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Advancement of microchannels-based heat spreaders and applications in solar/thermal/electric conversion

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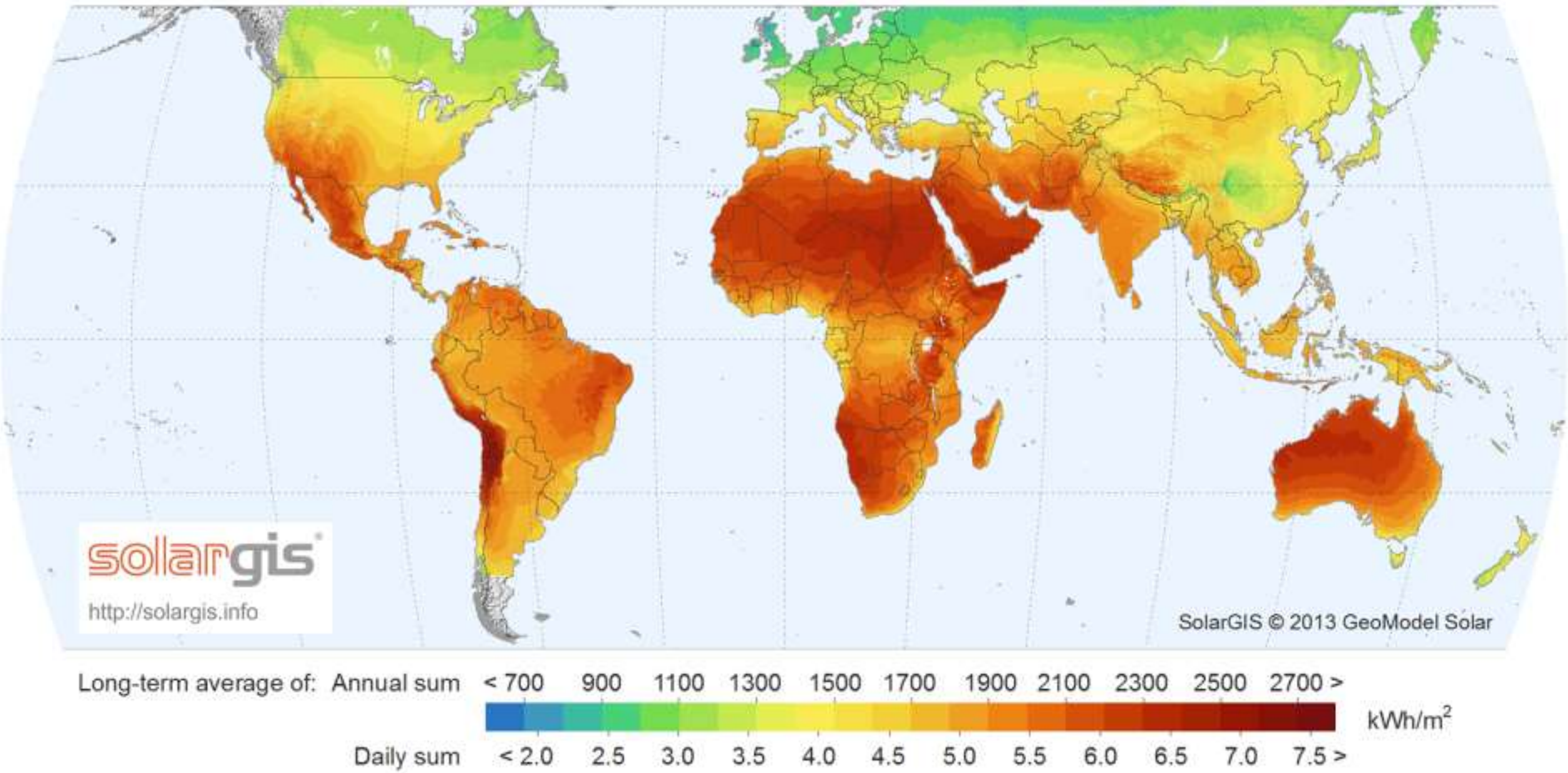
Presentation Outline

- Introduction
- Solar energy technology
  - Photovoltaics
  - Solar collectors (thermal Engineering)
- Microstructured heat sinks
  - Single-phase flow
  - Multiphase flow
  - Waste heat reuse
  - Novel designs
- Concluding remarks

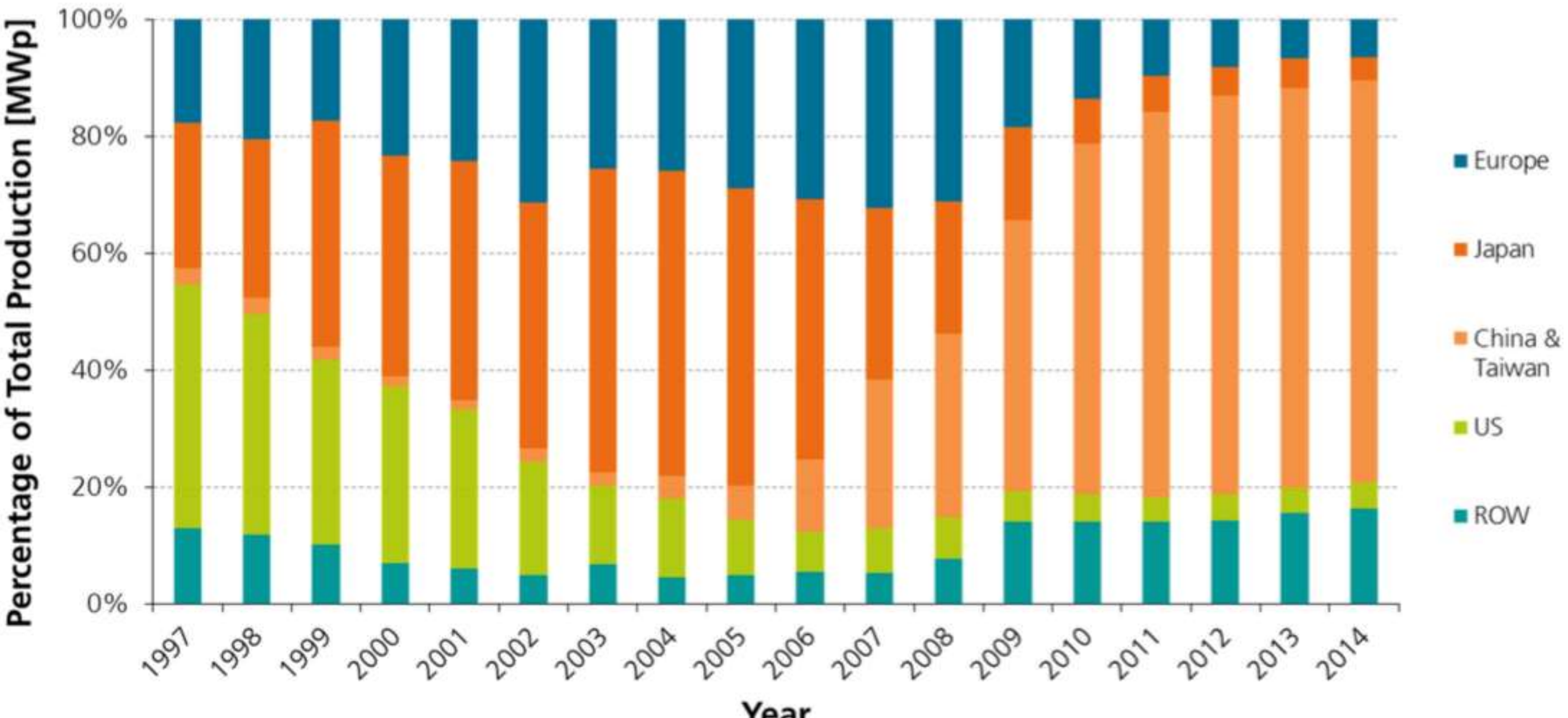
Introduction

- Solar irradiation



Introduction

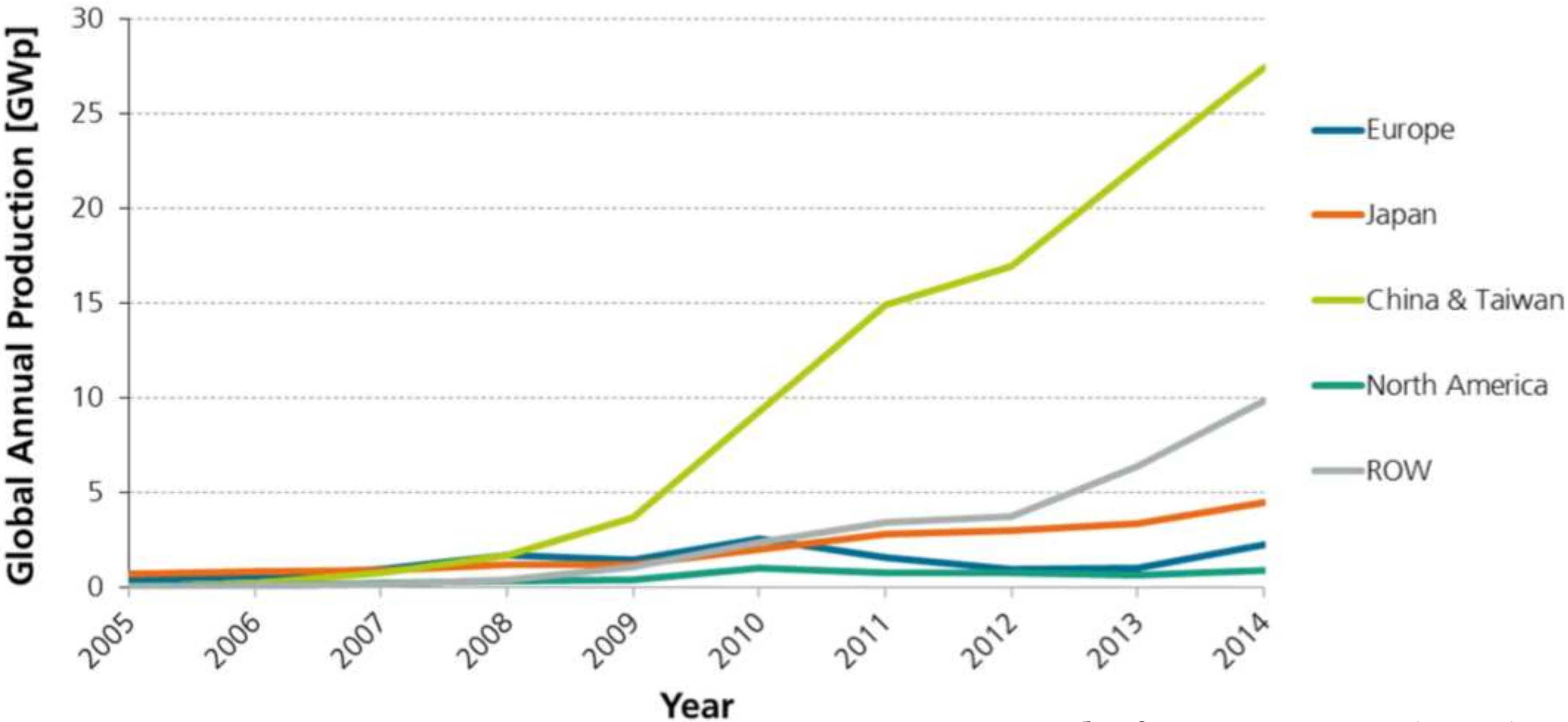
- Solar energy around the world:



Fraunhofer ISE Report (2016)

Introduction

- Solar energy around the world:



Fraunhofer ISE Report (2016)

Introduction

- Solar energy around the world:
  - Europe
  - China
  - Japan
  - United States
  - Canada

National Renewable Energy Action Plan:

- 20% of energy consumed in EU will come from renewable sources by 2020.

- The emission of greenhouse gases should be reduced by 20% in 2020, if compared with 1990.

Germany: 7% of electricity demand was generated by PV in 2014.

Spain has the 6th largest operational solar thermal power station.

Introduction

- Solar energy around the world:
  - Europe
  - China
  - Japan
  - United States
  - Canada

In 2015, China spent 2.5x more on clean energy than EU.

Largest market for photovoltaics and solar thermal collectors since 2015.

70.6% of the world's capacity in solar thermal collectors.

13th five year plan:

- Triple solar capacity by 2020.

The largest photovoltaic power station is located in China.

Introduction

- Solar energy around the world:
  - Europe
  - China
  - Japan
  - United States
  - Canada

Shifting from nuclear power to other forms of energy generation since Fukushima.

