H2020 European project STREAMS: general overview

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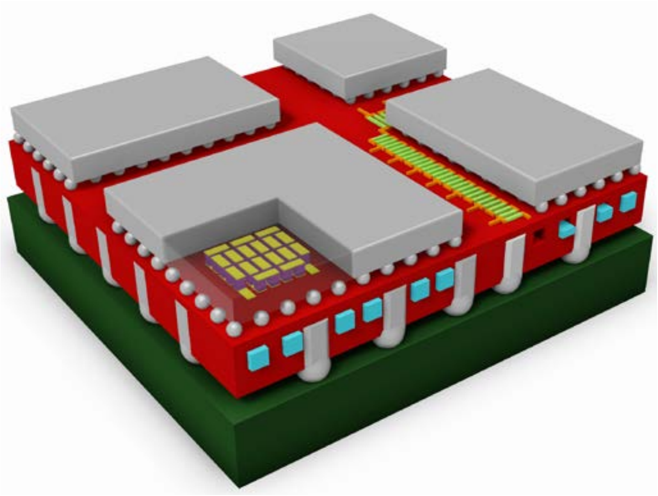
STREAMS
Smart Technologies for eneRgy Efficient Active cooling in Advanced Microelectronic Systems

THERMINIC 2018, Stockholm, Sweden
2018-09-26

Outline



General introduction

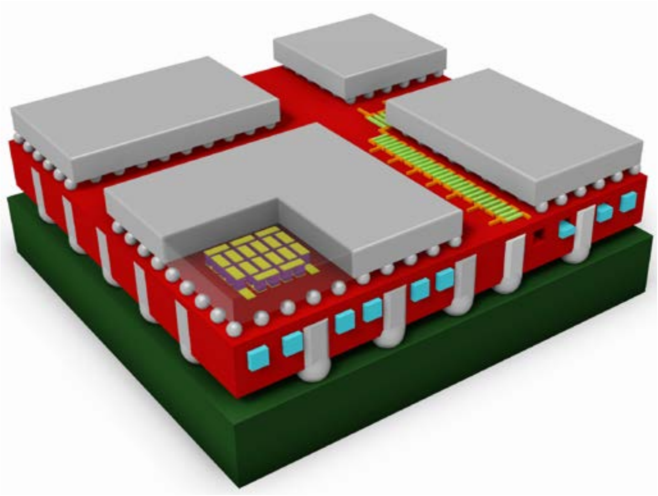
- Versatile microfluidic actuation
- Thermal mapping
- Thermal energy harvesting

Integration

Front-side / Back-side

Harvesting versus Cooling

Outline



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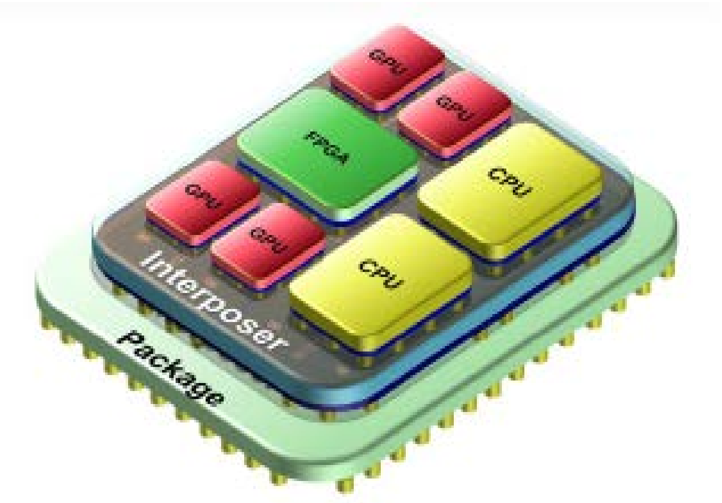
STREAMS context

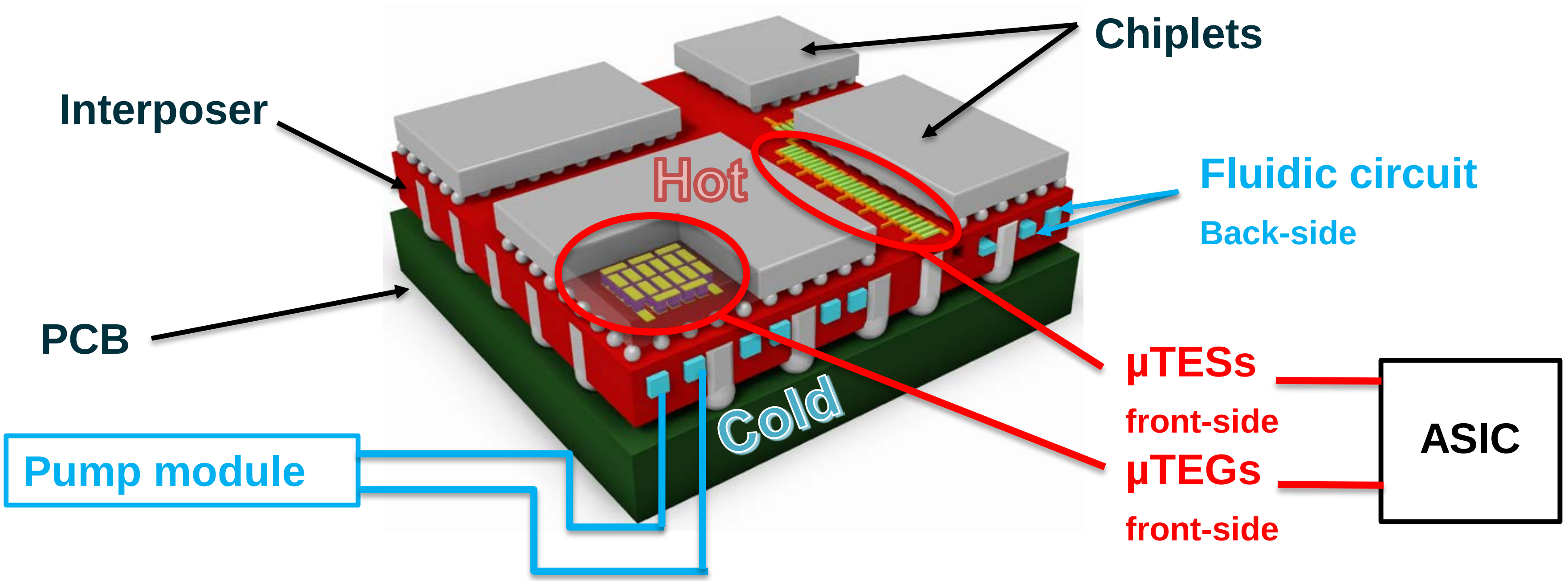
- Many-core architectures for HPC / server
  - 3D Technology
  - Thermal management



