WASHINGTON STATE UNIVERSITY

# CHARACTERIZATION OF A THERMAL SWITCH WITH A DIELECTRIC LIQUID (GLYCERIN) MICRO DROPLET


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## INTRODUCTION

Variable Conductance MEMS for:

- Thermal Control of Pulsed Thermoelectric Coolers
- Thermal Cycling for Sample Concentration (MGA)
- Thermal Control of Chip Scale Atomic Clocks
- Thermal Cycling for DNA Amplification (PCR)
- The efficiency and speed of MEMS Thermal Actuator

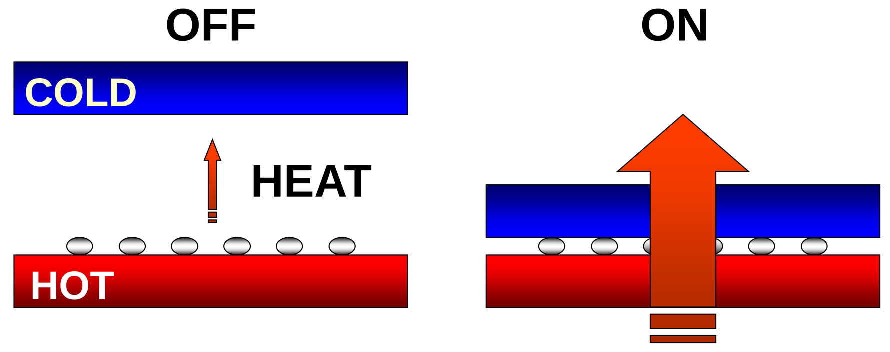
Fast MEMS Thermal Switches Control Heat Transfer over

- Millisecond Time Scales
- Micrometer Length Scales

Thermal Switch Operation:

"OFF" State–Switch Open–High Thermal Resistance, $R_{OFF}$

"ON" State–Switch Closed–Low Thermal Resistance, $R_{ON}$




## PURPOSE

•The experiment is set up to measure the thermal contact resistance of the dielectric liquid, glycerin.