In 2015, 3.5% of electric energy consumed in Japan was generated by photovoltaics.

Japan is building the world's largest floating solar power plant (floatovoltaics).

Introduction

- Solar energy around the world:
  - Europe
  - China
  - Japan
  - United States
  - Canada

4.4% of the world's total solar thermal power capacity is installed in North America.

8 of the 10 largest photovoltaic power stations are located in the US.

Since 2008, solar energy installations have grown from 1.2GW to 30GW.

Introduction

- Solar energy around the world:
  - Europe
  - China
  - Japan
  - United States
  - Canada

Canada:

Located in high latitude, it has a small solar potential, due to less solar irradiation.

Investment in solar generation stations are growing.

Has one of the three biggest solar companies in the world.

Introduction

- Solar energy around the world:
  - Europe
  - China
  - Japan
  - United States
  - Canada

+ 80% of PV module production

"Projeto Ituverava"-Bahia
254MW -2017

Introduction

"The Stone Age came to an end not for a lack of stones and the oil age will end, but not for a lack of oil."
Ahmed Zaki Yamani

1930 -

Global Warming + End of Oil Age → **Incentives**

+ Research
+ Production

Solar Power

− Costs

+ Competitiveness

+ Incentives

Solar energy technology

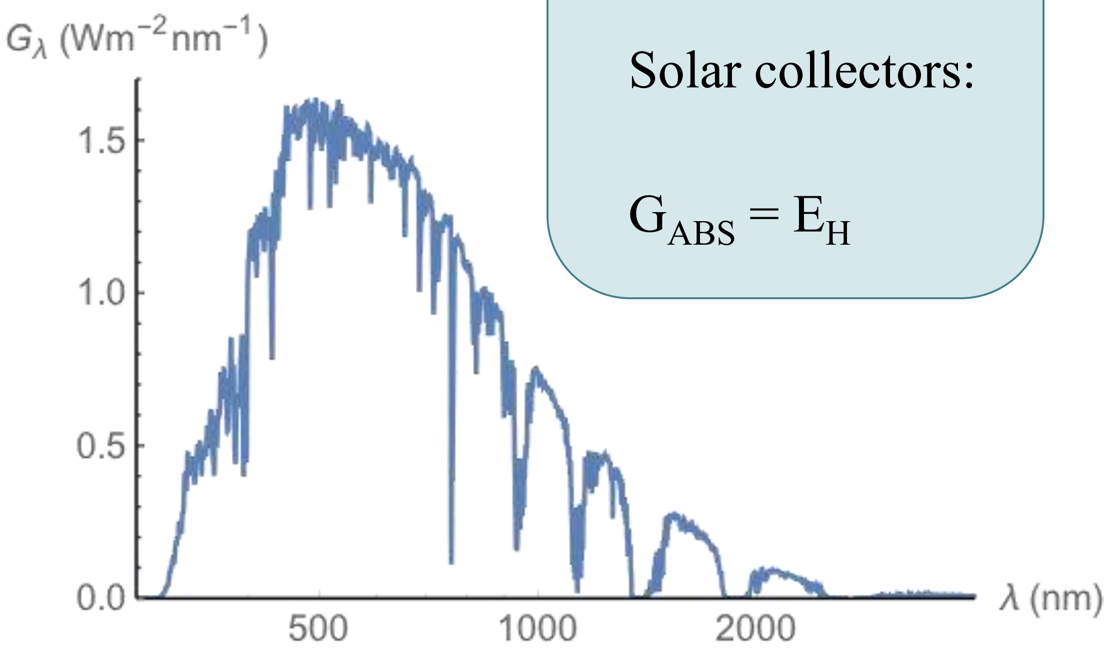
- Photovoltaics x Solar collectors

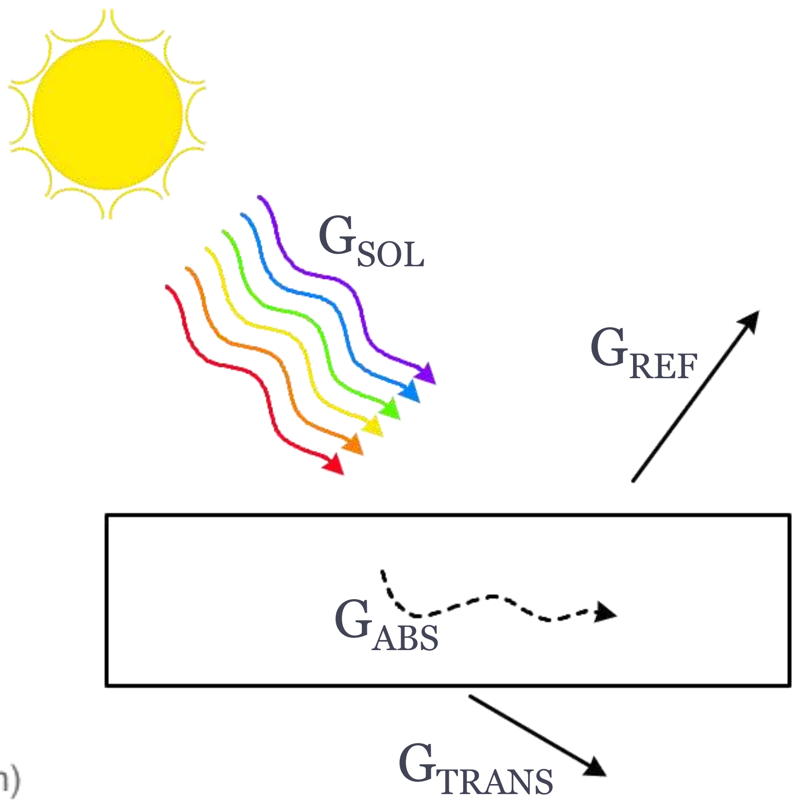
Photovoltaics:

$$G_{ABS} = E_{EL} + E_H$$

Solar collectors:

$$G_{ABS} = E_H$$





Solar energy technology

- Photovoltaics:
  - Direct conversion into electricity;
  - Part of the absorbed energy is converted into heat;

- Tracking systems;
- New materials;
- Thin films
- Multi-junctions;

Solar energy technology

- Cooling challenges:
  - High heat flux removal (~1MW/m^2)
  - Non-uniform heating
  - Temperature variation during operation

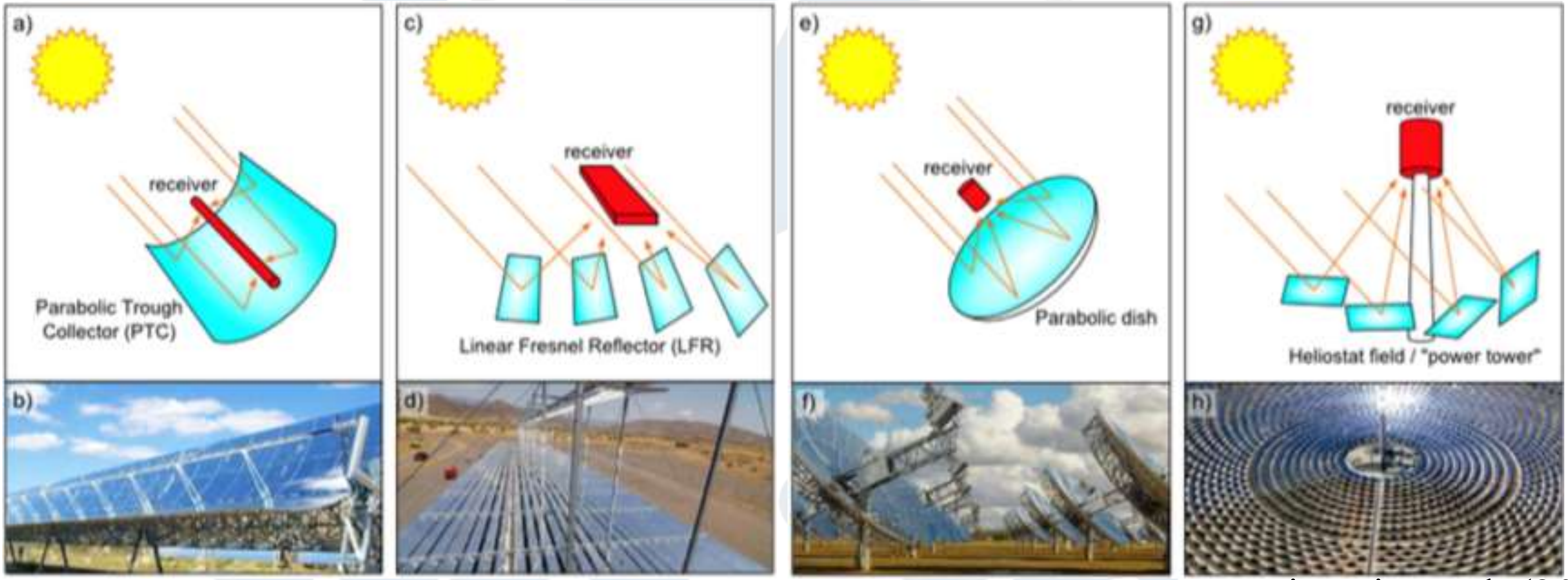
SIMILAR REQUIREMENTS FROM ELECTRONICS INDUSTRY!!!

Solar energy technology

- Concentrating photovoltaics cooling techniques:
  - Heat pipe cooling
  - Jet impingement
  - Liquid immersion
  - Phase change material
  - **Microchannel heat sinks**

Solar energy technology

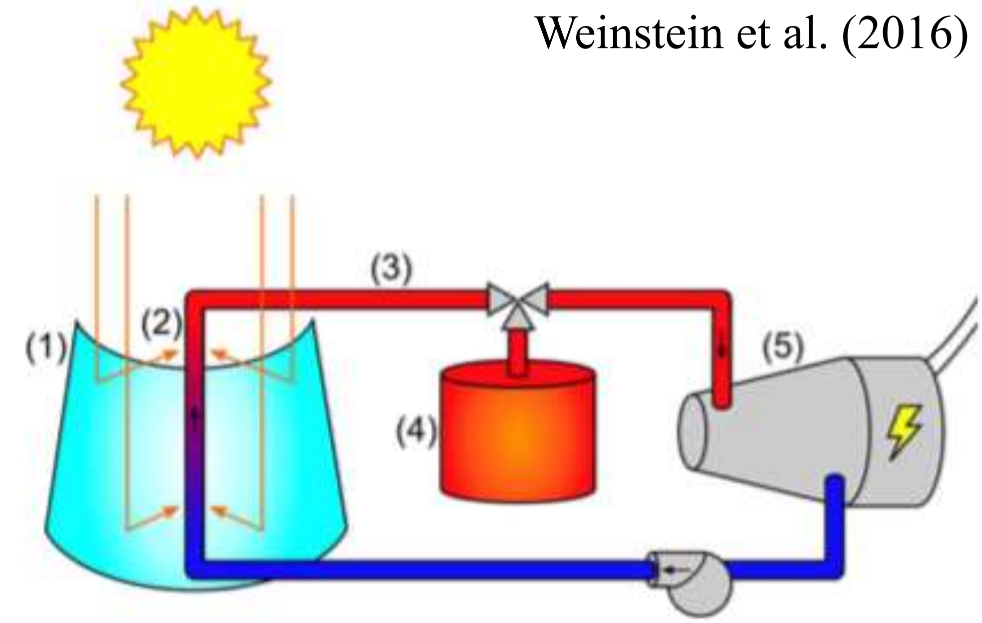
- Solar collectors:
  - Conversion into heat;
  - Low-cost;
  - Benefit from advances in photovoltaic technology.