➢ H2020 European project STREAMS: active cooling for silicon interposers

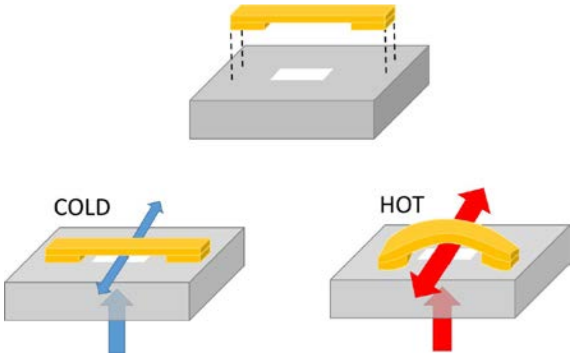
STREAMS objectives

- 3 functionalities:
  - Versatile microfluidic actuation
  - Precise thermal mapping (micro-thermo-electric sensors = µTES)
  - Thermal energy harvesting (micro-thermo-electric generators = µTEG)



STREAMS functionality 1

Versatile microfluidic actuation

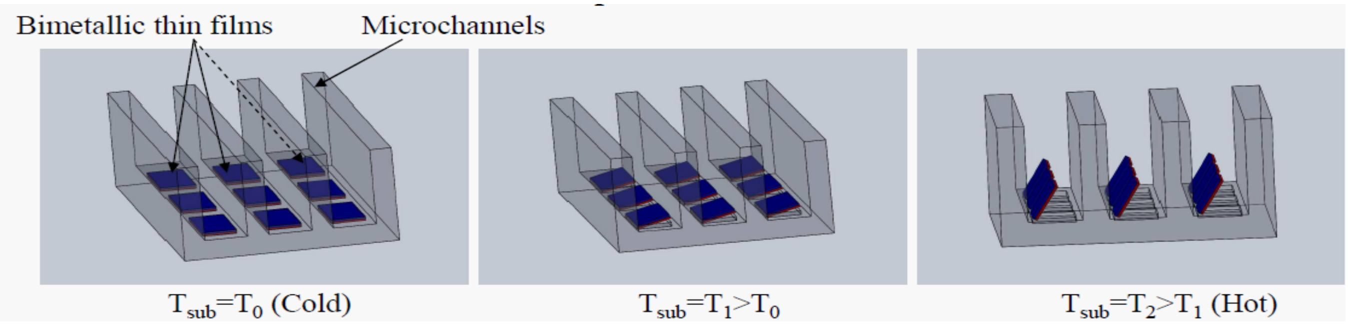


- Self adaptive micro-valve

"Thermoregulated Microvalve for Self-Adaptive Microfluidic Cooling" STREAMS session 2

- Adaptive fins

"Thermostatic Fins for Spatially and Temporally Adaptive Microfluidic Cooling" STREAMS session 2



➢ Use pumping power only when needed!

"Variable Pumping Control for Low Power Microfluidic Chip Cooling" STREAMS session 2