## FABRICATION

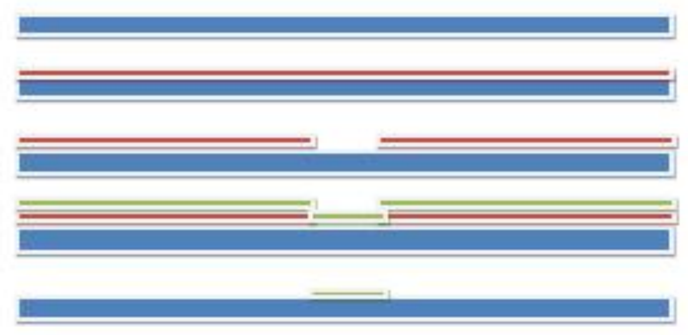
•Oxidized Silicon Wafer

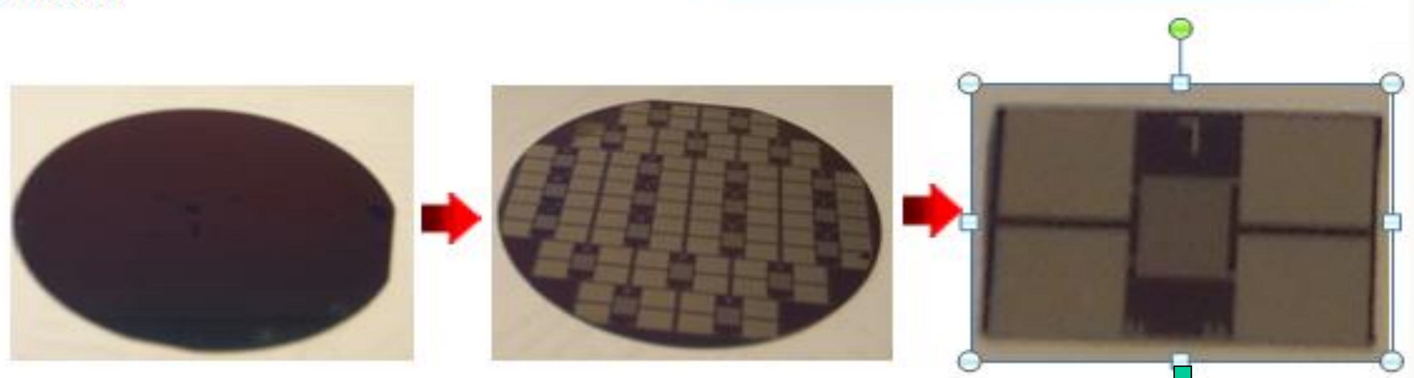
•Photo resist coated

•Photolithography

•Platinum sputtered on the wafer

•Lift off

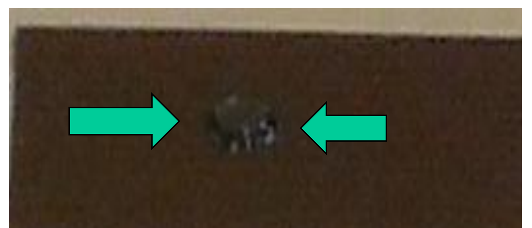




Resistance Temperature Detector (RTD)

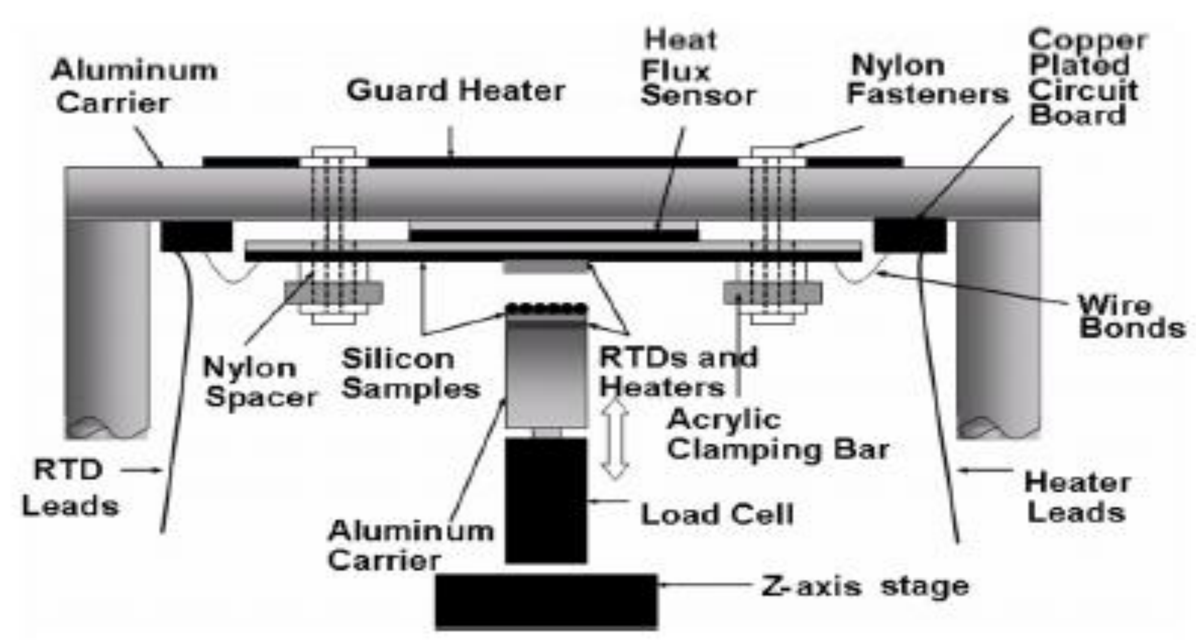
## THERMAL CONTACTS

• Dielectric-Liquid Micro droplet of Glycerin



1 micro liter of glycerin

## EXPERIMENT SET UP




## METHODOLOGY

1. Calibration of two Platinum Resistance Thermometer (PRT) samples by using an oven and oscilloscope
2. Installation of two PRT samples onto the experimental test stand
3. Calibration of laser sensor detector
4. Using the load cell and the step motor to zero out the position where two samples touch, and then recording the position
5. Applying 1 micro liter of glycerin to top of bottom sample
6. To bring the PRT samples closer by having the glycerin on the bottom sample touch the upper sample., the height at the time is around 450 micron
7. To bring down pressure of the test stand to 0.45 torr using a bell jar and vacuum
8. Applying voltages to test stand until it reaches a steady state
9. Testing of thermal resistance of a droplet at different heights
10. All data are to be collected with an oscilloscope in a vacuum at a steady state then recorded on an Excel spreadsheet