Weinstein et al. (2016)

Solar energy technology

- Solar collectors:
  - Applications:
    - Power cycles
    - Hydrogen production
    - Water desalination
    - Water heating
    - Photocatalysis



Weinstein et al. (2016)

Microstructured heat sinks

- Applications demands:
  - High heat transfer rates
  - Low temperature gradients
  - Minimum energy consumption
  - Low-cost
  - Up-scalable fabrication
  - Reliability
    - Low temperature variation
    - High Critical Heat Flux
    - Leak-proof
    - Minimum maintenance

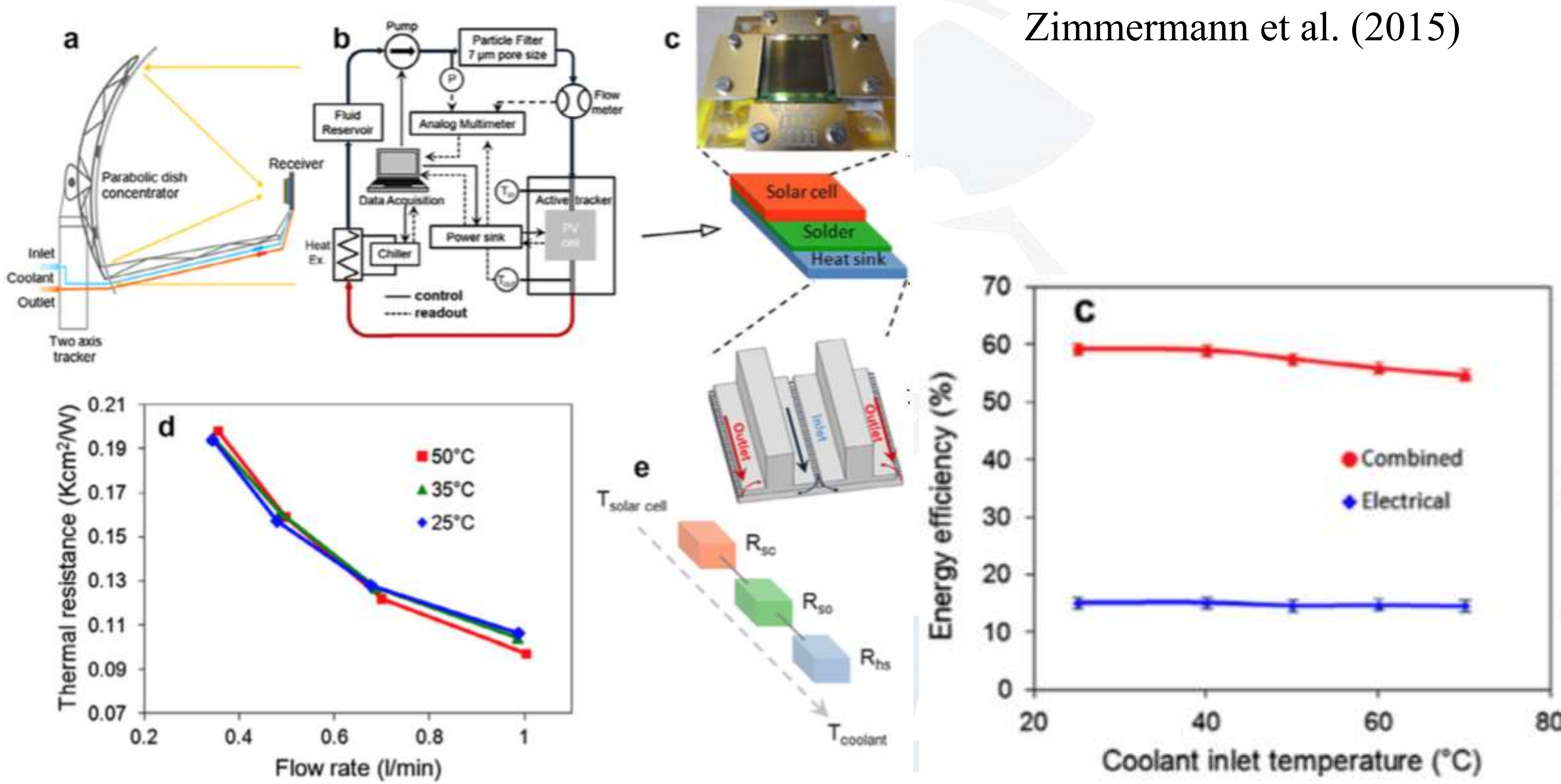
Microstructured heat sinks

- Single-phase flow
  - Commercial devices are available
  - Limited performance
    - High temperature gradients
    - High pumping power

Microstructured heat sinks

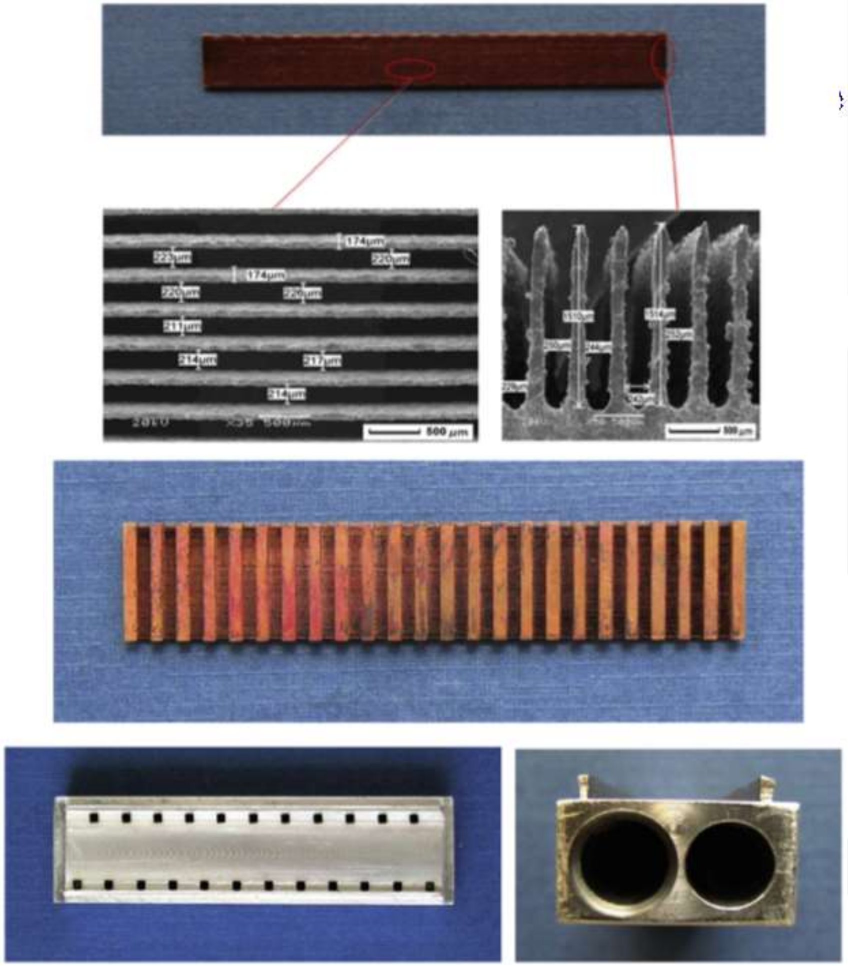
- Single-phase flow

Zimmermann et al. (2015)

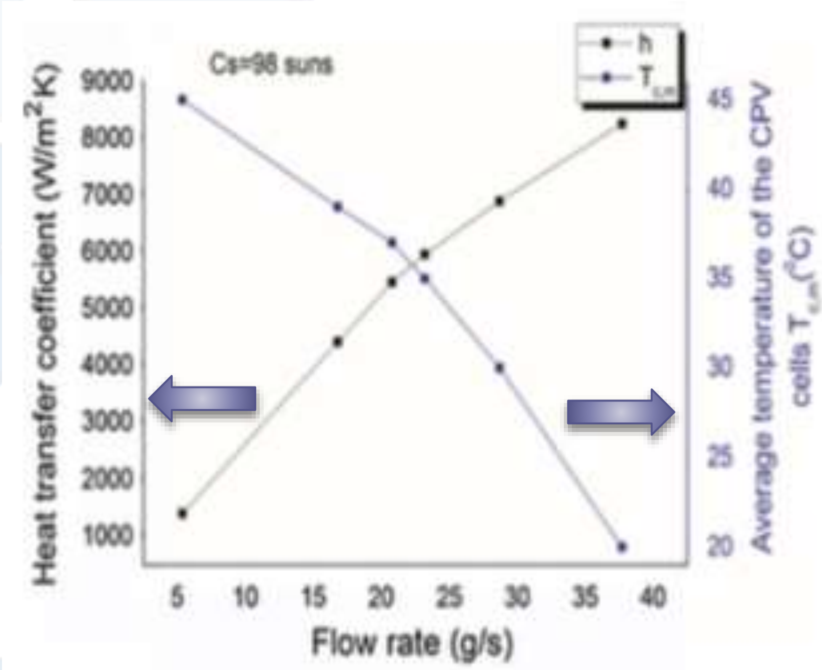


Microstructured heat sinks

- Single-phase flow



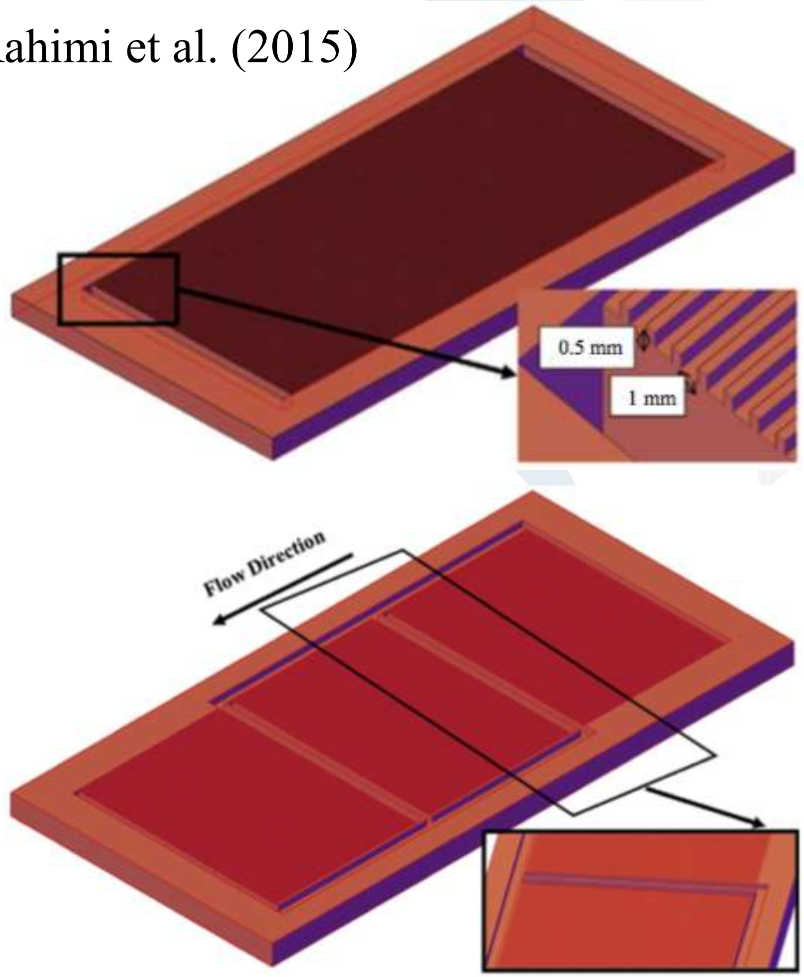
Yang and Zuo (2015)



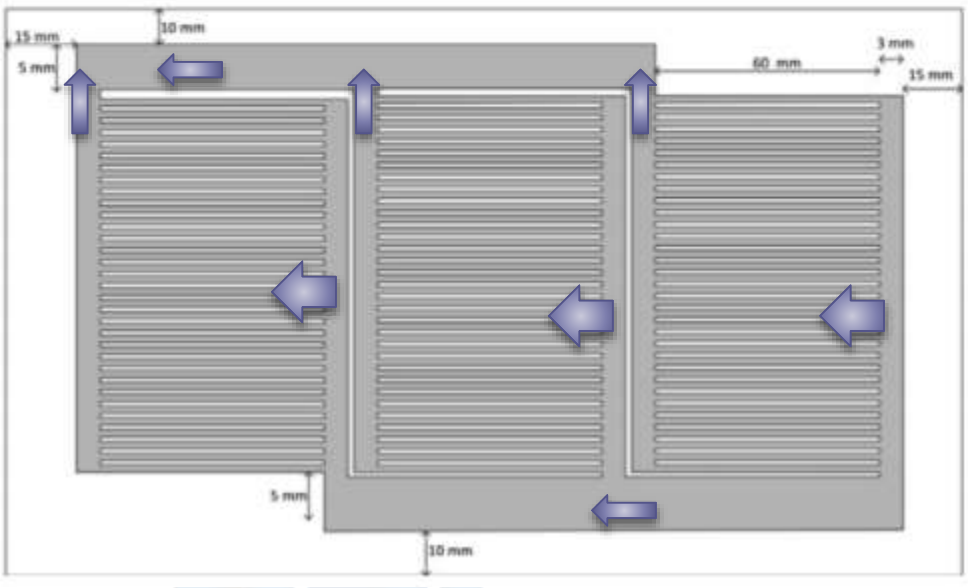
Microstructured heat sinks

- Single-phase flow

Rahimi et al. (2015)

