Microfluidic cell cooling system for electronics

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Smart Technologies for eneRgy Efficient Active cooling in Advanced Microelectronic Systems

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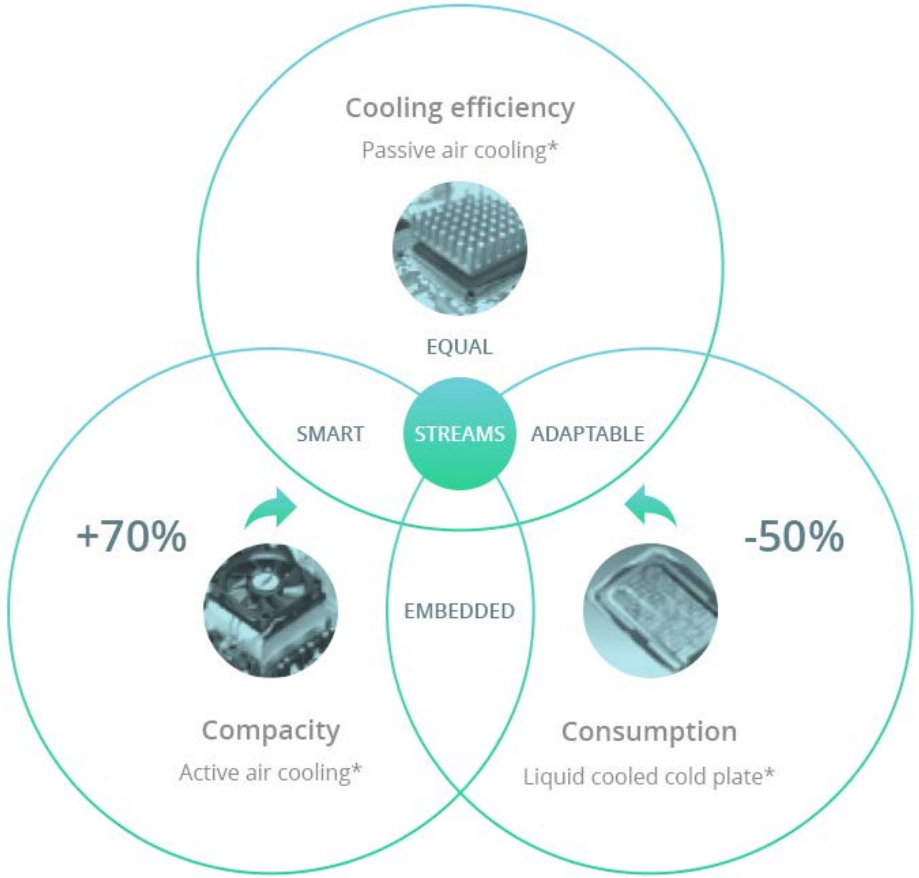
STREAMS Project

Smart Technologies for energy Efficient Active cooling in Advanced Microelectronic Systems



* Low points of state-of-the-art thermal management solutions

Consortium:

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Thermal viability on advanced ICs

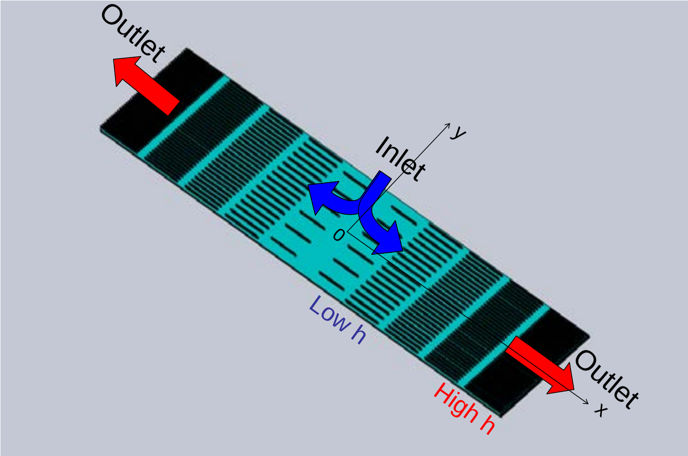
Liquid cooling based on microchannels

- Low thermal resistance coefficients.
- Large pressure drop (high pumping powers).
- Poor temperature uniformity.

