**Micro White Paper**
Group 5

## Introduction

It is a huge challenge to manage the heat generated by the miniaturized electronic devices. In the USA alone, data centres consume the same amount of energy to satisfy their cooling demands as does the city of Philadelphia for its residential needs.[1]
The hydronic surface with different geometry and microfluidic water-circuits could help to solve this problem. Previous works have shown that the bifurcated design can improve the fluid flow distribution and thermal distribution compared to conventional channel designs.[2,3,4]
Here we design a structure with the features of branching and topologies. This design may produce more surface convection because of its geometry then show better performance of cooling the electronic devices.
This design can also be applied to medical areas, such as using it as a model to study the drug diffusion. The flexibility in geometry enables the generation of different concentration gradients. This will also add geometric resistance. We can use the channel to simulate the blood vessels and see how the shape of blood vessels affect the delivery of drugs to tumors or tissues and leads to limited treatment.[5]

## Concept

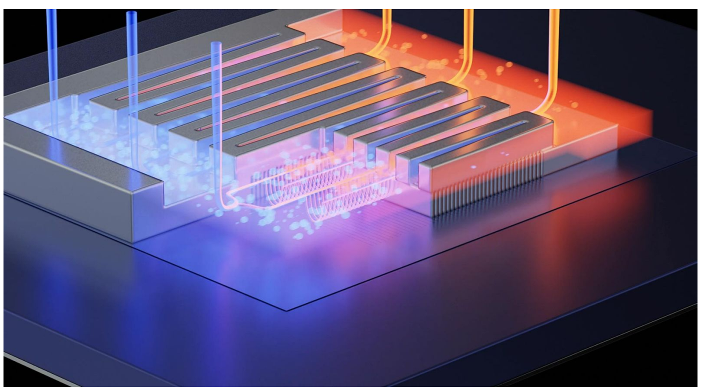


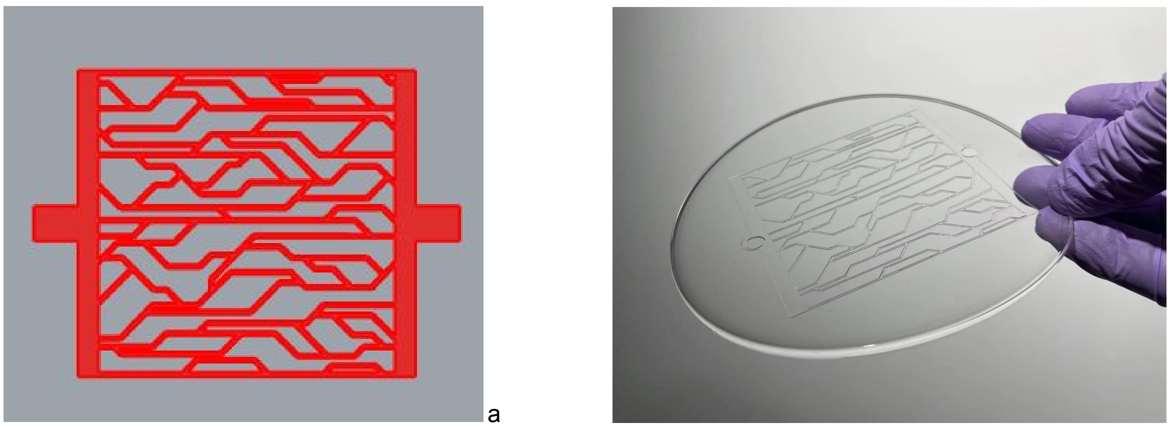
Figure1. Precedent

The use of microfluidic technology has been successfully applied in cooling the miniaturized electronic devices. The cooling rates of early research can reach around 790 W/cm2 or even higher.[6,7] However, the microfluidic cooling system was separated from the electronic chips.
Our inspiration comes from a research published in *Nature* (fig.1), which will lead to even more compact electronic devices and enable the integration of power converters, with several high-voltage devices, into a single chip by developing an integrated microfluidic cooling technology together with the electronics, that can efficiently manage the large heat fluxes generated by transistors.[8]
Here, we try to use an integral cooling system for microchips [4]. By changing the pattern of the microfluidic chip, to increase the surface convection with electronic chips. We hope the properties of branching and topologies can enable us to future increase the cooling rate.