STREAMS functionality 2

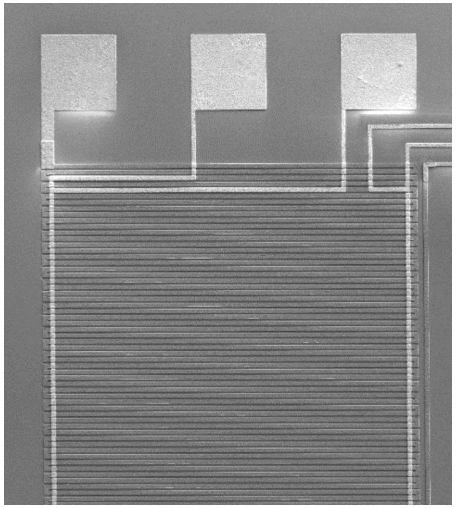
Thermal mapping

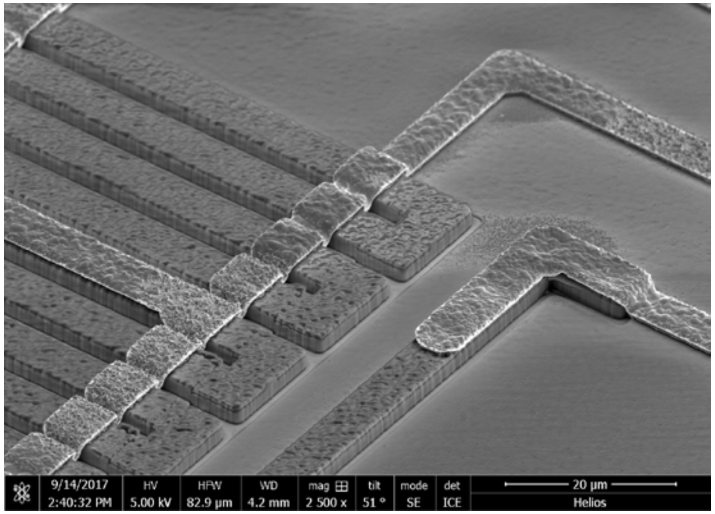
- Micro-thermo-electric sensors = µTES

"Integrated Thermoelectric Sensors for Thermal Monitoring of Integrated Circuits" STREAMS session 1

➢ Heat flux sensors based on Seebeck thermoelectric effect

p-n junctions of thermoelectric material, V α ΔT





STREAMS functionality 3

Thermal energy harvesting

- Micro-thermo-electric generators = µTEG

"Embedded Thermal Energy Harvesting – Challenges & Opportunities" STREAMS session 1

➢ Seebeck thermoelectric effect

The harvested power is given by:

$$P_h = V_{oc}^2 / 4.R_{int}$$

Rint: µTEG internal resistance

V_{oc} : output voltage

$$V_{oc} = N \times S \times \Delta T$$

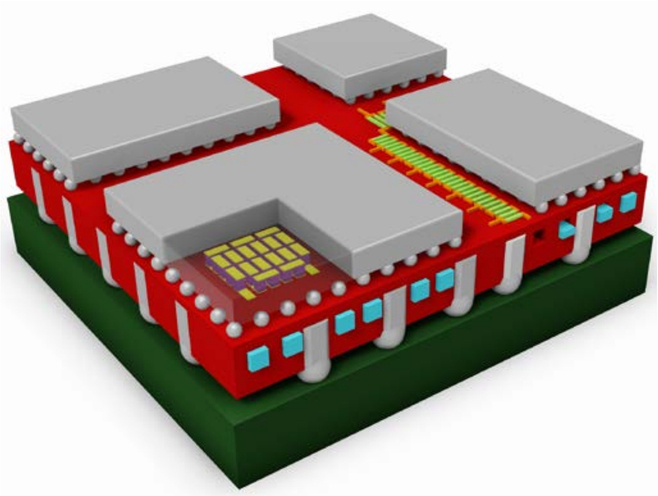
N : number of pn-junctions

S : Seebeck coefficient of a junction

ΔT: temperature difference between two junctions

➢ Maximize ΔT

Outline



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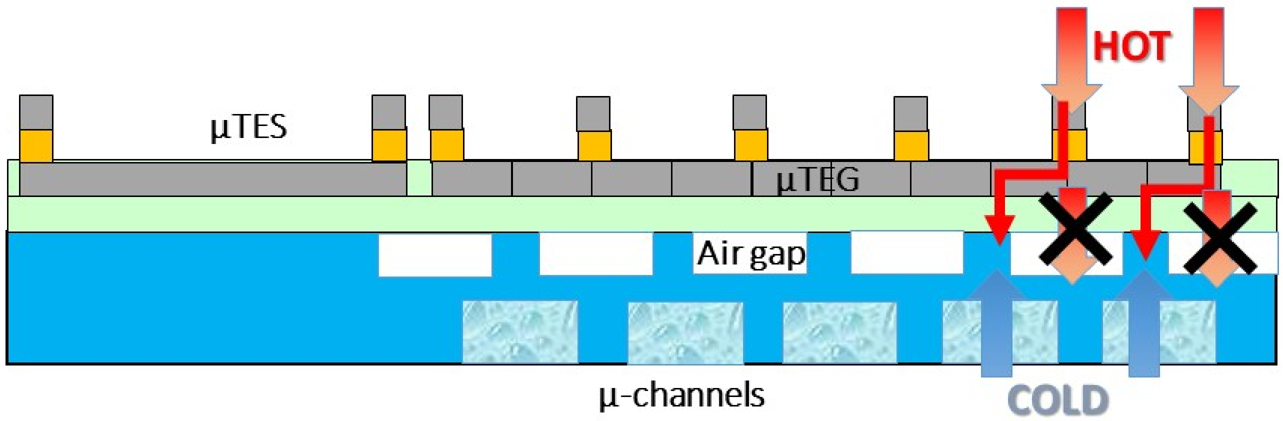
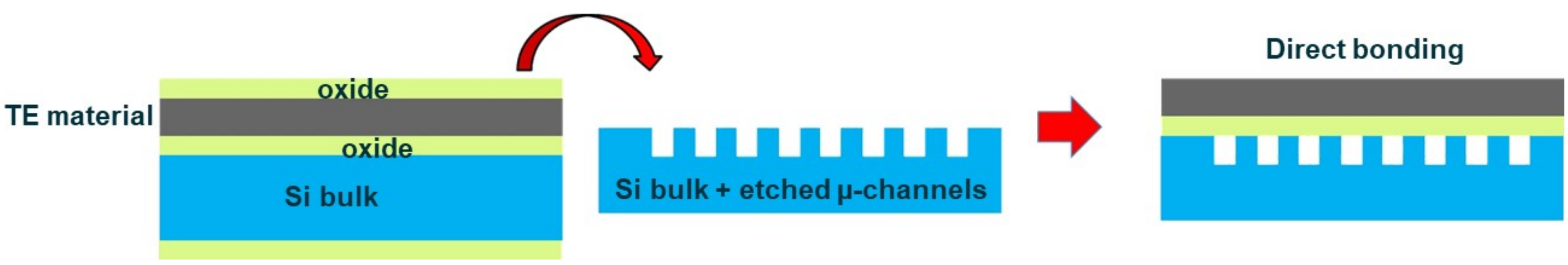
STREAMS integration