Enhanced microchannel

Hybrid jet impingement / microchannel

- High temperature uniformity
- Less pressure drop
- Not a “universal solution”

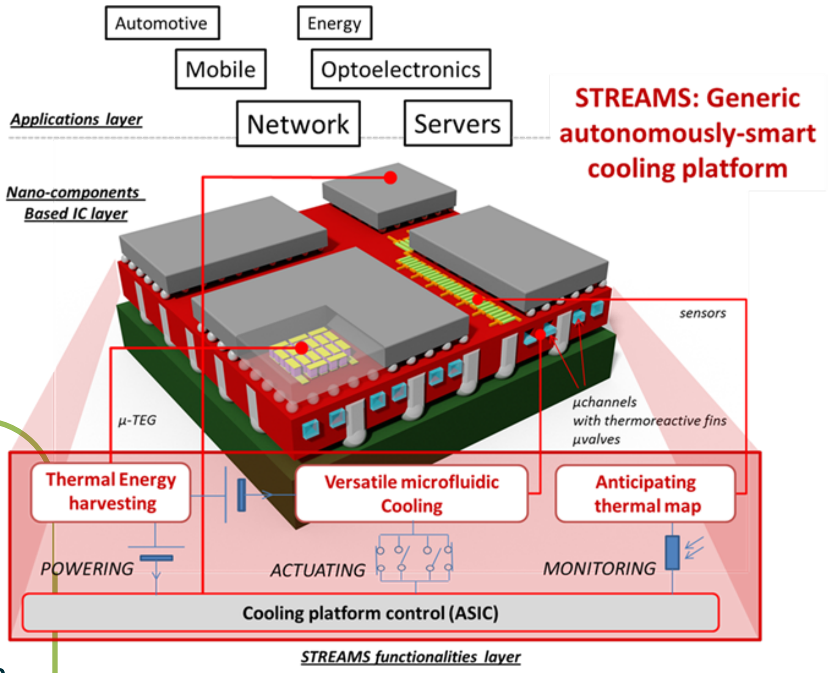


[1] Flow rate: $1{,}6\cdot10^{-5}$ m^3/s, heat flux: $50 W/cm^2$, standard deviation σ_T: ≈0,8 ºC.

[1] S. Riera, J. Barrau, M. Omri, L.G. Fréchette, J. Rosell, “Stepwise varying width microchannel cooling device for uniform wall temperature: experimental and numerical study”, Applied Thermal Engineering, Volume 78, Pages 30-38, 2015.

Proposal approach

Cooling device formed by a **matrix of microfluidic cells** with individual variable coolant flow rate.



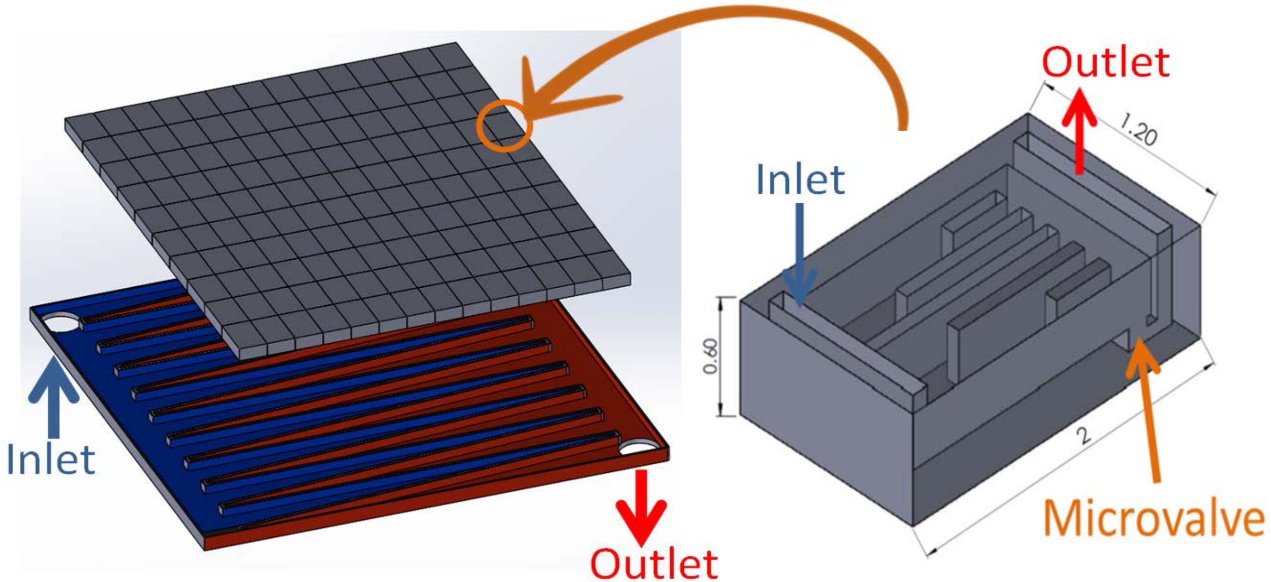
Main objective of the project:

Avoid overcooling

(By tailoring the distribution of the local heat extraction capacity to time dependent and non-uniform heat flux distributions)

Description of the thermal device

Matrix of microfluidic cells with distributor

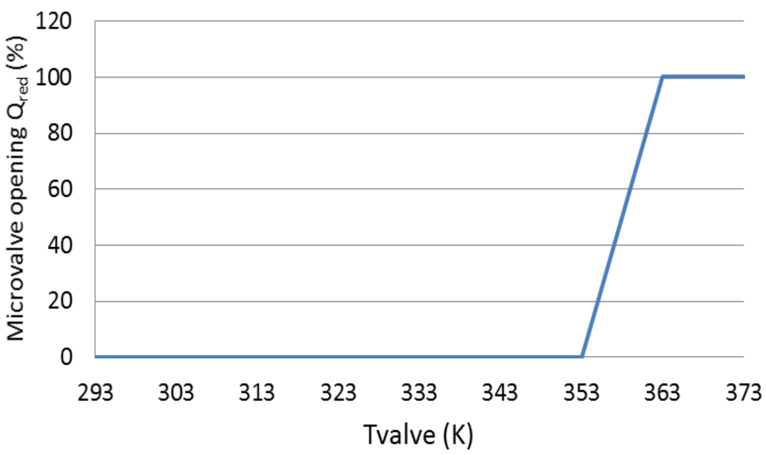


- Reduce the length of the coolant flow path (reduce ΔP).
- Locally control the flow rate in each cell through self-regulated microvalves.
- Microfluidic cell designed for optimum heat transfer while achieving good temperature uniformity.

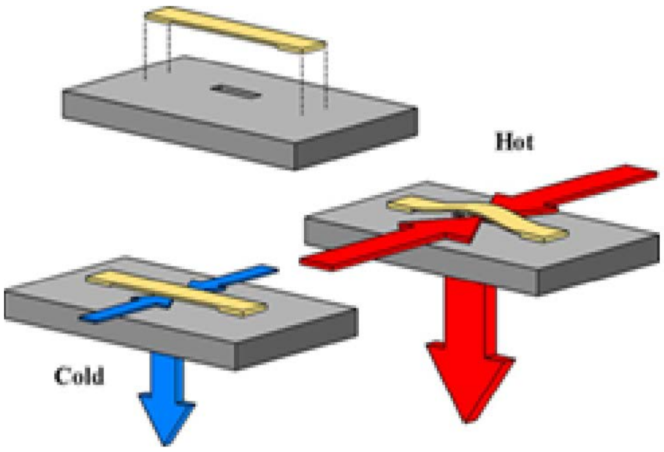
Thermal microvalves

Self adaptive microvalve: their aperture depends on their own temperature. [2]