## ANALYSIS

•All data collected are analyzed with these equations

•Thermal resistance of a gas layer at ambient pressure can be found in:

$$R_g = \frac{L}{kA}$$

•Thermal resistance for an air layer at a pressure of 0.5 torr can be found in:

$$R_g = \frac{\Delta T}{Q}$$

•The heat transfer rate across the low pressure air gap can be found in:

$$Q = \frac{kA(\Delta T - 2\delta T)}{L}$$

•The temperature jump due to mean free path length effect can be found in:

$$\delta T = \frac{2-\alpha}{\alpha}\,\frac{2\gamma}{\gamma+1}\,\frac{\lambda}{Pr}\,\frac{T1 - T2 - 2\delta T}{L}$$

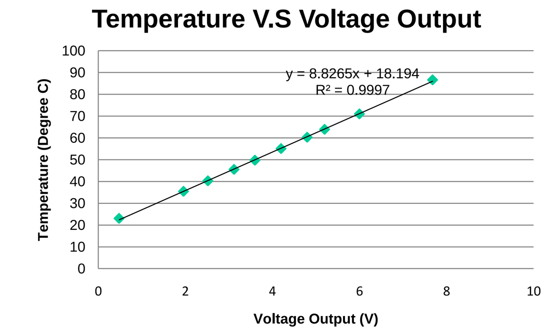
•Which the lamda is mean free path length, can be found in:

$$\lambda = 2.27 \times 10^{-5}\,\frac{T}{p}$$

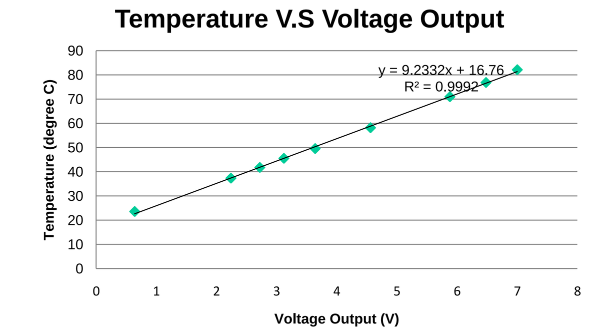
•The parallel heat leak resistance, Rp can be found in:

$$\frac{1}{R_p} = \frac{1}{R_m} - \frac{1}{R_g}$$

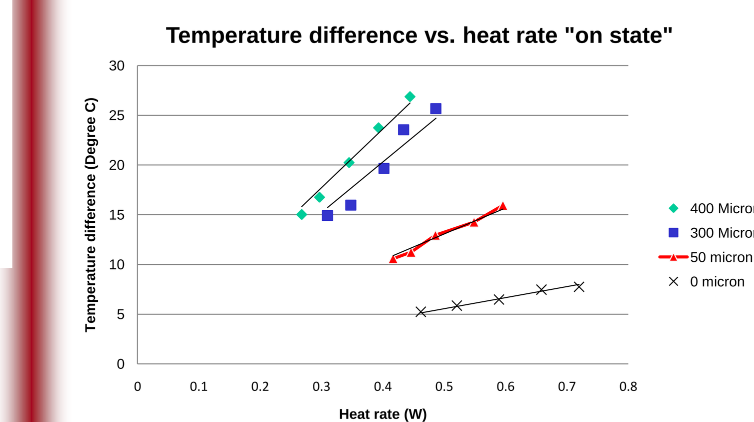
## RESULTS



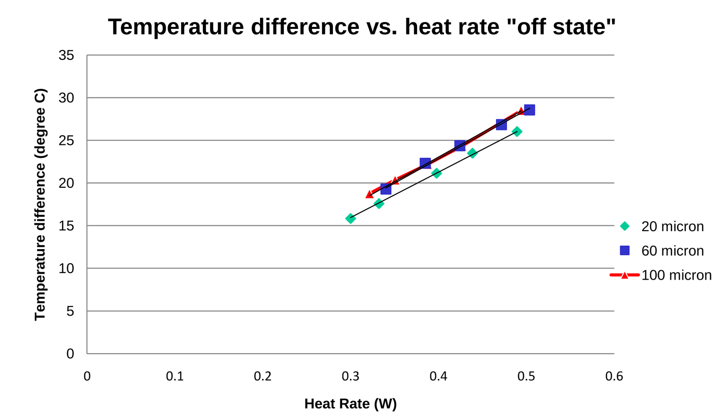

(Figure 1)