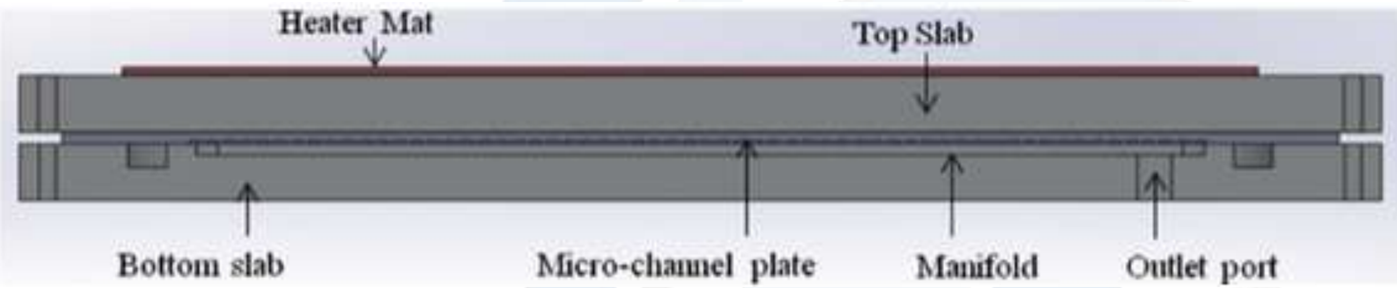


Multi header:
-Lower pressure drop
-Lower surface temperature
-Higher heat removal
-28% higher efficiency

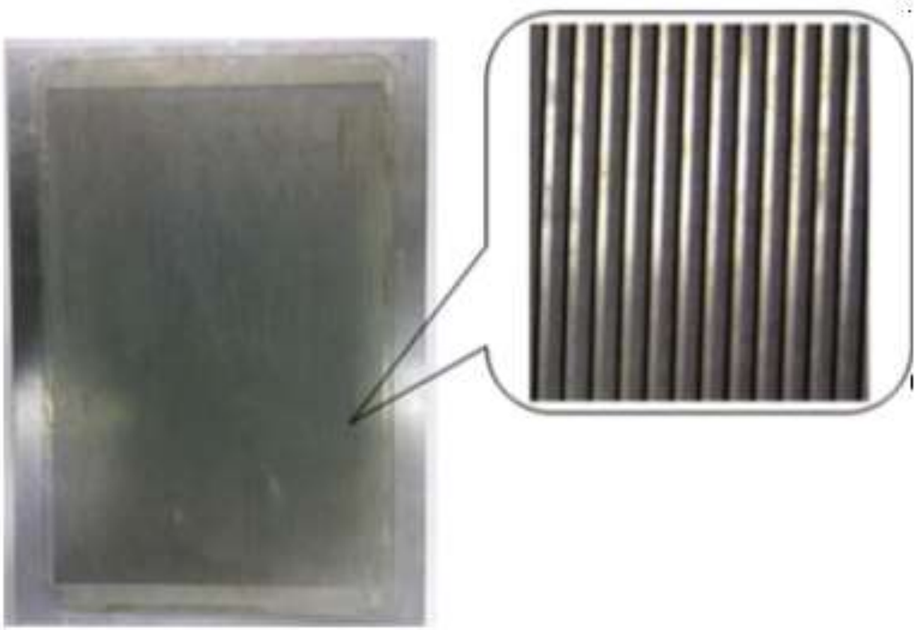


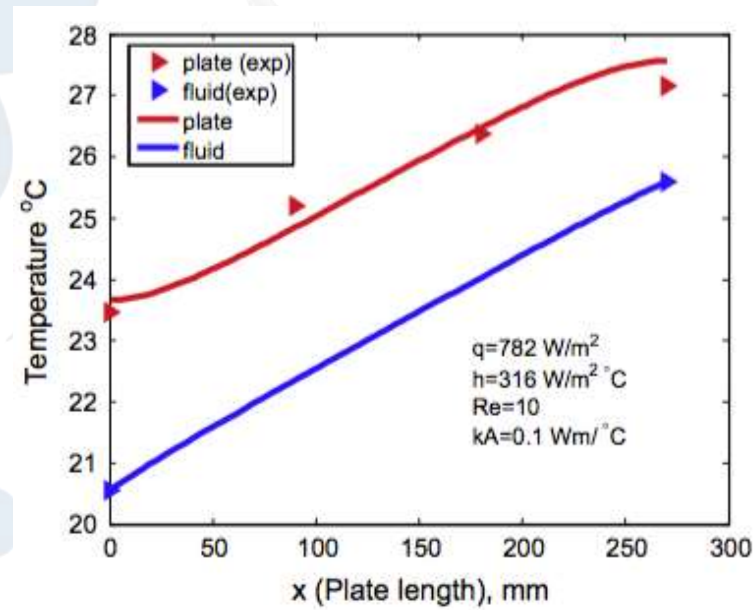
Microstructured heat sinks

- Single-phase flow



Oyinlola et al. (2015)

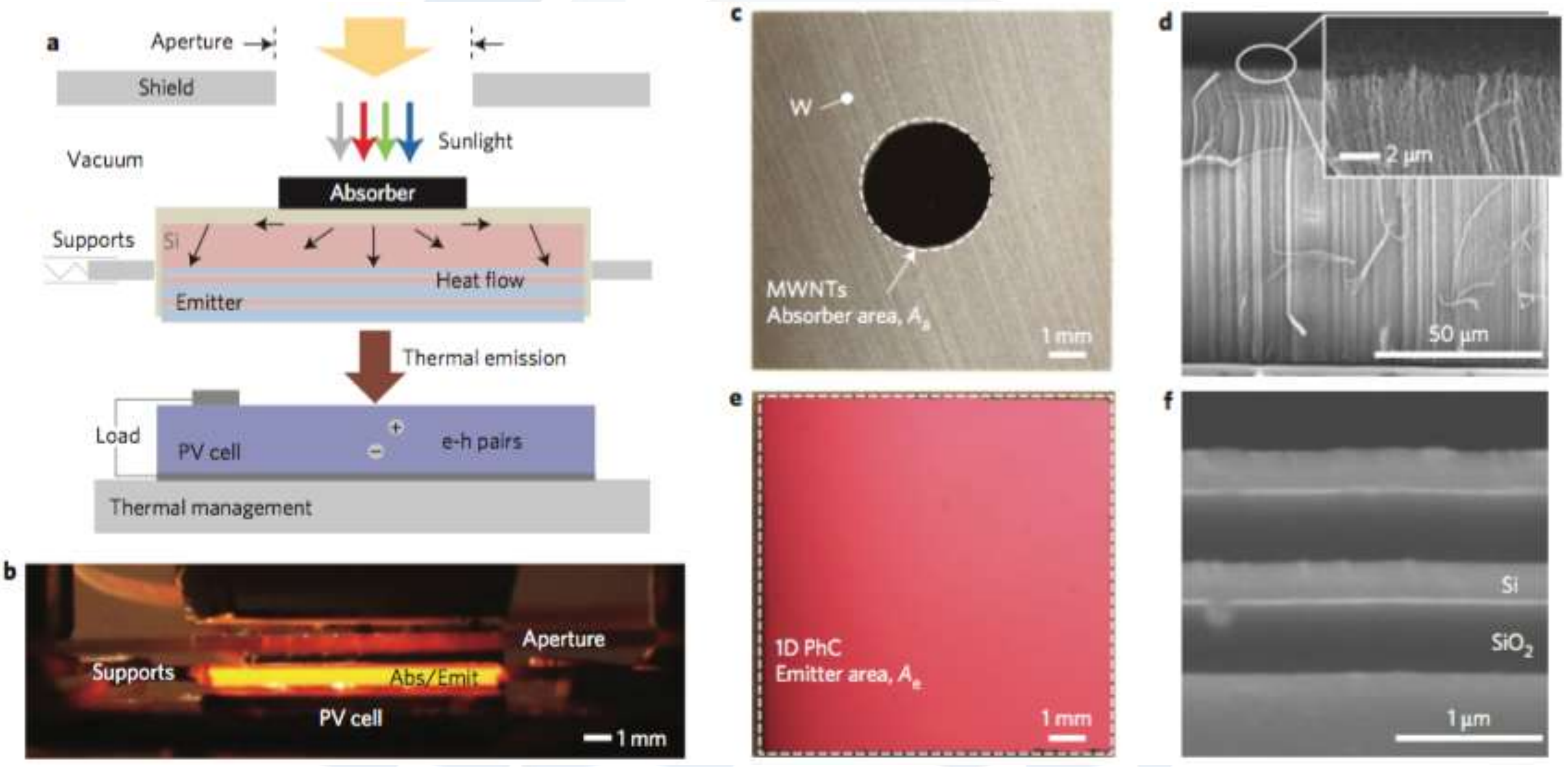




Microstructured heat sinks

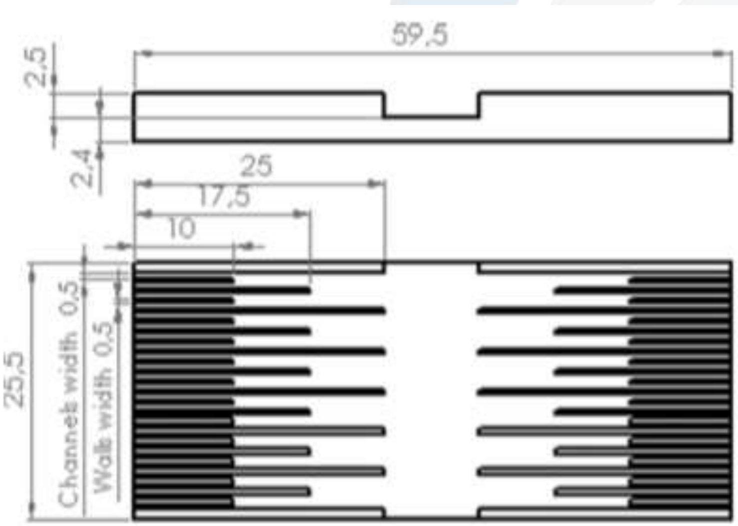
- Single-phase flow

Lenert et al. (2014)



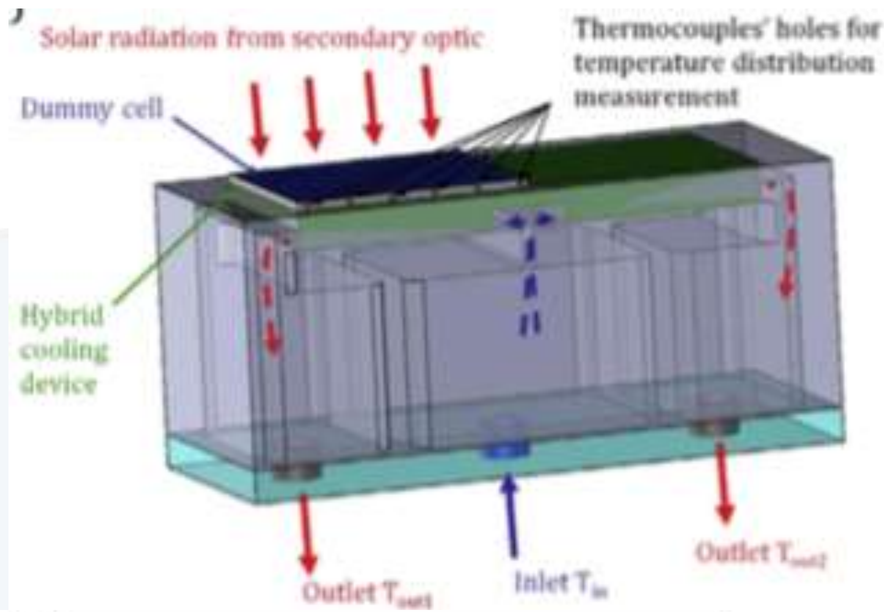
Microstructured heat sinks

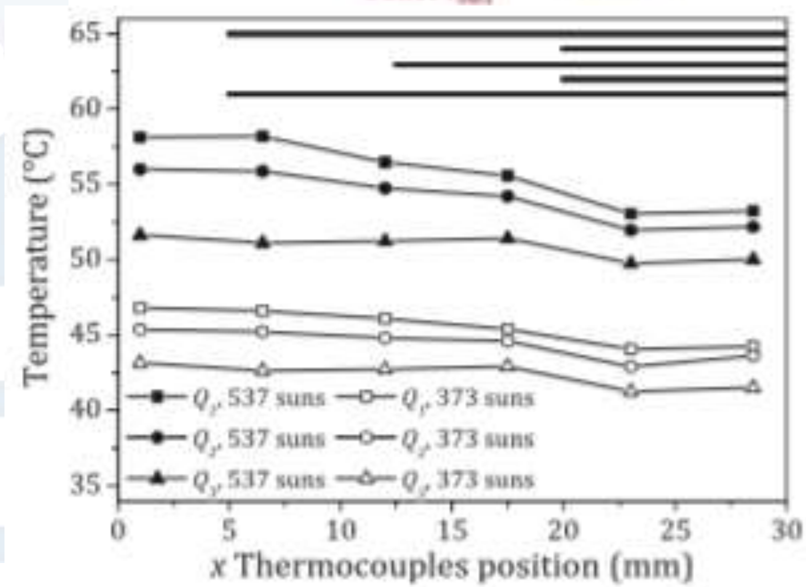
- Single-phase flow



Barrau et al. (2014)