## Prototype design

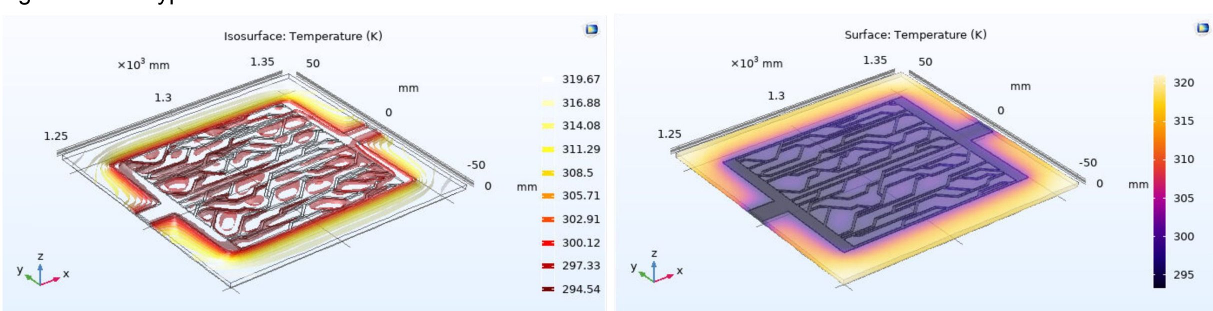
By using the bifurcated structure's character of improving the fluid flow distribution and thermal distribution, we designed the prototype with a branching pattern. The geometry produces more surface convection, which enables it to have a better performance of cooling the electronic devices. We also consider using it as a model to study the drug diffusion. The flexibility in geometry will enable the generation of different concentration gradients.

Critically, the prototype shown in fig.2, with a chaotic system, may perform better in achieving the function of uniform thermal distribution (fig.3). Yet when the prototype is applied to the other possible application - drug or oxygen delivery and diffusion, a more hierarchical structure is required, which can be designed with fewer and more regularly arranged connecting points.



a b

Figure2. Prototype




c

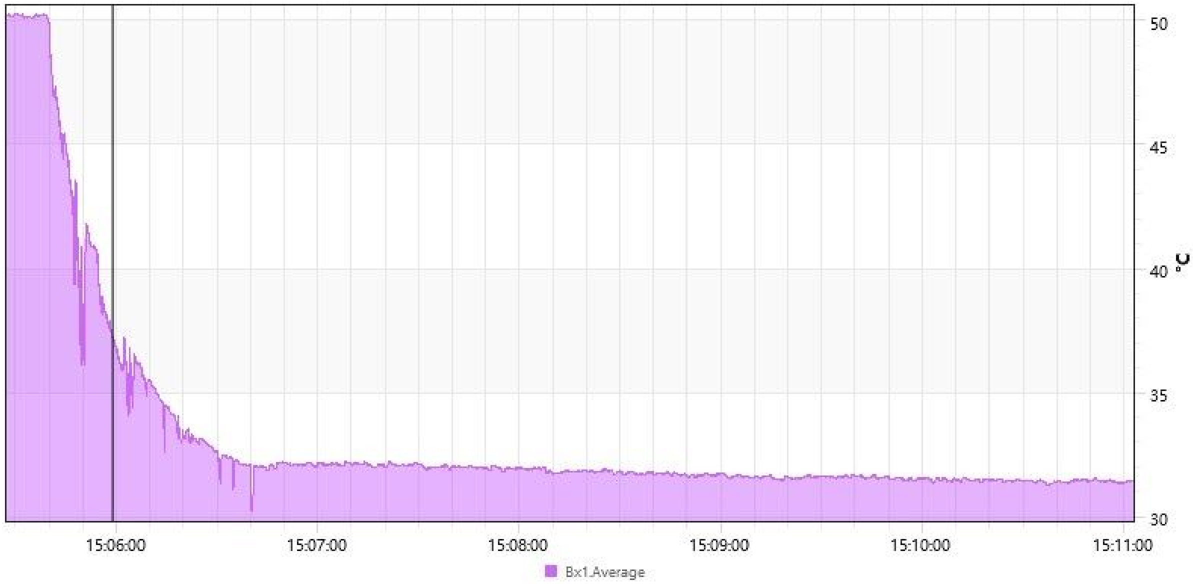
Figure3. Prototype cooling simulation

## Results

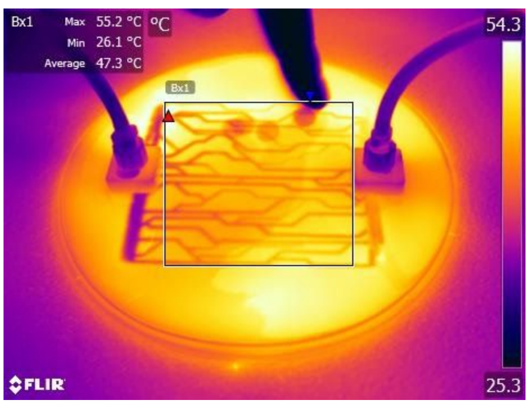
The results of FEM simulation (fig.5) on the thermal distribution show a strong similarity in trend to the one of the live lab section testing (fig.4).