Air gap:

- Maximize ΔT accross µTEG



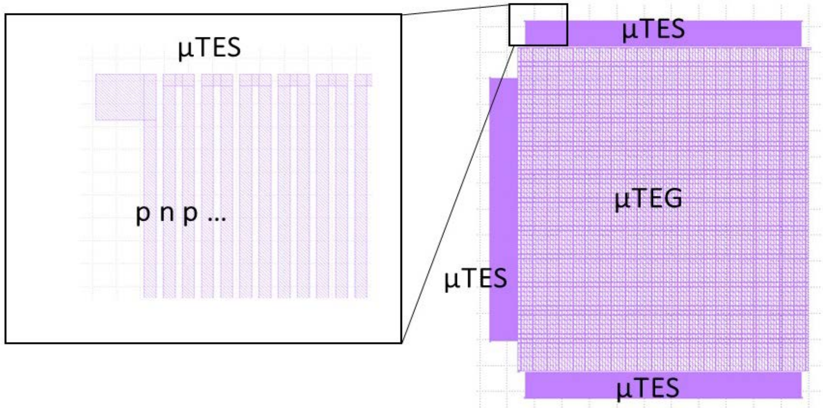
- Process flow:



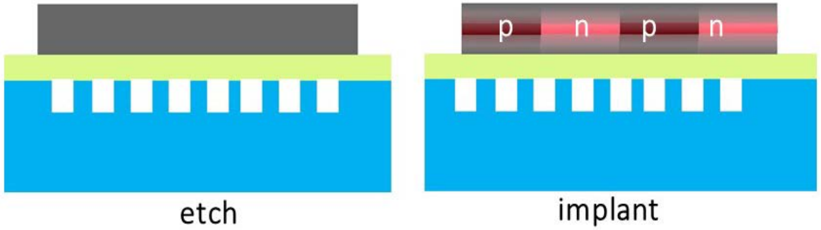
STREAMS integration

Front side integration of thermoelectrics:

- Thermoelectric material = poly-SiGe or Quantum Dots Super Lattices (Poly-SiGe + $TiSi_x$ dots)
- Layout:



- Process flow:



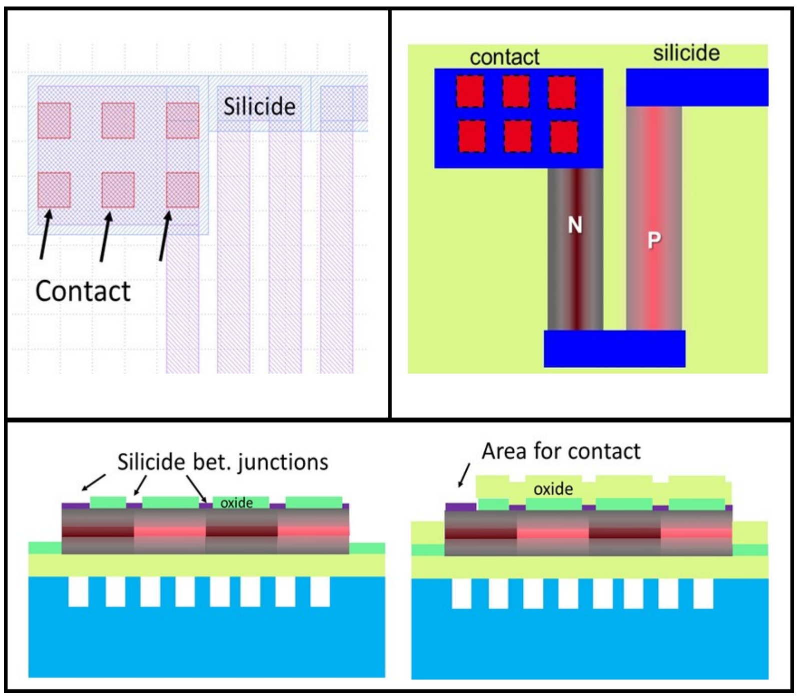
STREAMS integration

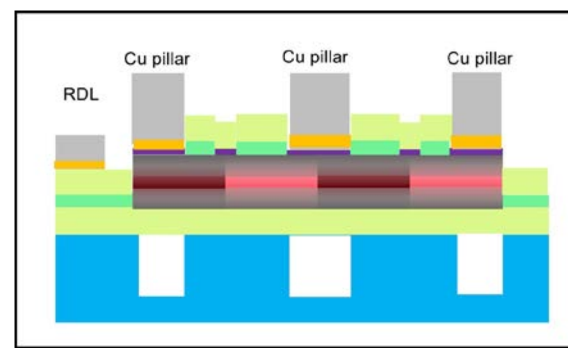
Front side integration:

- Electrical interconnects: Silicide, contacts, metal levels

- Layout:

- Process flow:

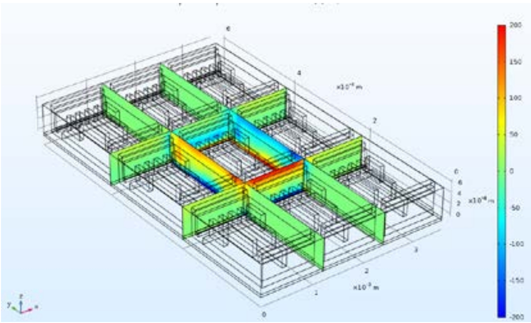




STREAMS integration

Back side integration of micro-fluidics:

- Array of cells



Single cell:

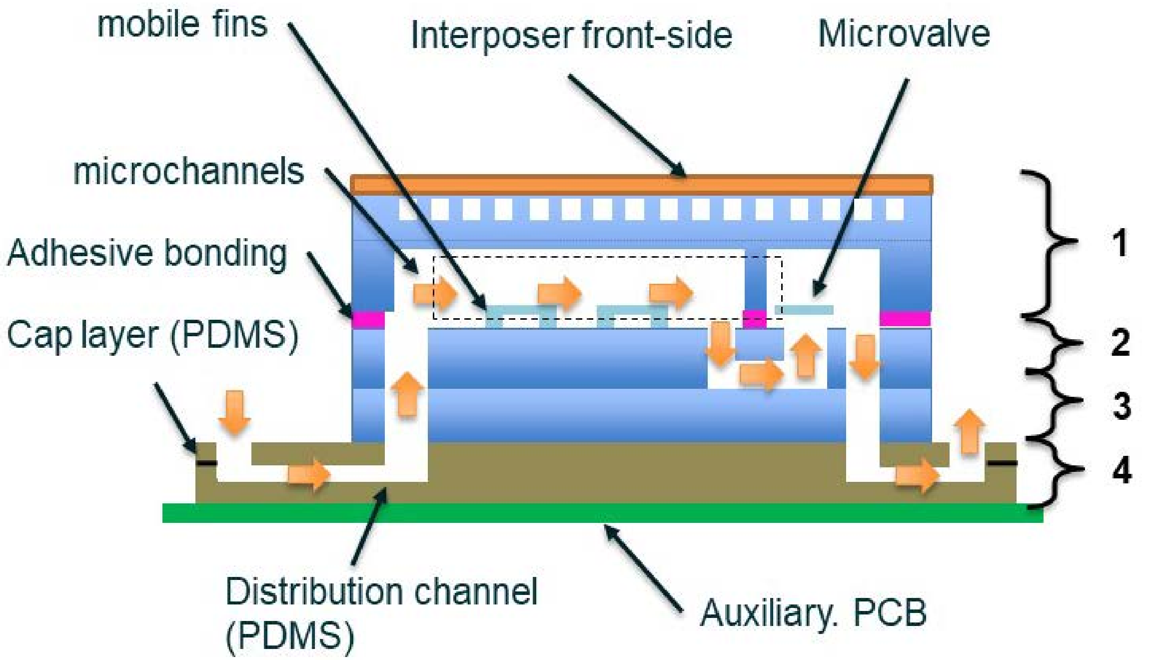
1 : interposer

2 : self-adaptive fins

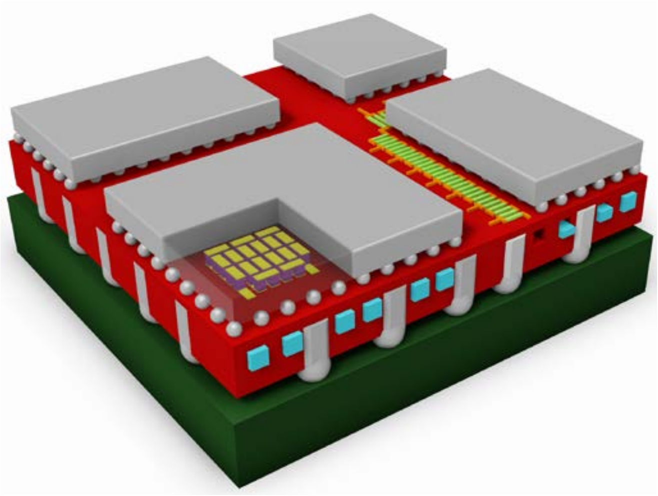
& valves

3 : inlet/outlet

4: PDMS distributor



Outline



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STREAMS compromise

Harvesting versus cooling:

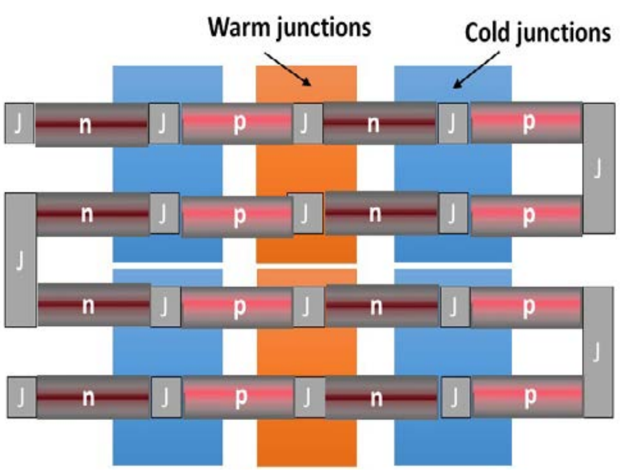
- Air gap = thermal resistance

➢ Compromise between T_{max} and ΔT across µTEG

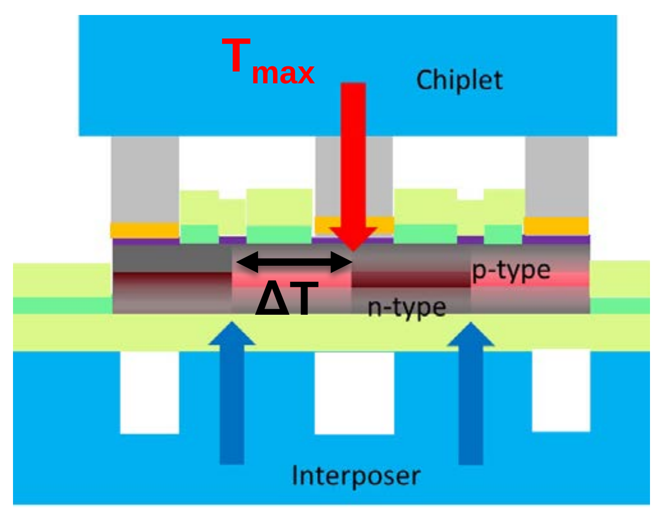
T_{max} = cooling

ΔT = harvesting

µTEG top view:



µTEG cross section :

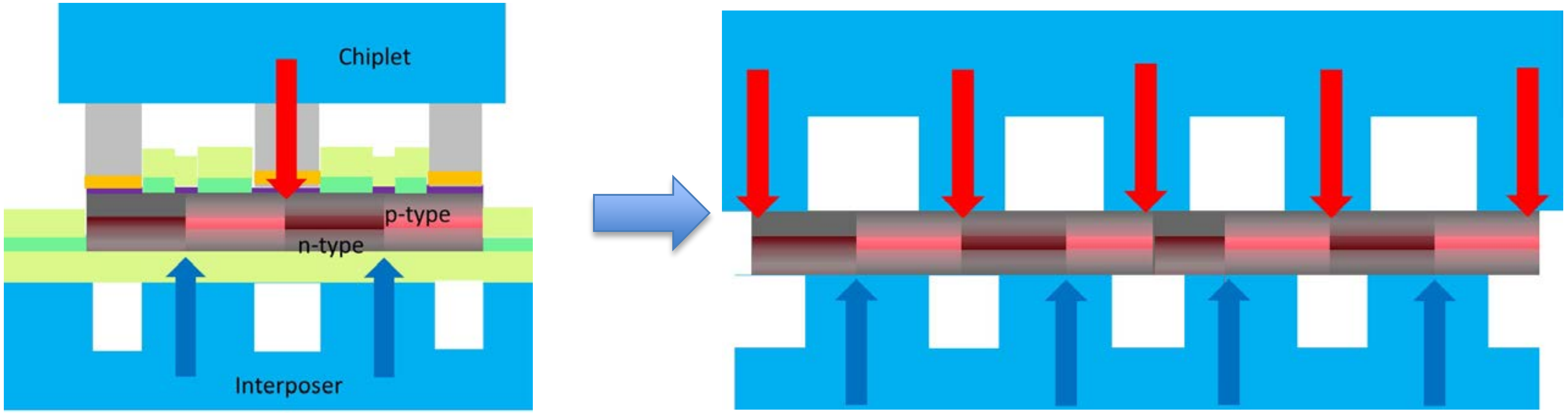


STREAMS compromise

Harvesting versus cooling:

- Before thermal modelling…

Simplification:

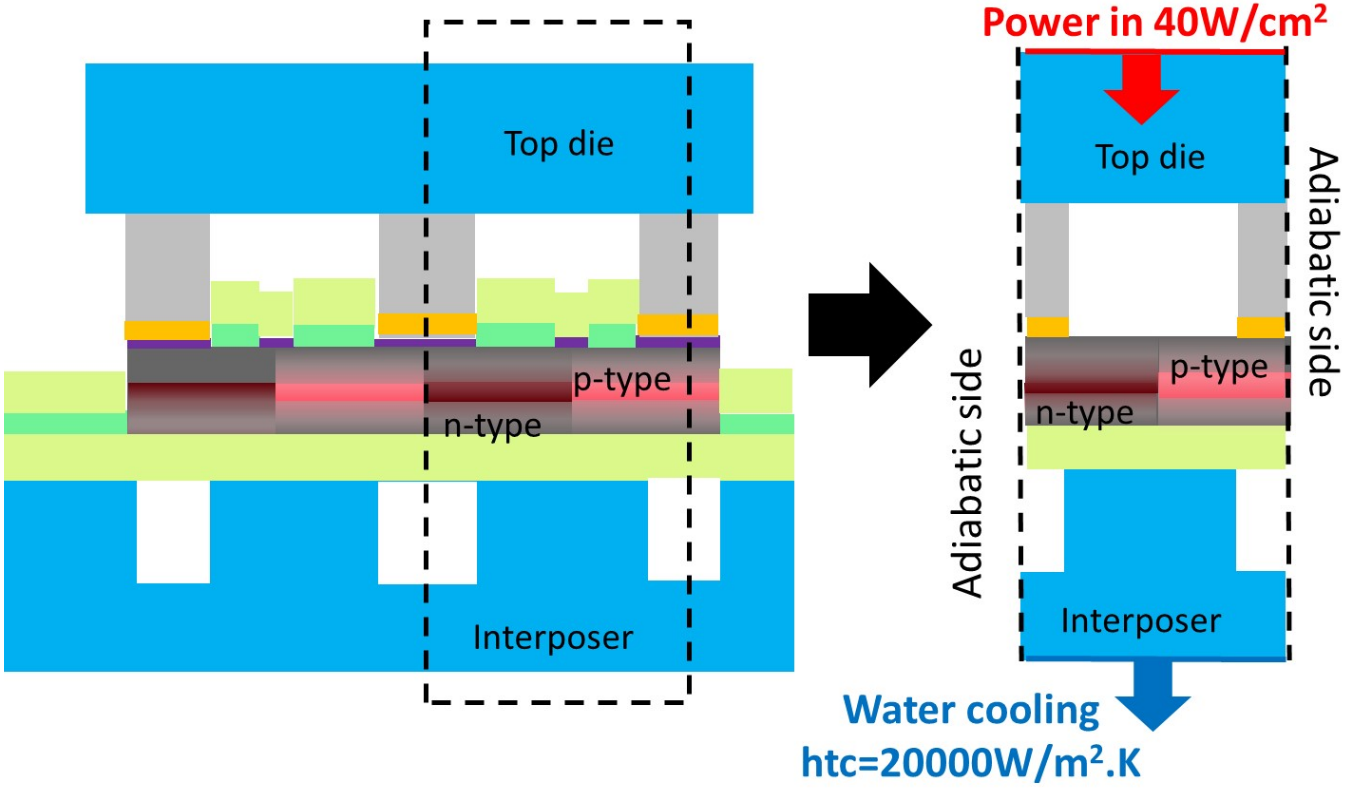


- Symmetry of the structure => 2 air gaps
- One air gap is fixed (interconnects design rule)
- One is (almost) free…

STREAMS compromise

Harvesting versus cooling:

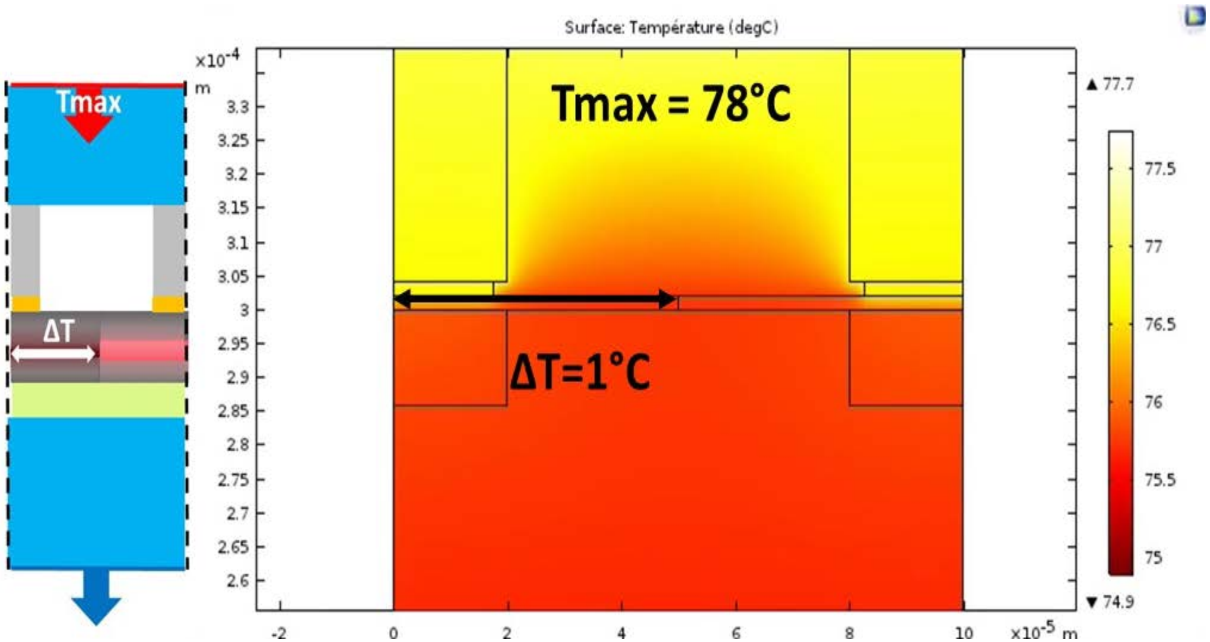
- Simulations



STREAMS compromise

Harvesting versus cooling:

- Simulation: no air gap



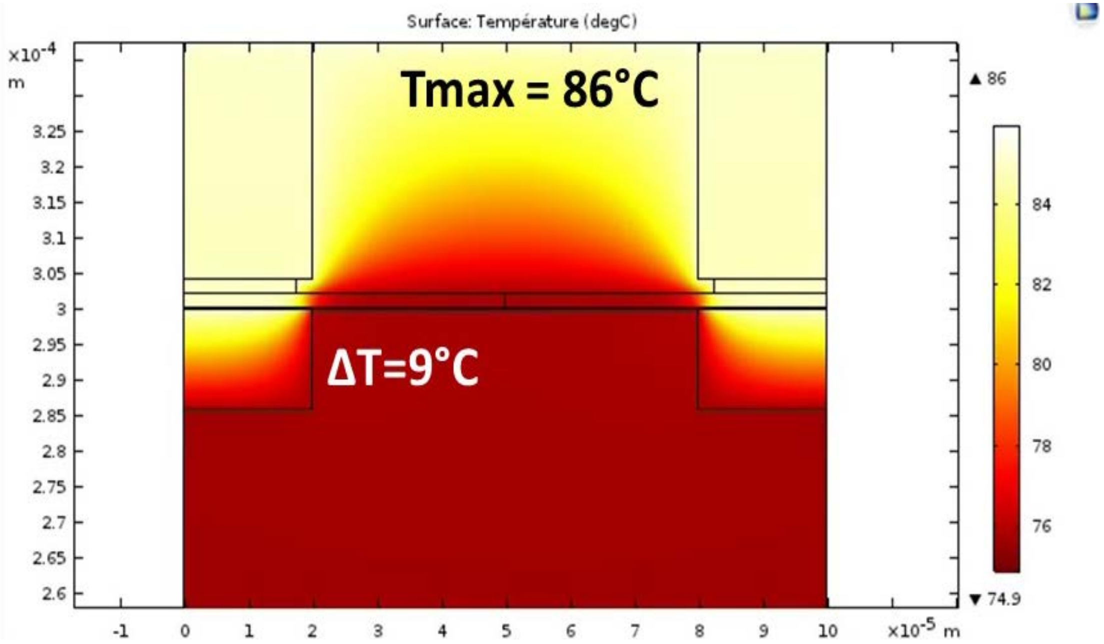
➢ Maximum cooling

➢ But harvesting very poor…

STREAMS compromise

Harvesting versus cooling:

- Simulation: air gap width 30µm

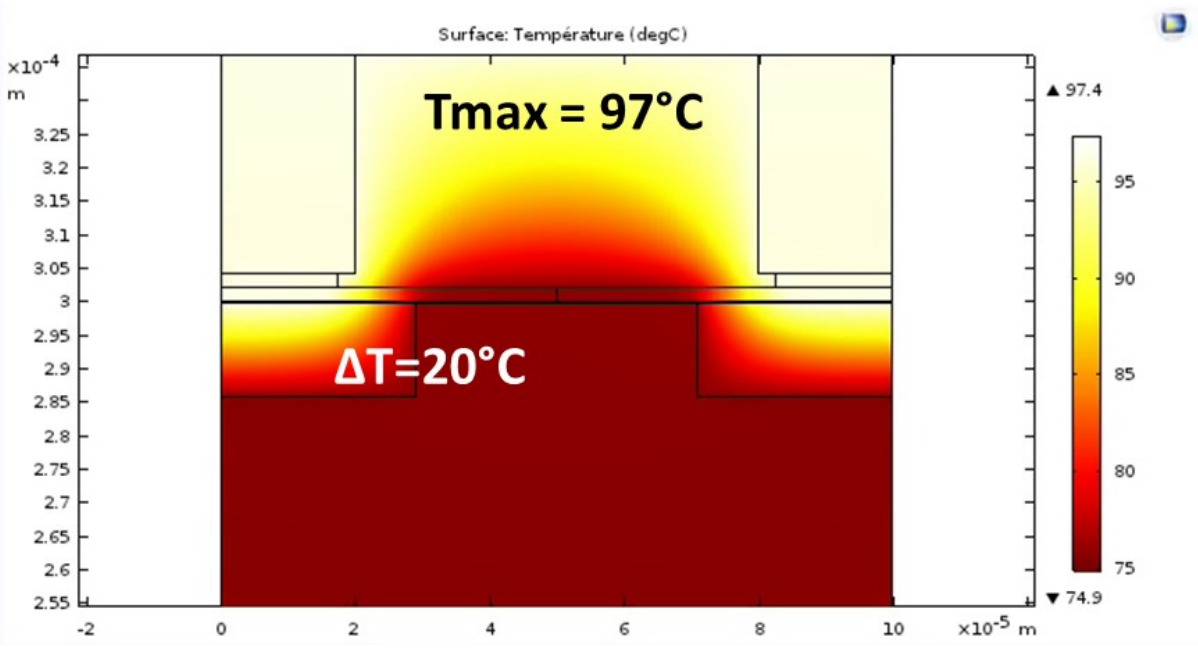


- ➢ Resonnable cooling
- ➢ Harvested power α square (ΔT)

STREAMS compromise

Harvesting versus cooling:

- Simulation: wider air gap



➢ STREAMS target: ΔT between 10 and 15°C

Summary

- 3 functionalities:
  - Versatile microfluidic actuation
    - “Thermoregulated Microvalve for Self-Adaptive Microfluidic Cooling”
    - “Thermostatic Fins for Spatially and Temporally Adaptive Microfluidic Cooling”
    - “Variable Pumping Control for Low Power Microfluidic Chip Cooling”
  - Thermal mapping (µTES)
    - “Integrated Thermoelectric Sensors for Thermal Monitoring of Integrated Circuits”
  - Harvesting (µTEG)
    - “Embedded Thermal Energy Harvesting – Challenges & Opportunities”
- Integration

  Front-side/Backside
- Harvesting vs cooling

Thank you for your attention

Acknowledgments

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