Opening function of the microvalve

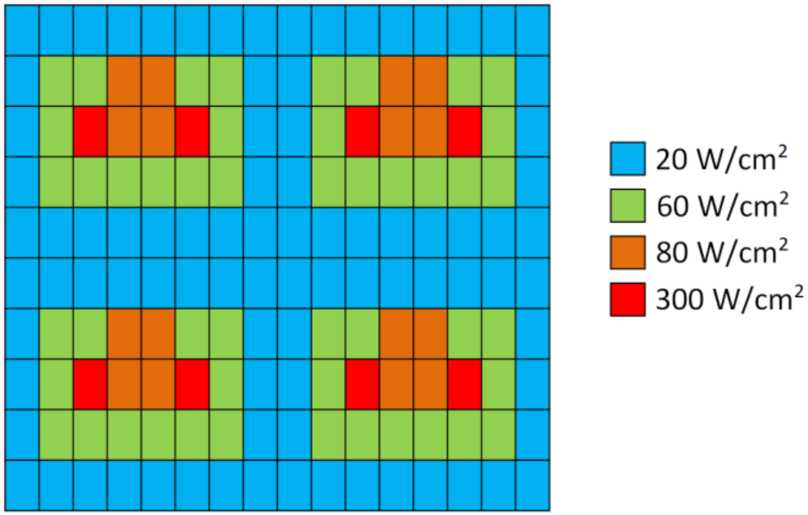


Placement of the hot and cold positions



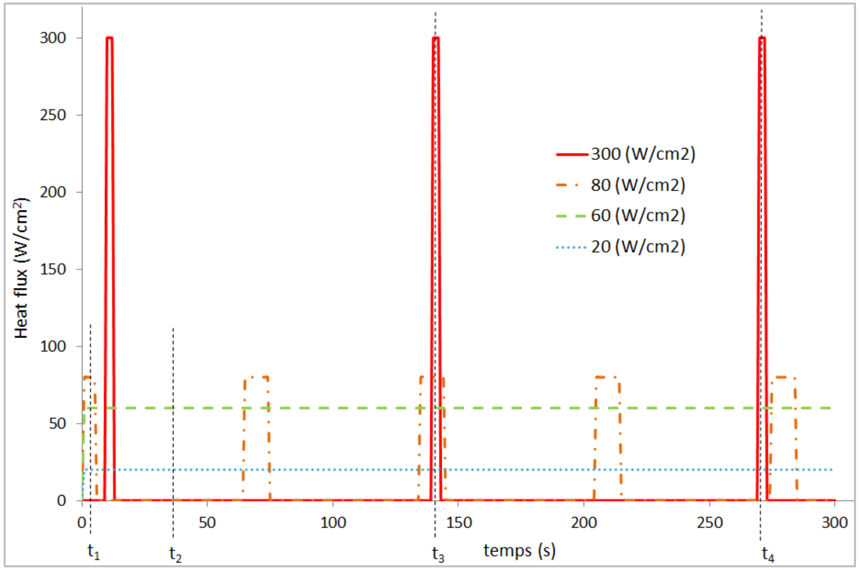
[2] M. McCarthy, N. Tiliakos, V. Modi, L.G. Fréchette, "Temperature-regulated nonlinear microvalves for self-adaptive MEMS cooling". Journal of Microelectromechanical Systems, Volume 17, Pages 998–1009, 2008.

Heat load scenario

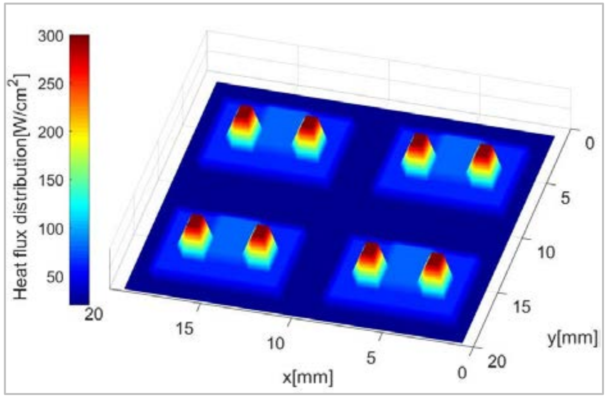


Matrix of 16x10 microfluidic cells.

Time dependence of the heat loads



- Inlet temperature: 50ºC (worst condition)
- Maximum temperature on the chip surface < 100ºC (design condition)