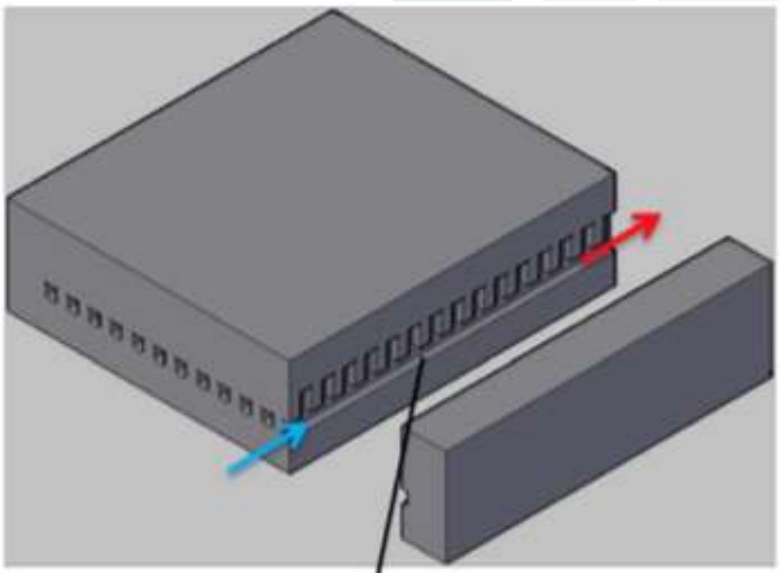
Q1=1.39 l/min
Q3=2,94 l/min





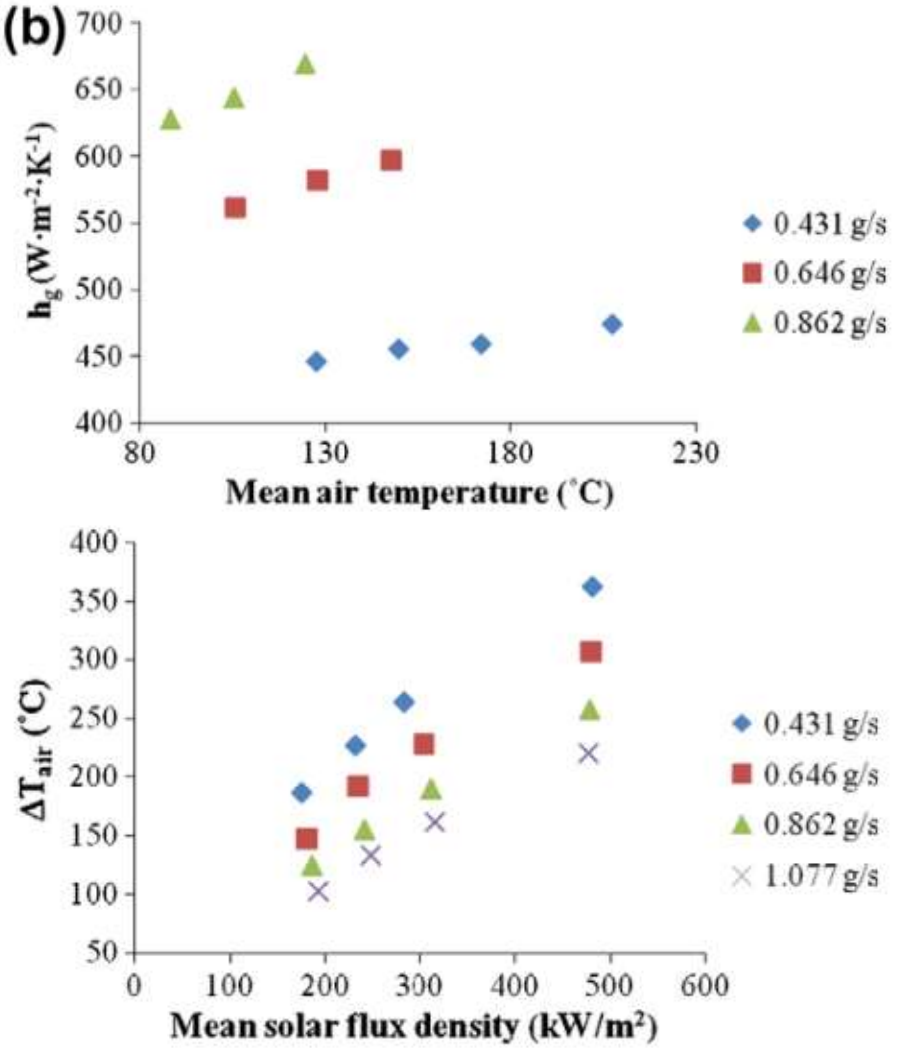
Microstructured heat sinks

- Single-phase flow



Li et al. (2013)

Pressurized-air (~900^{o}C)

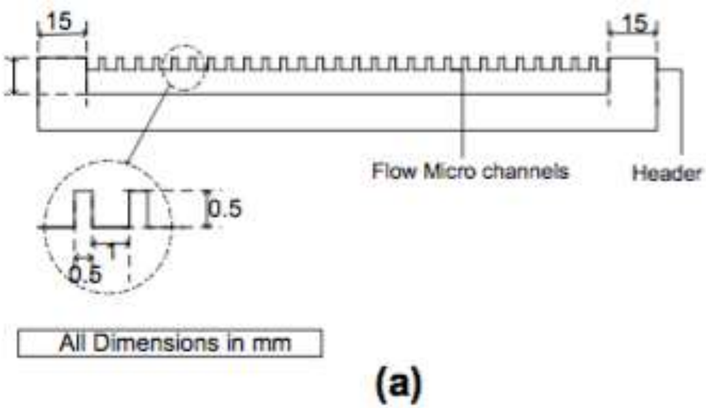


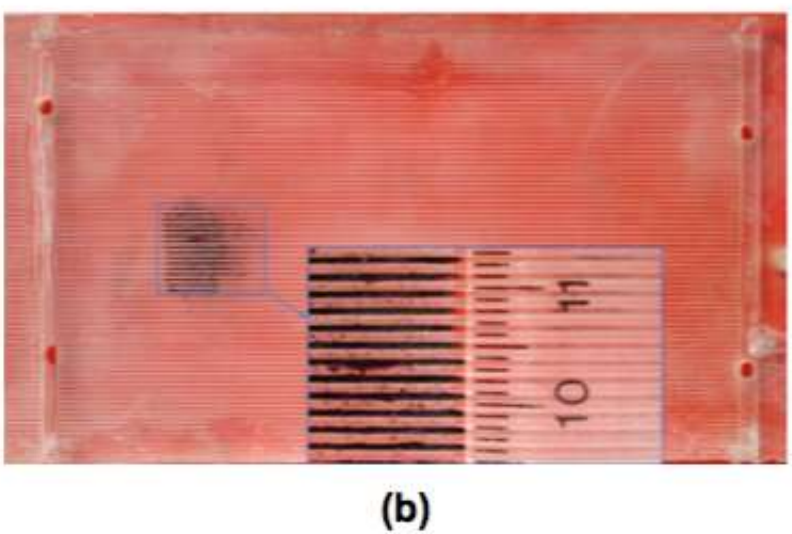
Microstructured heat sinks

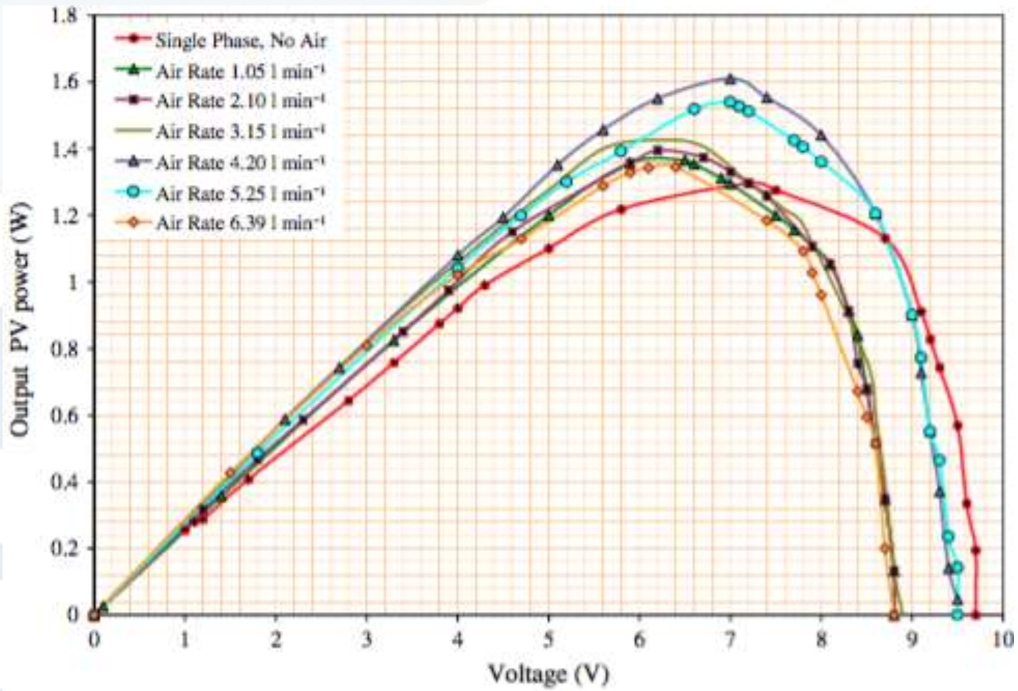
- Two-phase flow
  - Non-condensable-liquid
  - Flow boiling
    - Selected saturation temperature and fluid velocity
    - Minimum temperature variation
    - Latent heat

