can be applied anywhere from healthcare in medical diagnostics to pharmaceutical companies miniaturizing reactions to reduce reagent consumption.
- MEMS microheater technology can be used to actively mix fluids vs. passive mixing solutions, ultimately saving on real estate need.




Concept: A timed pulse sent to the microheater should create a drive bubble causing enough disruption in the channel to mix the two flows.




Primiceri, E., Chiriacò, M., Rinaldi, R. and Maruccio, G. (2018). *Cell chips as new tools for cell biology – results, perspectives and opportunities.*

## III. Heat Transfer Theory

Fourier's Law for heat transfer was employed to give an estimate of the thermal resistance of the $SiO_2$ layer:

$$R_\theta = \frac{x}{A \times k}$$

*where:*

- $R_\theta$ is the thermal resistance of the $SiO_2$ layer (°C/Watt)
- $x$ is the length of the thermal path (m)
- $A$ is the cross-sectional area of the polysilicon heater ($m^2$)
- $k$ is the thermal conductivity of $SiO_2$ (1.4 Watt/m°C)

Assuming a 1D heat transfer model, the voltage needed to heat the polysilicon to a given temperature is represented as:

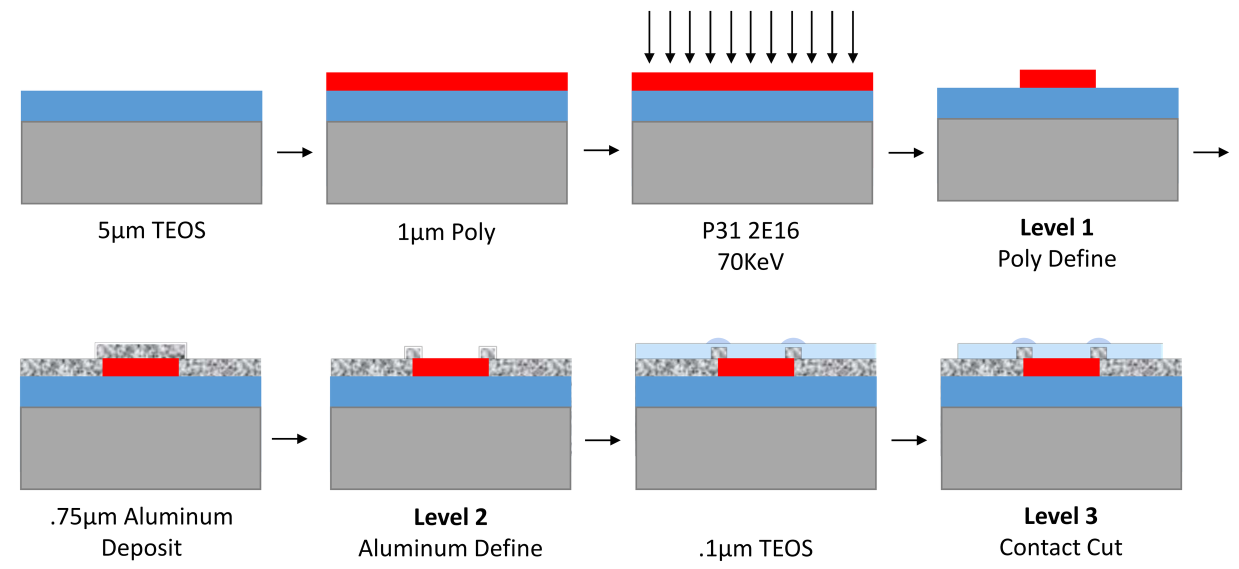
$$V_{app} = \sqrt{\frac{\Delta T \times R}{R_\theta}}$$

*where:*

- $\Delta T$ is the desired temperature change of the polysilicon heater (°C)
- $R$ is the resistance of the polysilicon heater (Ω)

## IV. Fabrication Process Flow

Polysilicon heaters were fabricated using a surface MEMS process.



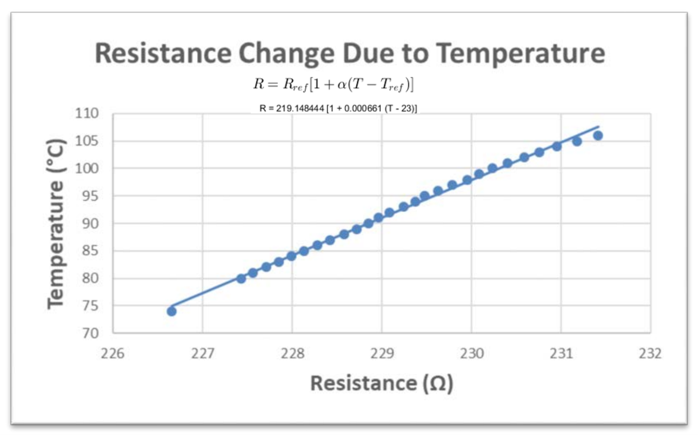

Design Considerations:

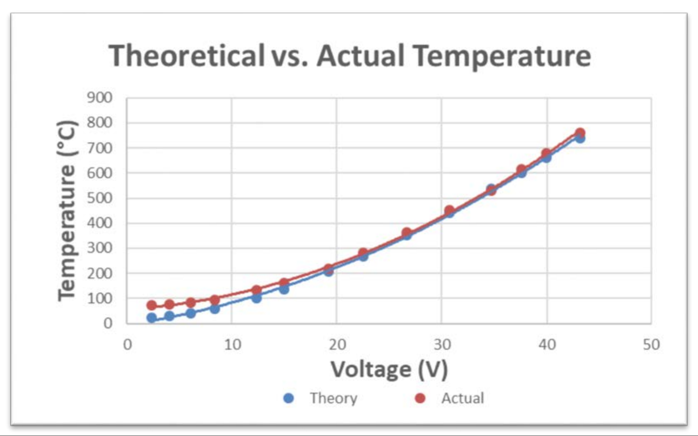
- A thick thermally resistive material should be present underneath the polysilicon layer to force heat upwards towards the fluid.
- A thin thermally conductive layer should be used to electrically isolate any electrical connections from the fluid above.

## V. Temperature Calibration

Temperature calibration for the fabricated microheaters was performed.

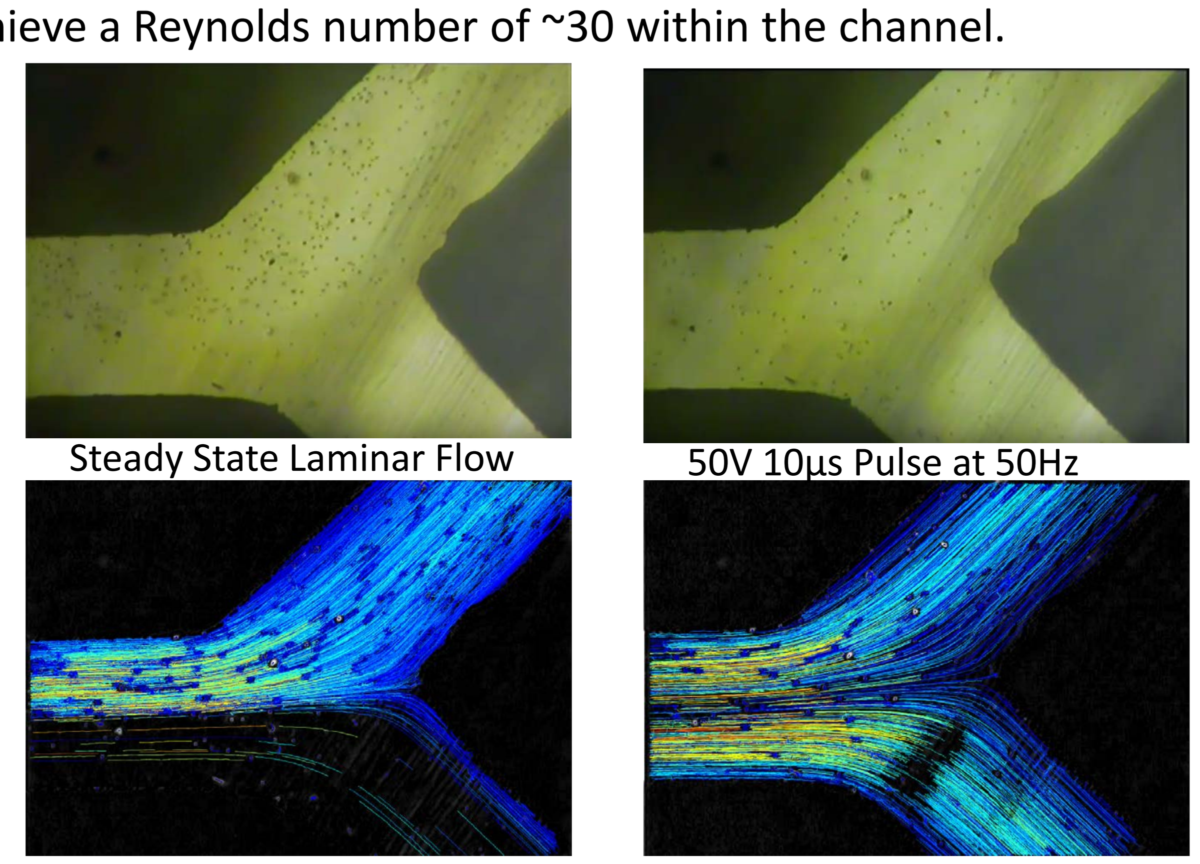
The thermal coefficient of resistance (α) for the doped polysilicon was found to be 6.61E-4/°C.