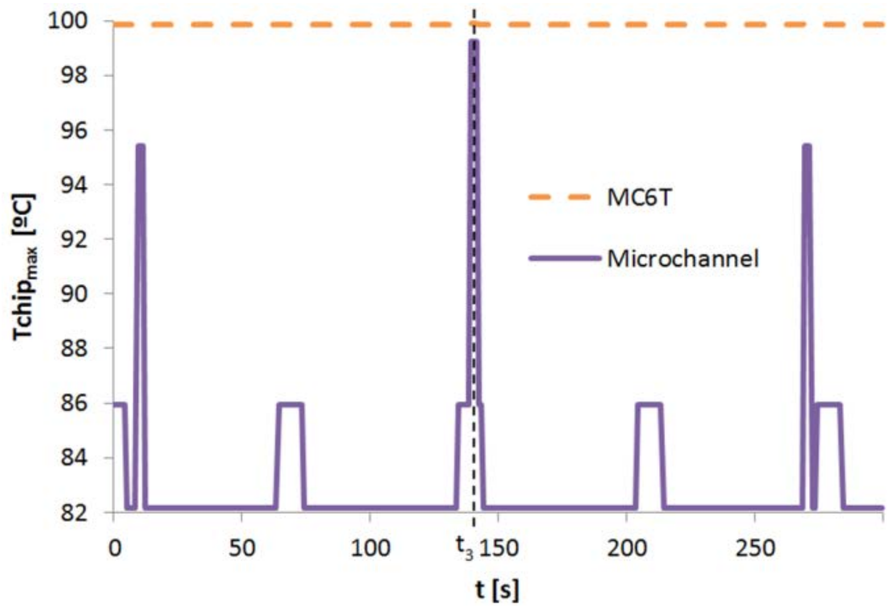


Heat flux distribution for t_3

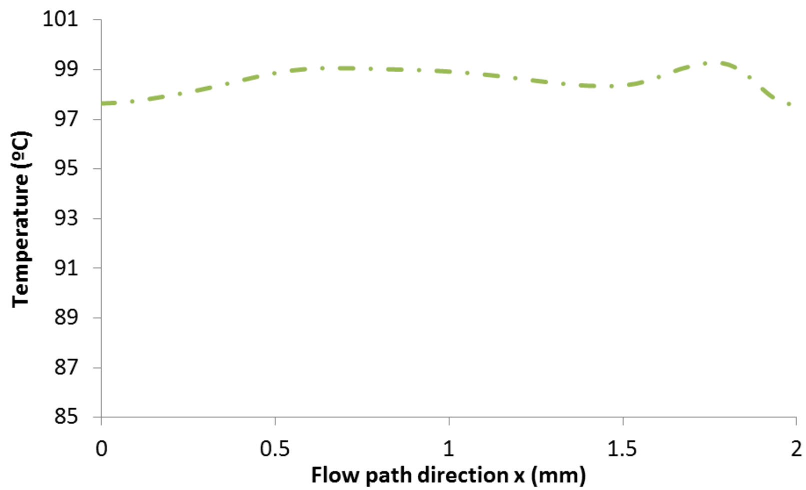
Temperature uniformity over time

Objective of this study

Thermo-hydraulic performance of the microfluidic cells matrix under non-uniform and time dependent heat load scenario.