Microstructured heat sinks

- Two-phase flow



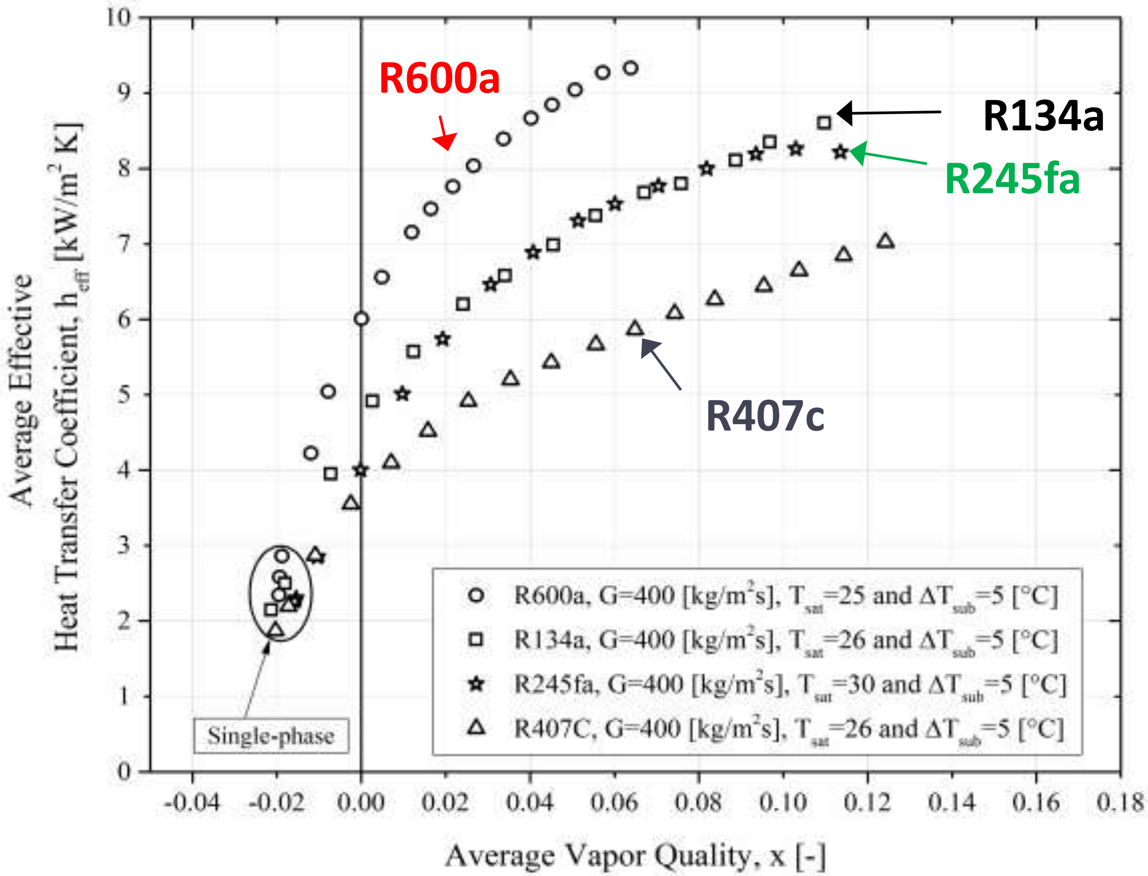


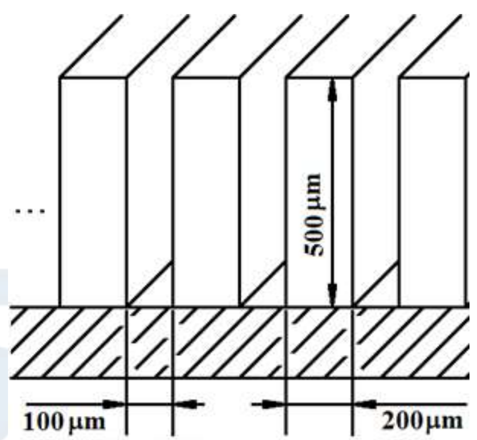


Valeh-e-Sheyda et al. (2013)