## VI. Results

Particles were used to verify mixing. A flow rate of .02ml/min was used to achieve a Reynolds number of ~30 within the channel.



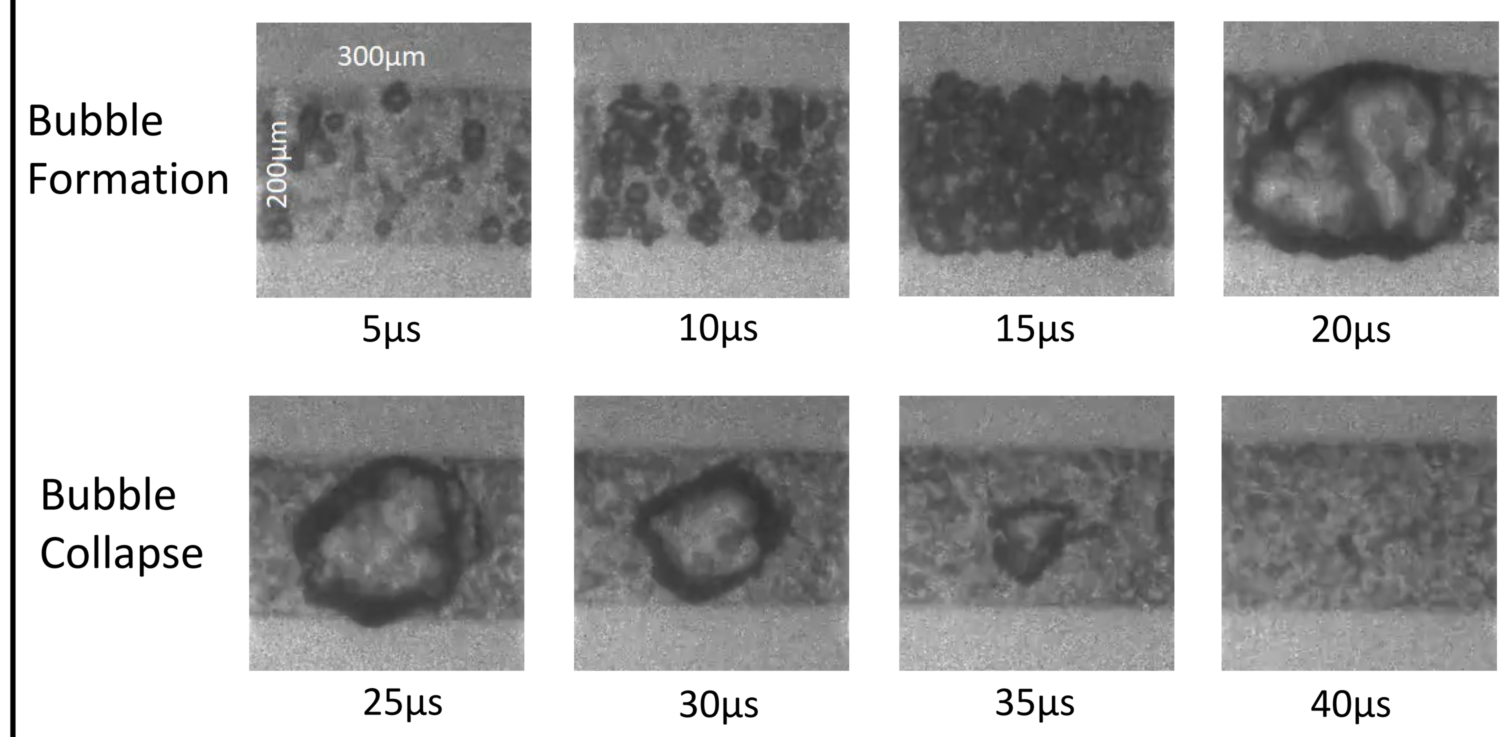
Steady State Laminar Flow

50V 10µs Pulse at 50Hz

Particle tracking software was used to illustrate mixing and flow rate.

## VII. Drive Bubble

A 65V, 10µs pulse was examined using a stroboscopic effect produced from a synchronized laser. Images were captured in increments of 5µs after t=0 for the 10µs pulse.




Visualizing a drive bubble confirms that the mixing mechanism for this microheater design is caused by a metastable boiling response.

The drive bubble is seen to grow to cover the entire heater length within 20µs of the start of the initial pulse before collapsing within the next 20µs.

## VIII. Conclusions

- A MEMS microheater was designed and fabricated.
- Pulsatory mixing effects of the microheater were demonstrated.
- Evidence that mixing is caused by a drive bubble was shown.

### Future Work

- Calibrate the integrated flow sensors in the design to allow for a feedback loop to the microheater which can control pulse frequency depending on flow rate.
- Create a mixing metric to quantify mixing based upon several variables such as, flow rate, pulse time, and pulse frequency.

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