Chip maximum temperature over time

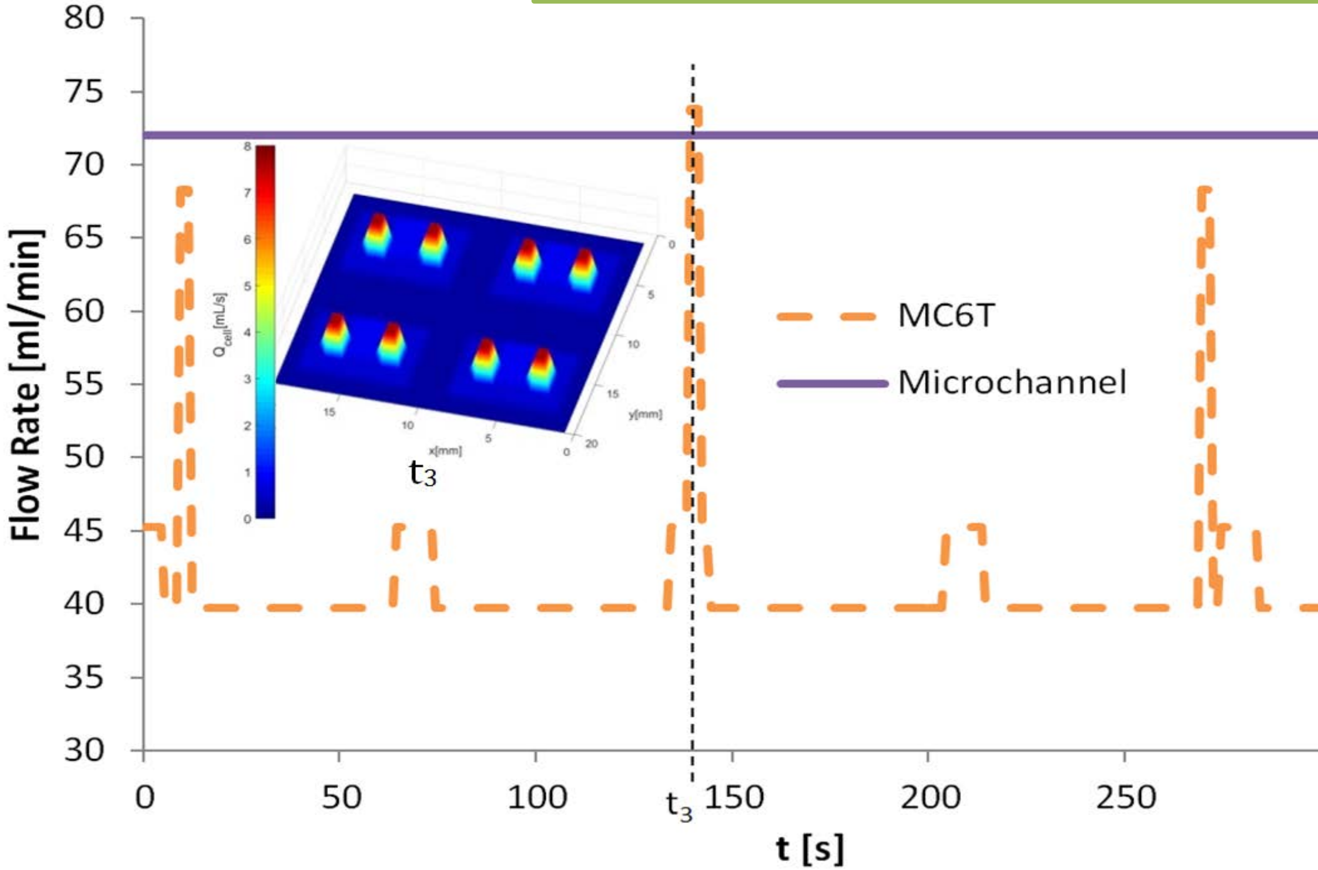


Temperature distribution on the microfluidic cell at chip surface (when submitted to 300 W/cm²).

Flow rate over time

In conventional microchannels

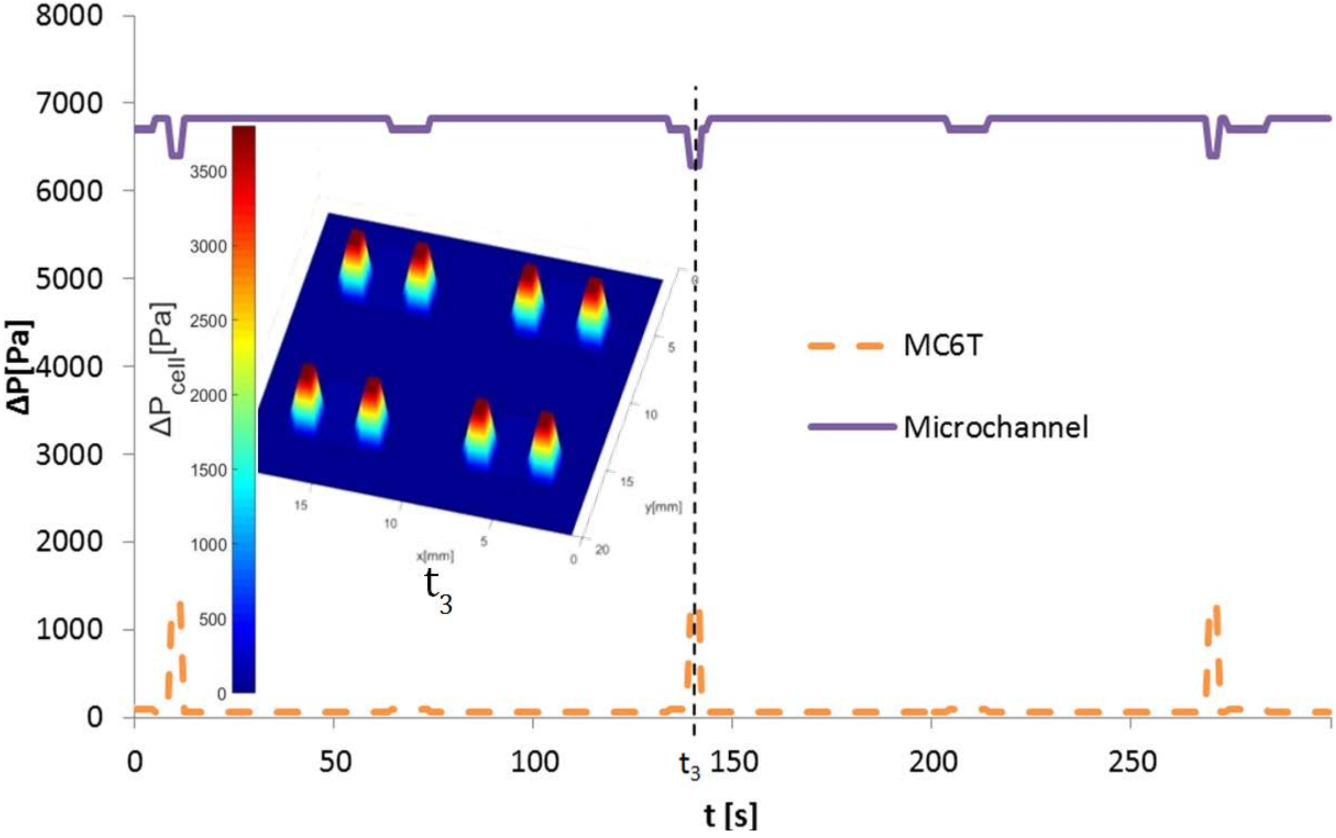
- High and constant flow rate (not tailored).