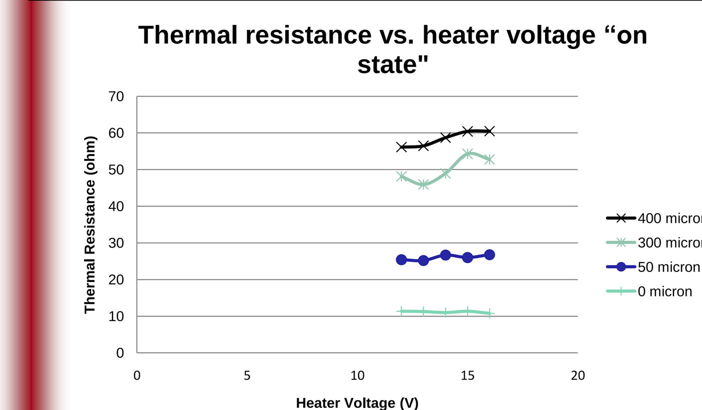

(Figure 2)



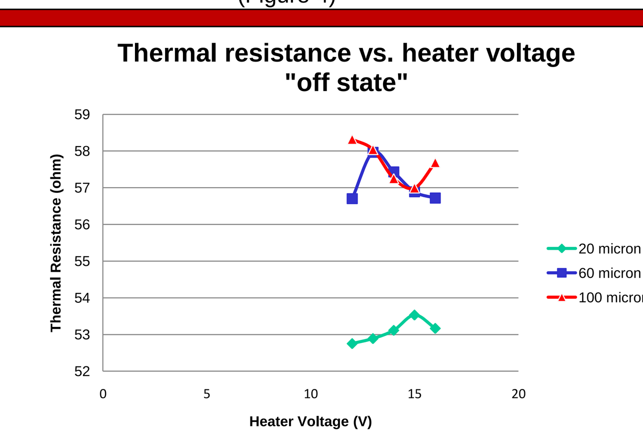

(Figure 3)




(Figure 4)




(Figure 5)




(Figure 6)

| On State 1 | |
|---|---|
| Droplet height (micron) | Corrected Resistance (ohm) |
| 400 | 259.7781415 |
| 300 | 148.5806745 |
| 50 | 39.71229865 |
| 0 | 13.08610897 |
| Mean Corrected Resistance | 115.2893059 |

| On State 2 | |
|---|---|
| Droplet height (micron) | Corrected Resistance (ohm) |
| 0 | 13.08610897 |
| Mean Corrected Resistance | 13.08610897 |

| Off State | |
|---|---|
| Gap length (Micron) | Corrected Resistance (ohm) |
| 20 | 179.3443587 |
| 60 | 235.9664174 |
| 100 | 245.0549056 |
| Mean Corrected Resistance | 220.1218939 |

| Performance | |
|---|---|
| Off State/On state 1 | 1.909300192 |
| Off State/On state 2 | 16.82103477 |

Table 1

## DISCUSSION

➢As shown above in figure 1 and 2, the two calibrations of PRT form linear lines. As the temperature goes up, the thermal resistance also increases. Hence the voltage output goes up with the same applied current.

➢Figure 3 shows that when the switch is "on" the droplet height decreases and the temperature difference between the two PRT samples decreases. Figure 4 is when the switch is "off" and it gives the same outcomes as when the switch is "on".

➢Figure 5 shows that when the switch is "on" the droplet height decreases along with the thermal resistance. Figure 6 shows the switch "off" and it works exactly as when the switch is "on".

➢Table 1 shows that when the switch is turned "on" and in a state where the two PRT samples are in complete contact, the performance is much greater.

## CONCLUSION

Thermal Switch with dielectric liquid of glycerin has a 6 times greater performance than just polished silicon, 2 times greater than aligned carbon nanotube bundles, and 10 times less effective performance than silicon with Hg micro droplets. All results are from previous research.

## ACKNOWLEDGMENTS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