Microstructured heat sinks

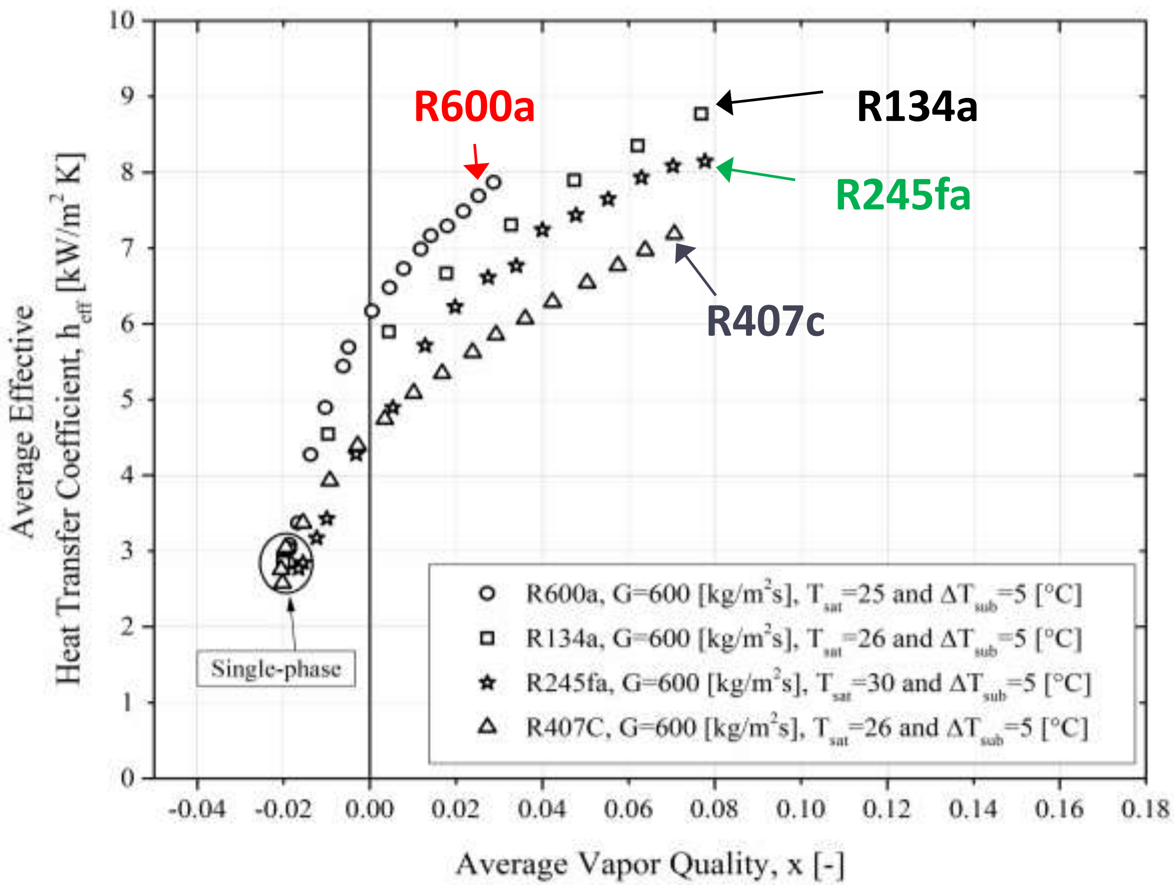
- Two-phase flow
  - Low G

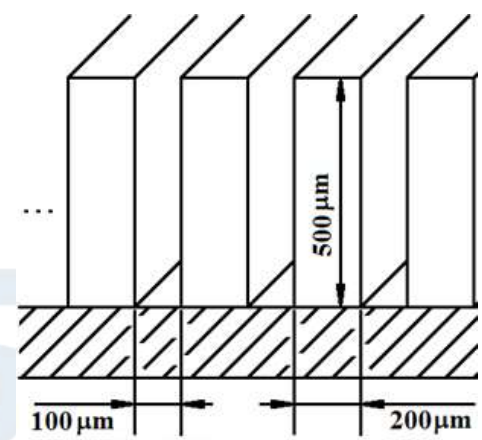




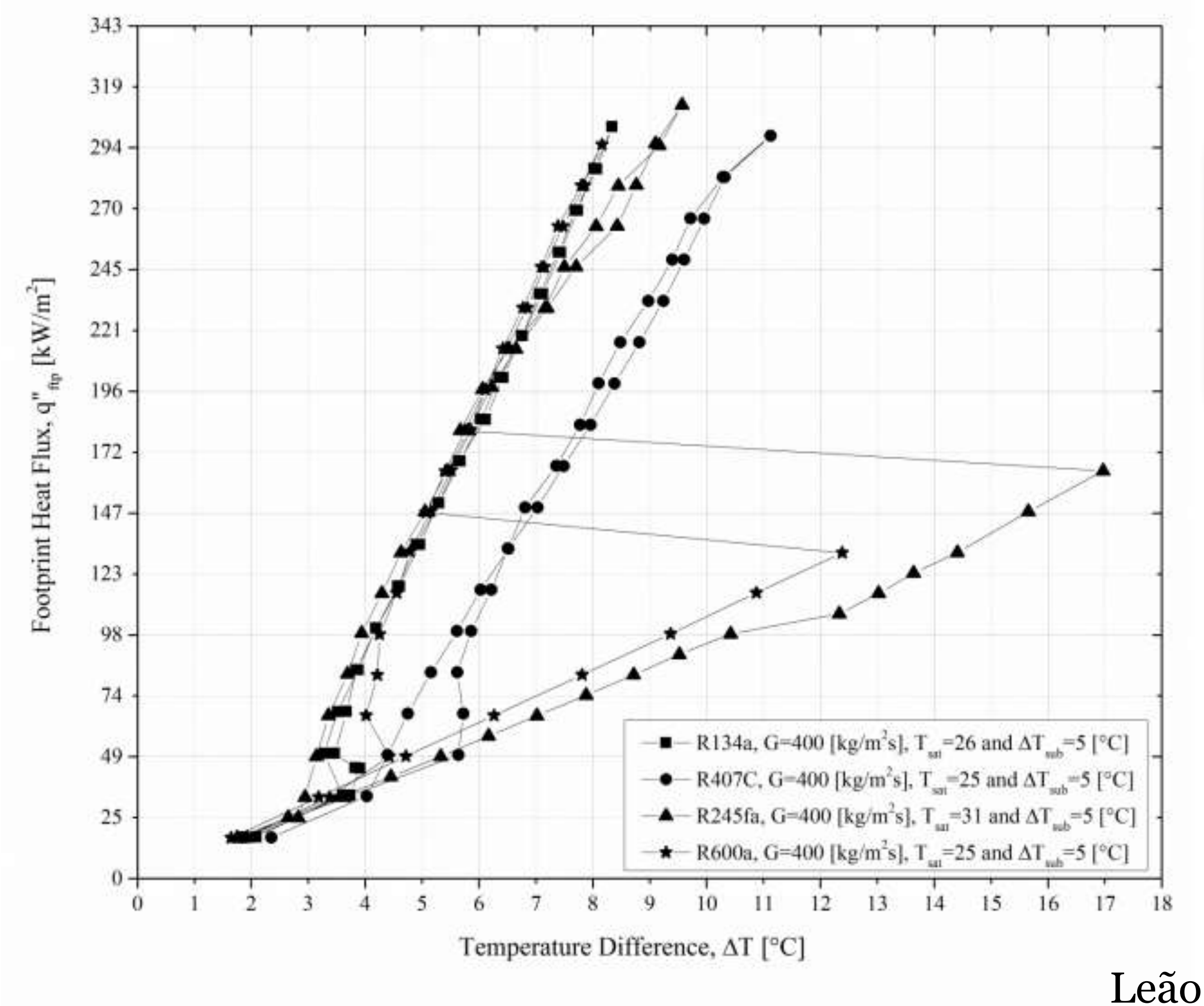
Microstructured heat sinks

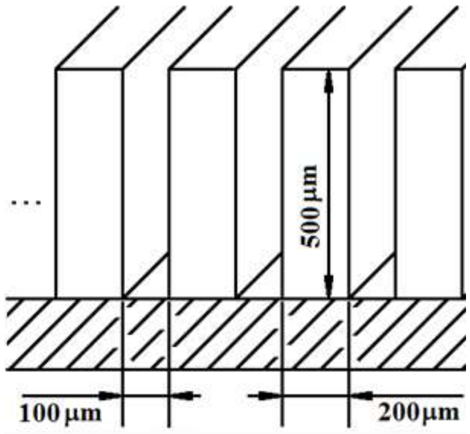
- Two-phase flow
  - High G





Microstructured heat sinks



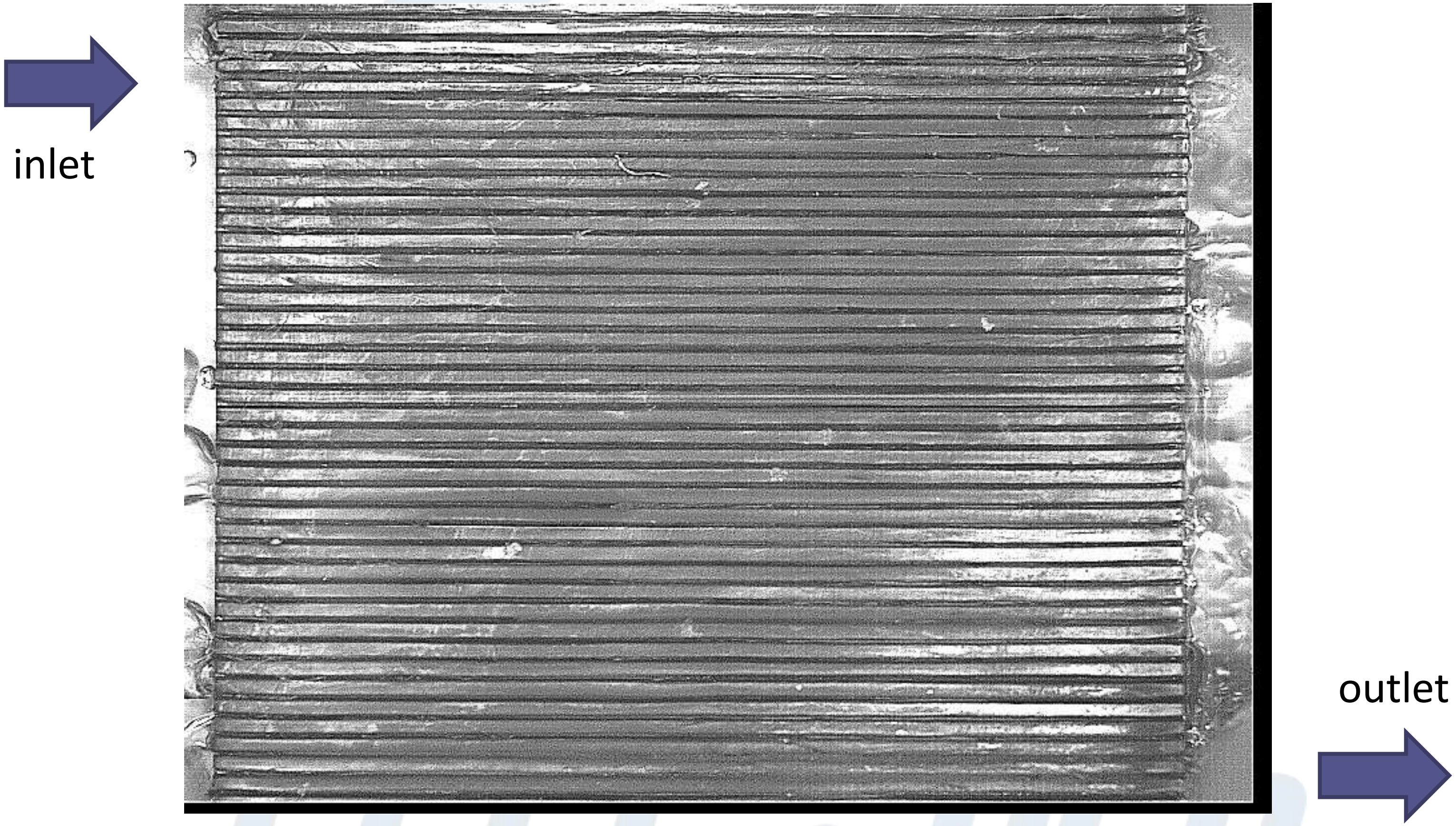


Leão and Ribatski (2015);

Microstructured heat sinks

- Two-phase flow
  - Back flows

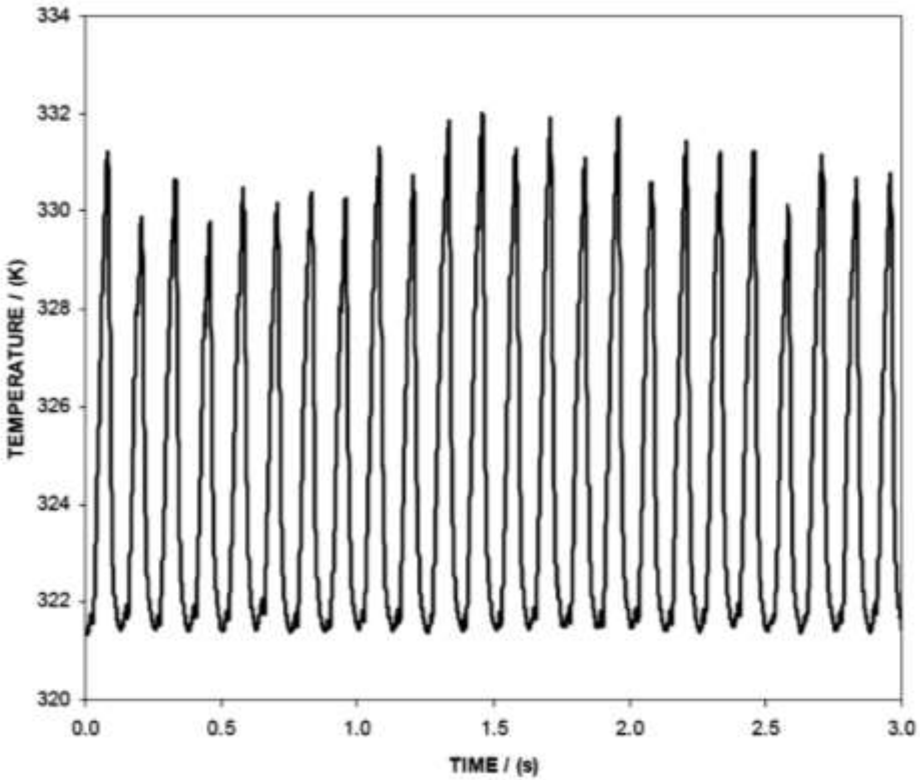
Leão and Ribatski (2014)



$P_{in} \approx 180$ kPa, $T_{sat} \approx 31$ °C, G=400 kg/m²s,
$\Delta T_{sub} = 5$ °C and $q''_{footprint}$=100 kW/m²

Microstructured heat sinks

- Two-phase flow
  - Back flows



Consolini et al. (2007)

Outer wall temperature fluctuations for flow boiling of R-134a in a single 0.8 mm circular channel, taken at half the channel length (heat flux: 140 kW/m^2 , mass velocity: 300 kg/m^{2}s, saturation temperature: 31 °C, channel length: 70 mm).

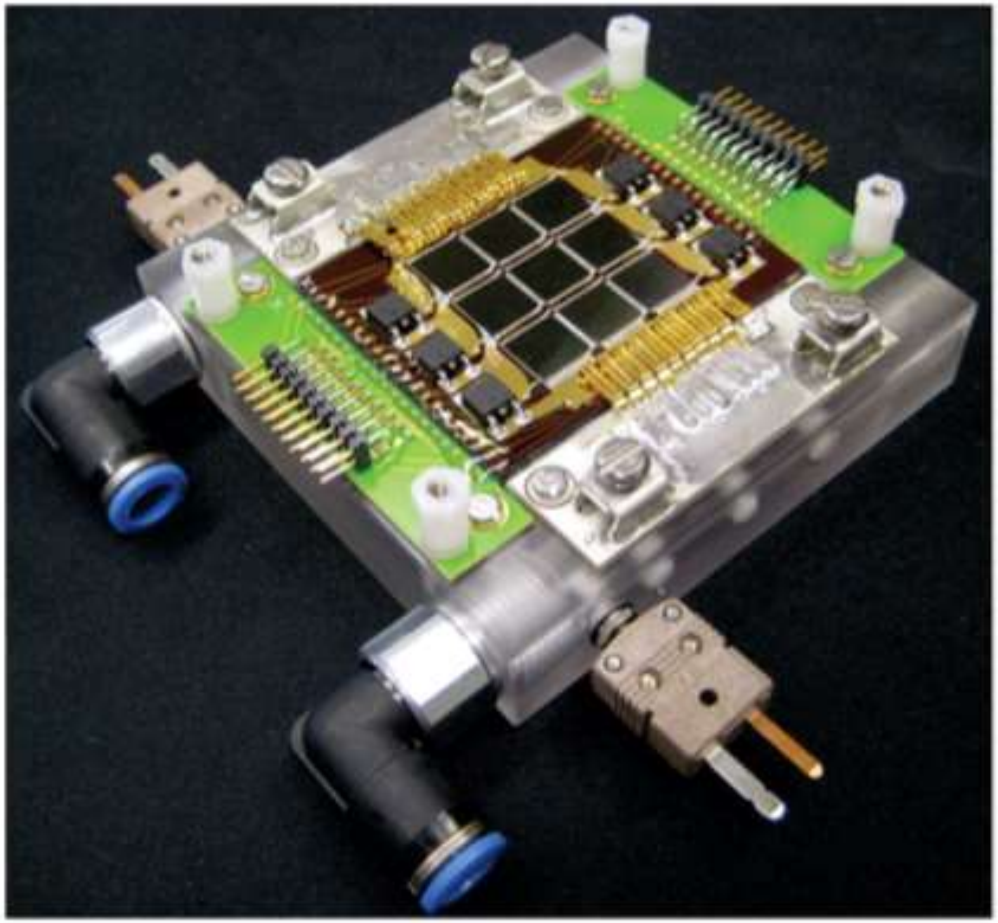
Microstructured heat sinks

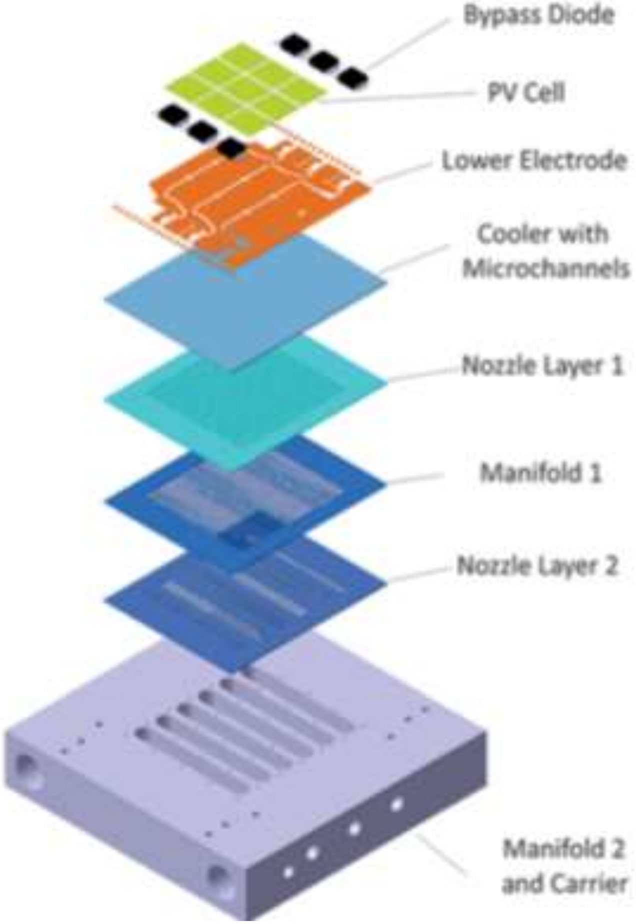
- Waste heat reuse
  - Thermodynamic cycles
    - Organic Rankine Cycle
    - Ericsson or Stirling cycles
    - Refrigeration
  - Water desalination
  - Hydrogen production
  - Ambient heating