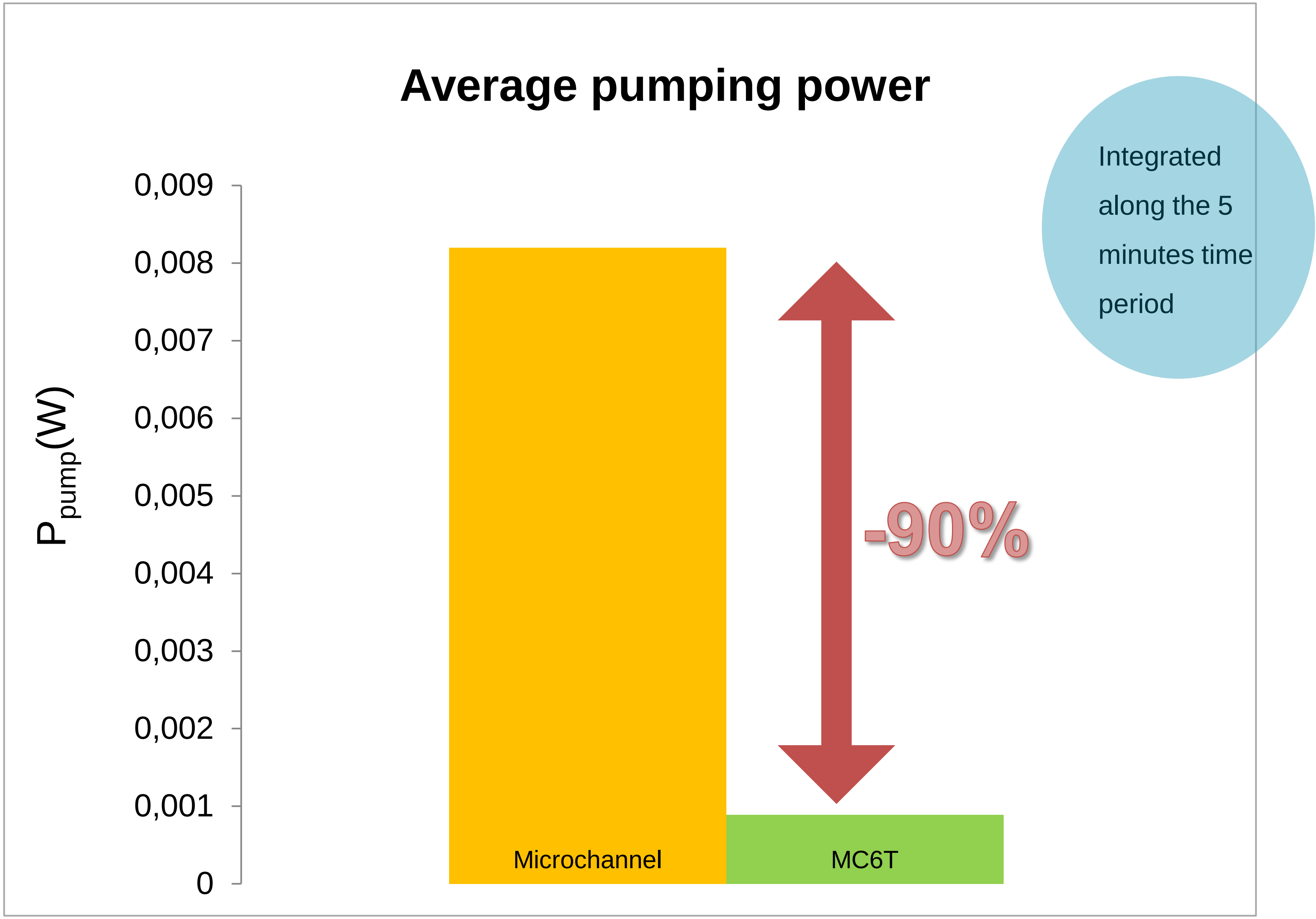
Pressure drop over time

In **conventional microchannels**

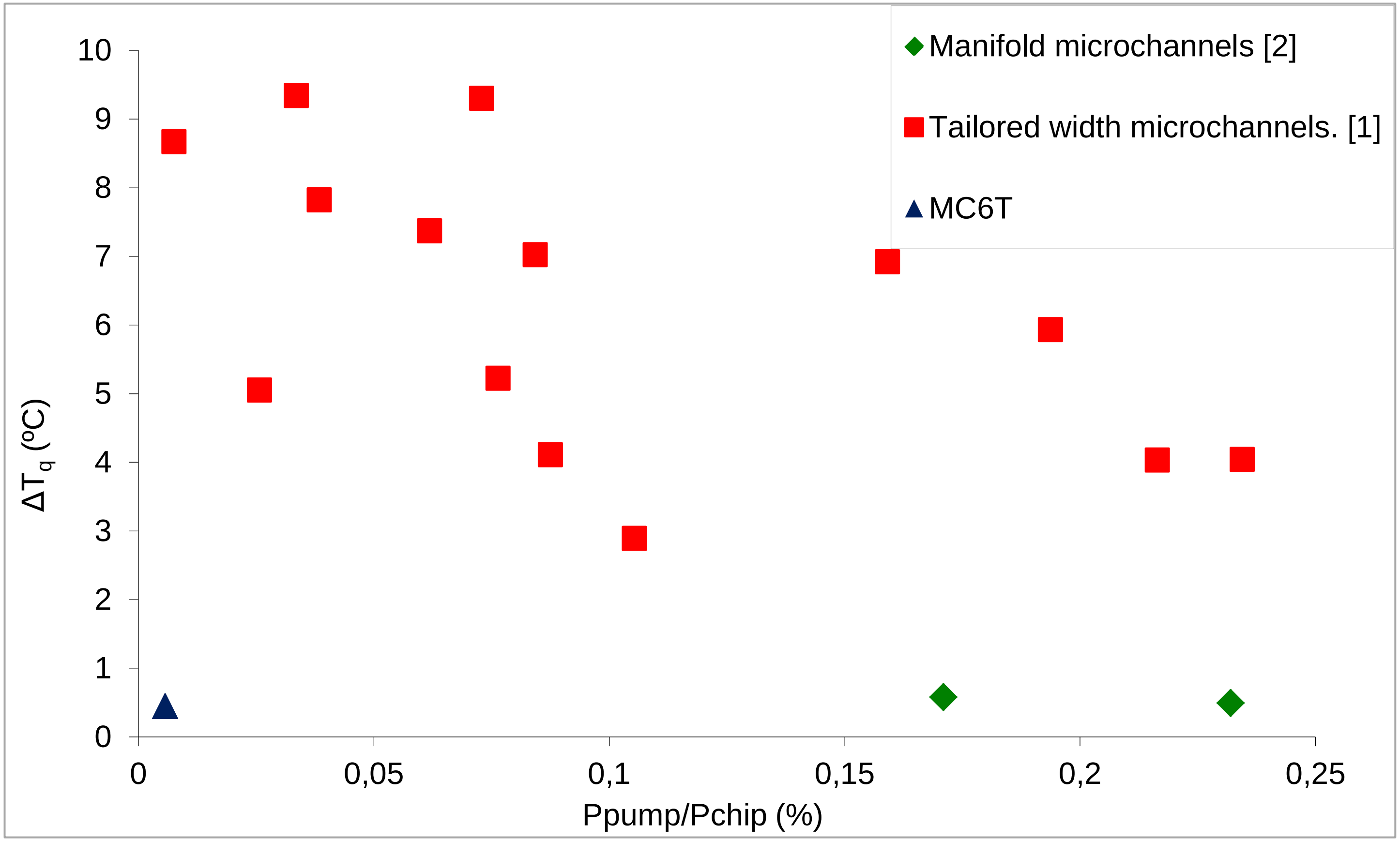
- High pressure drops (larger lengths).



Efficiency improvement



Overall pumping performance



$$\Delta T_q = \frac{\Delta T_{chip,max}}{\left(\frac{q''_{hs}}{q''_{bg}}\right)}$$

[2]

[2] C. S. Sharma, M. K. Tiwari, S. Zimmermann, T. Brunschwiler, G. Schlottig, B. Michel, and D. Poulikakos, "Energy efficient hotspot-targeted embedded liquid cooling of electronics," Appl. Energy, vol. 138, pp. 414–422, 2015.

[1] S. Riera, J. Barrau, M. Omri, L.G. Fréchette, J. Rosell, "Stepwise varying width microchannel cooling device for uniform wall temperature: experimental and numerical study", Applied Thermal Engineering, Volume 78, Pages 30-38, 2015.

Conclusions

Compared with conventional microchannel technology, the microfluidic cells matrix achieves:

- **89,2% of pumping power saved for a given heat load scenario.**
- Reduced **pressure drops** and **total coolant flow rates**.
- **Good temperature uniformity** even for **non-uniform and time dependent heat load scenarios**.

Acknowledgments

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Thanks for your attention

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