From fig.4, we can see the temperature has the most dramatic change in the first 15 seconds, then gradually decreases, finally stabilizes after 60 seconds. The FEM simulation has the similar trend curve (fig.5.a), yet the time required for it to reach the same heat distribution is longer compared with the physical model. From fig.5, we can see to reach the same heat distribution, the FEM simulation takes nearly twice as long as the lab testing. For this difference, we speculate the actual flow rate of each channel might be an influence factor. In general, the current structure, as a chaotic system with the maximum and minimum temperature difference of about 20 degrees, will be a good choice of achieving uniform thermal distribution.

Live Lab Section Testing

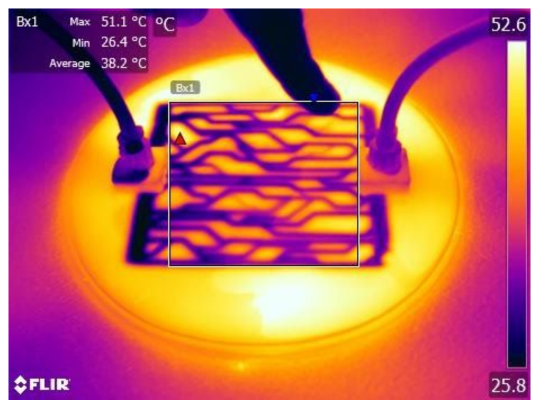



a



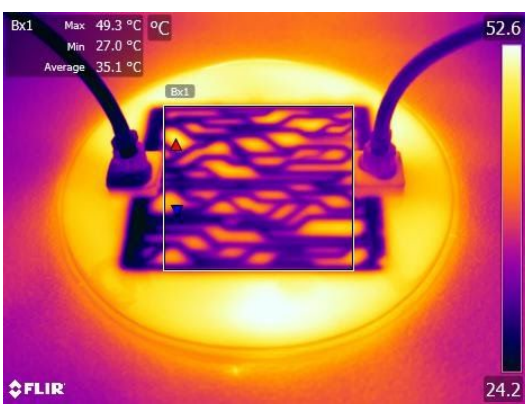

b

t = 15s



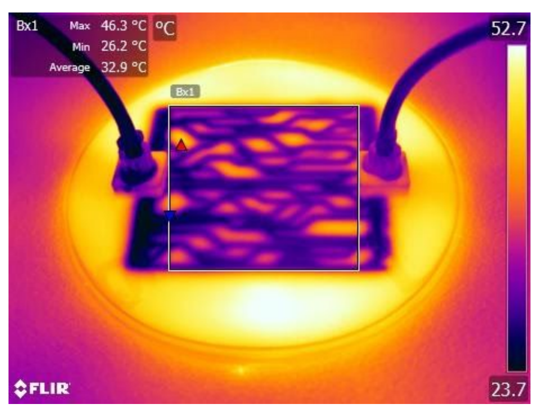

c

t = 30s




d

t = 45s

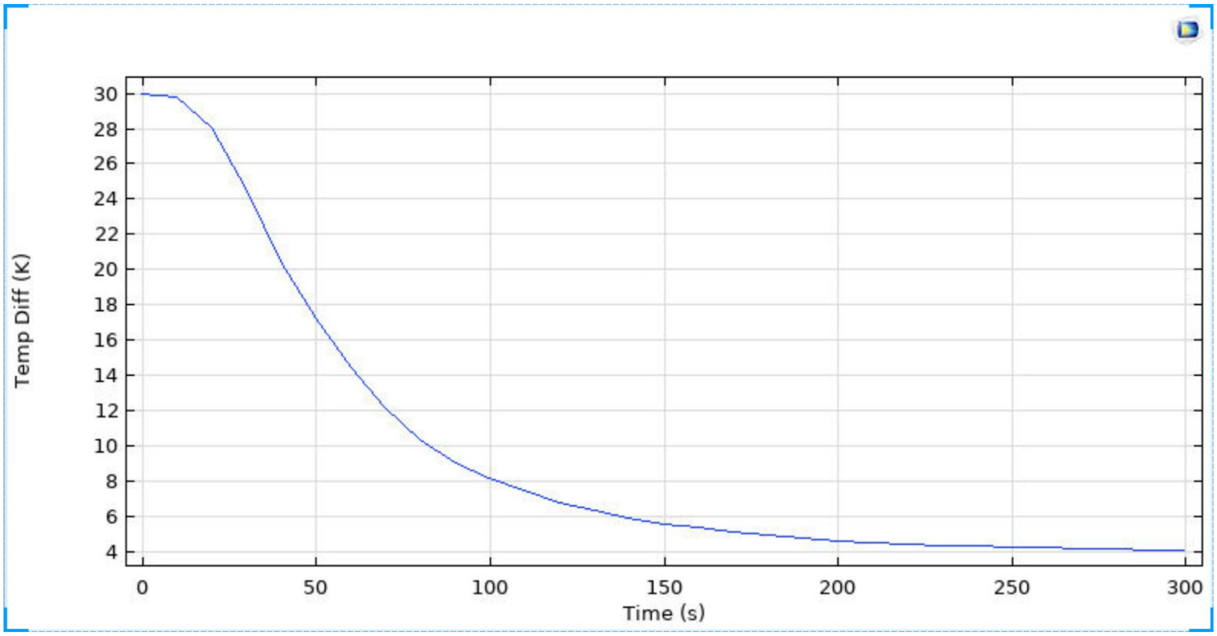



e

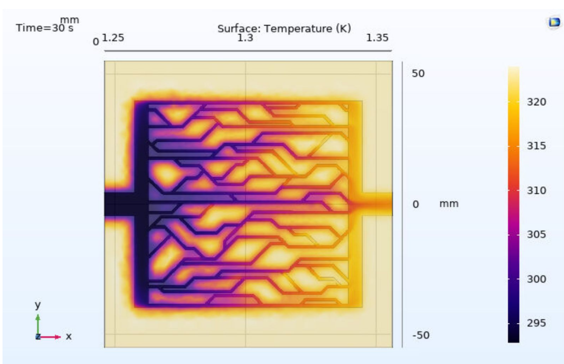
t = 60s

Figure4

FEM Simulation

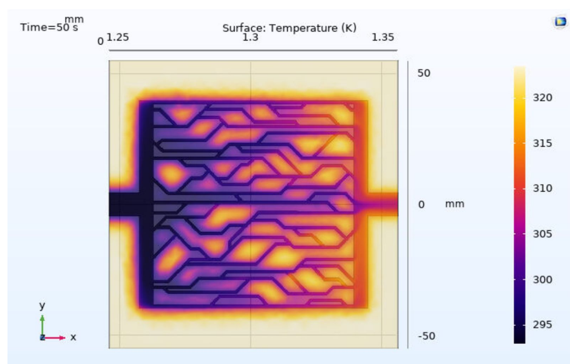


a



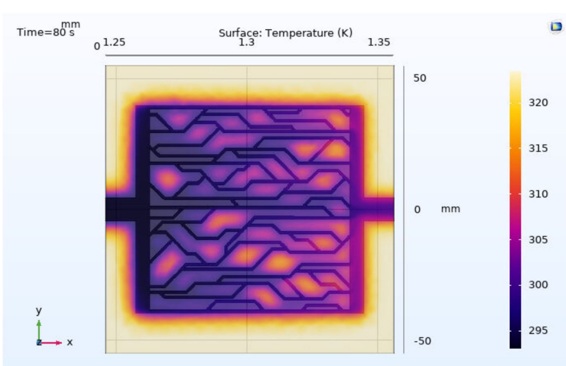
b

t = 30s



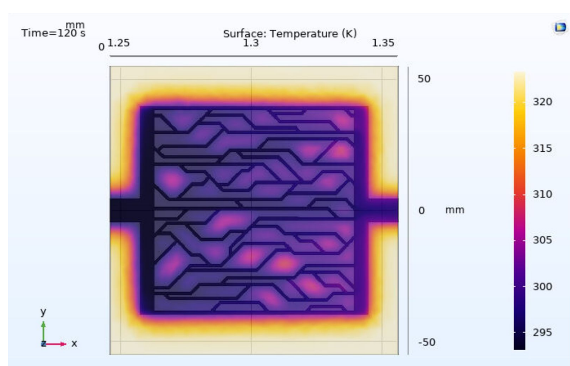
c

t = 50s



d

t = 80s



e

t = 120s

Figure5

**Reference**

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3. Ramos-Alvarado B, Li P, Liu H, Hernandez-Guerrero A. *Cfd study of liquid-cooled heat sinks with microchannel flow field configurations for electronics, fuel cells, and concentrated solar cells*. Appl Therm Eng 2011;31:2494–507.

4.Remco van Erp,Elison Matioli al et. *Co-designing electronics with microfluidics for more sustainable cooling*. Nature, Vol 585, 10 September 2020

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8. Van Erp, Remco, Soleimanzadeh, Reza, Nela, Luca, Kampitsis, Georgios, & Matioli, Elison. (2020). Co-designing electronics with microfluidics for more sustainable cooling. Nature (London), 585(7824), 211-216.