Microstructured heat sinks

Michel and Paredes (2013)
2000suns

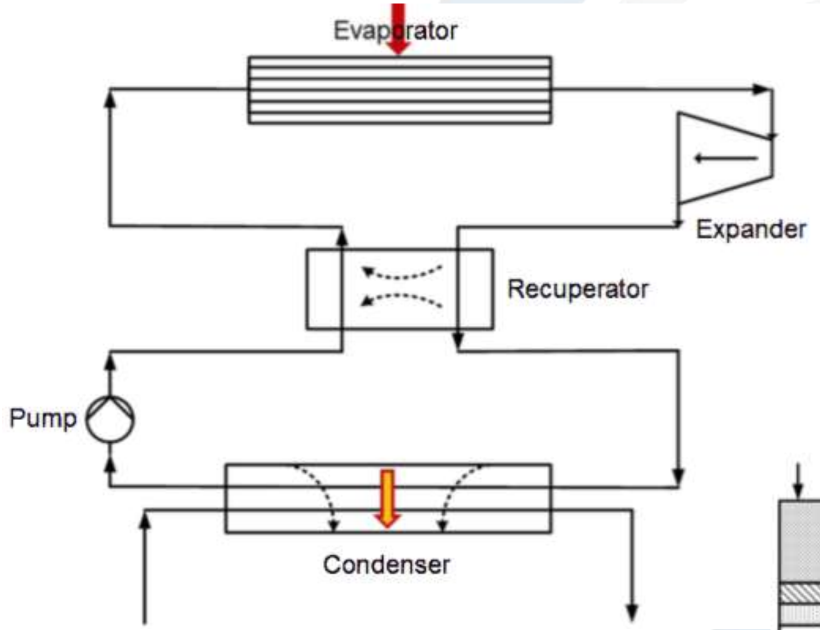
- Waste heat reuse



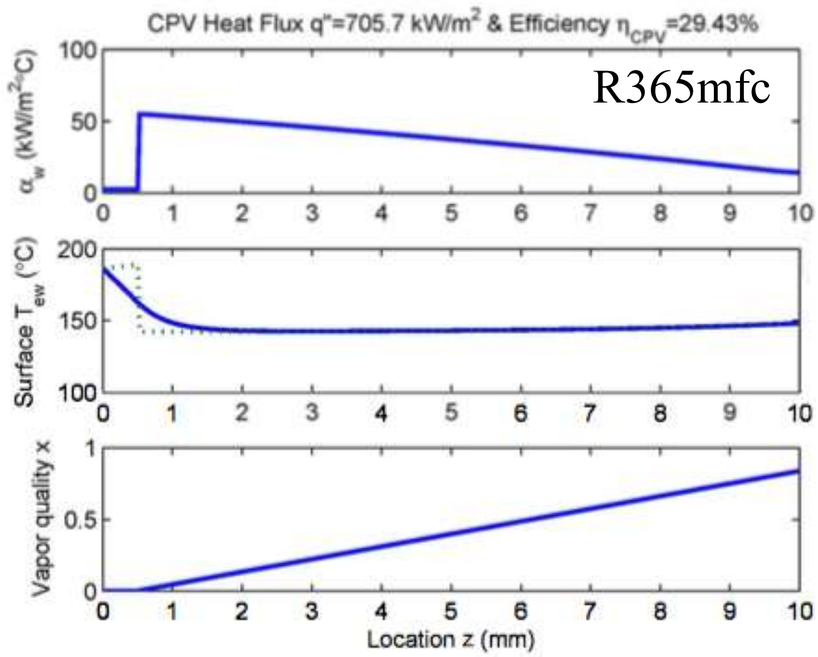


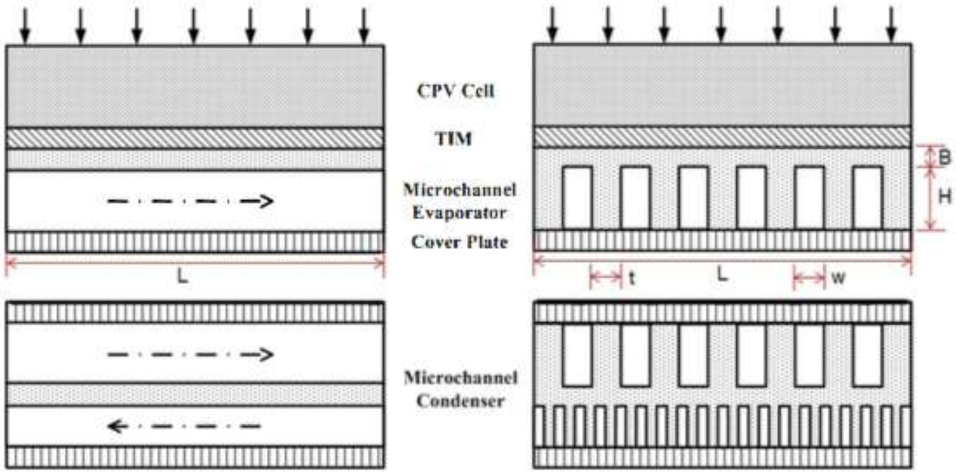
Microstructured heat sinks

- Waste heat reuse

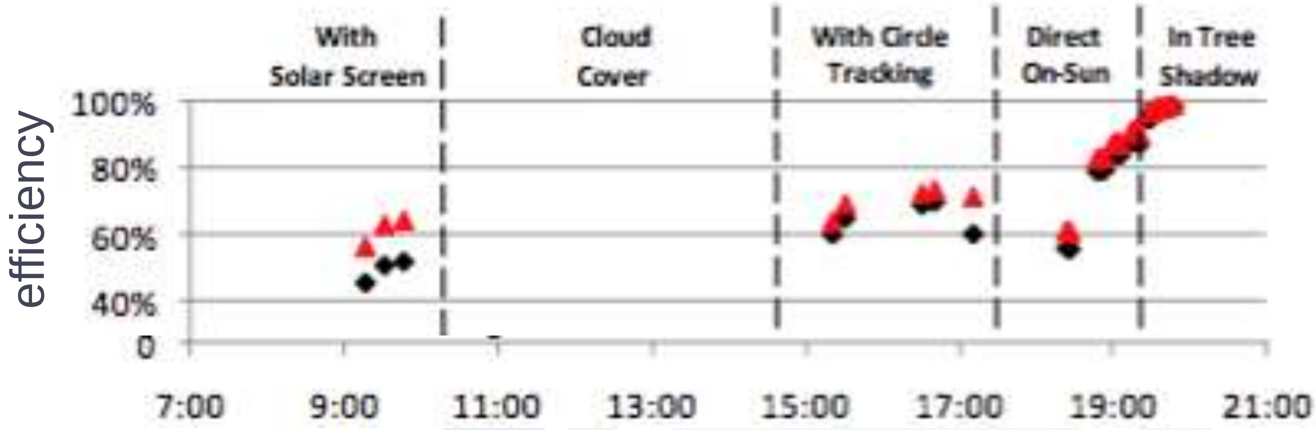


Zhang and Wang (2012)
η from 12 to 44%



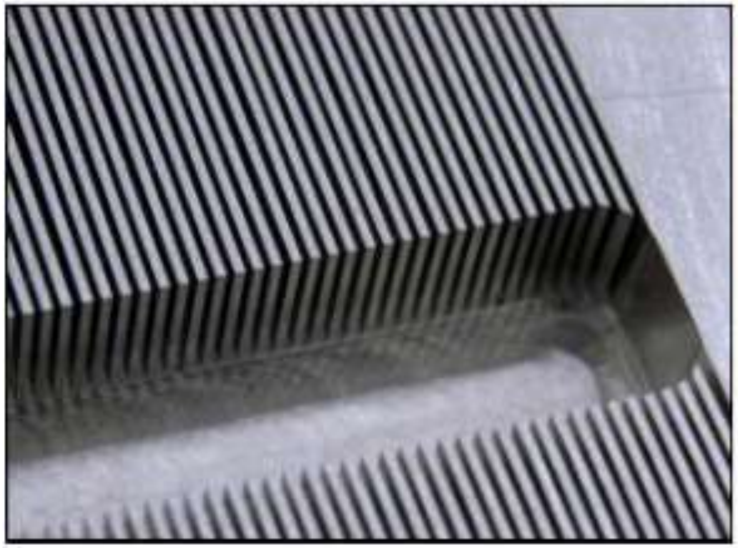


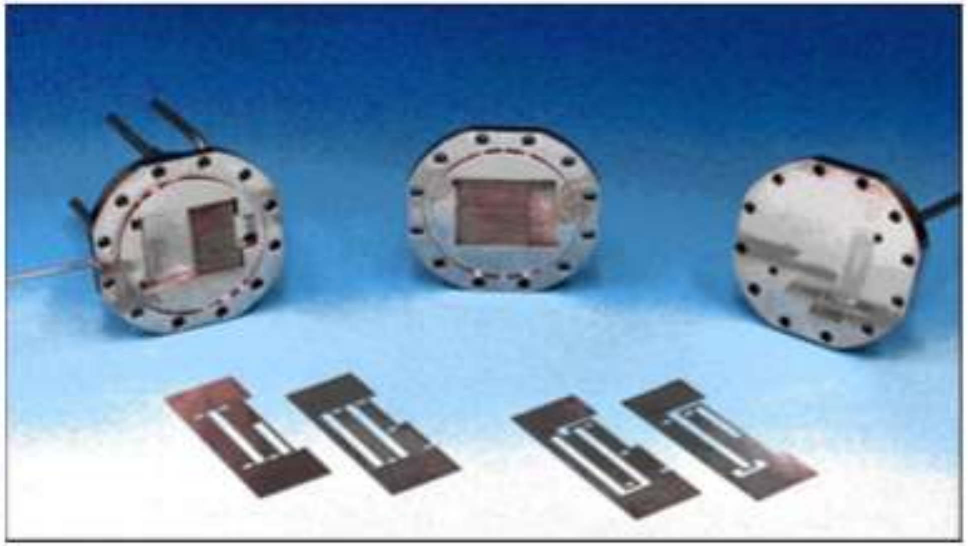
Microstructured heat sinks



steam
methane
reforming

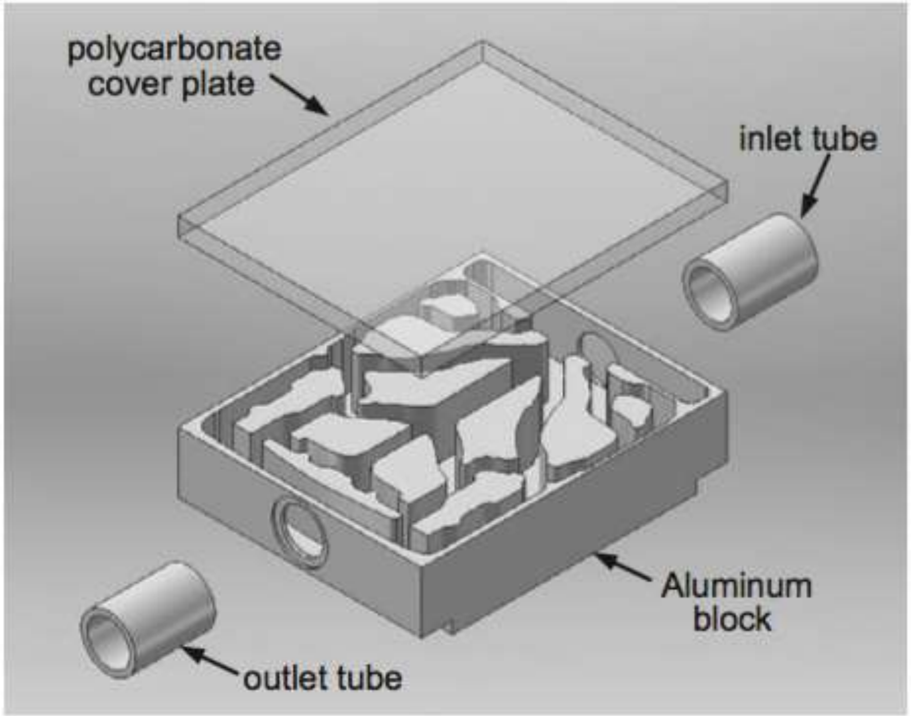
Wegeng et al. (2011)

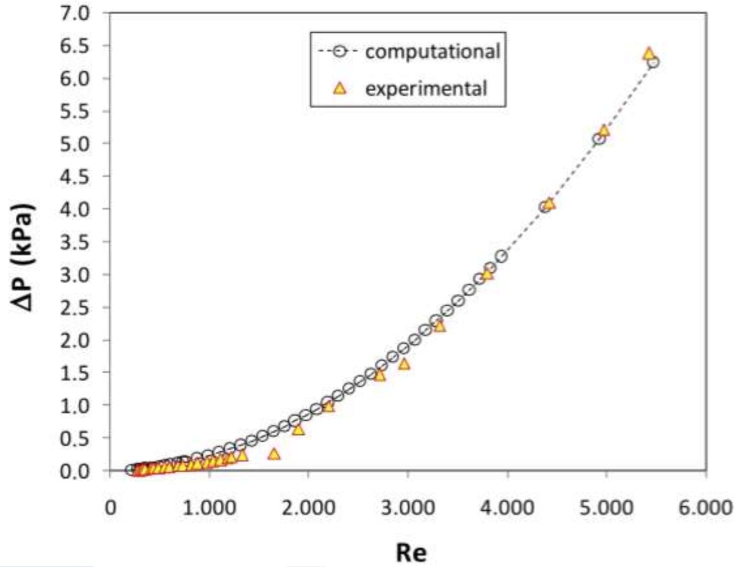


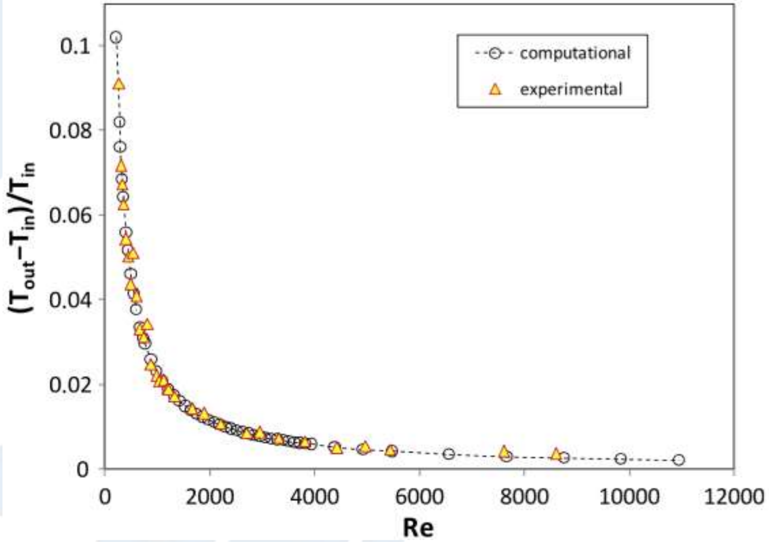


Microstructured heat sinks

- Novel designs





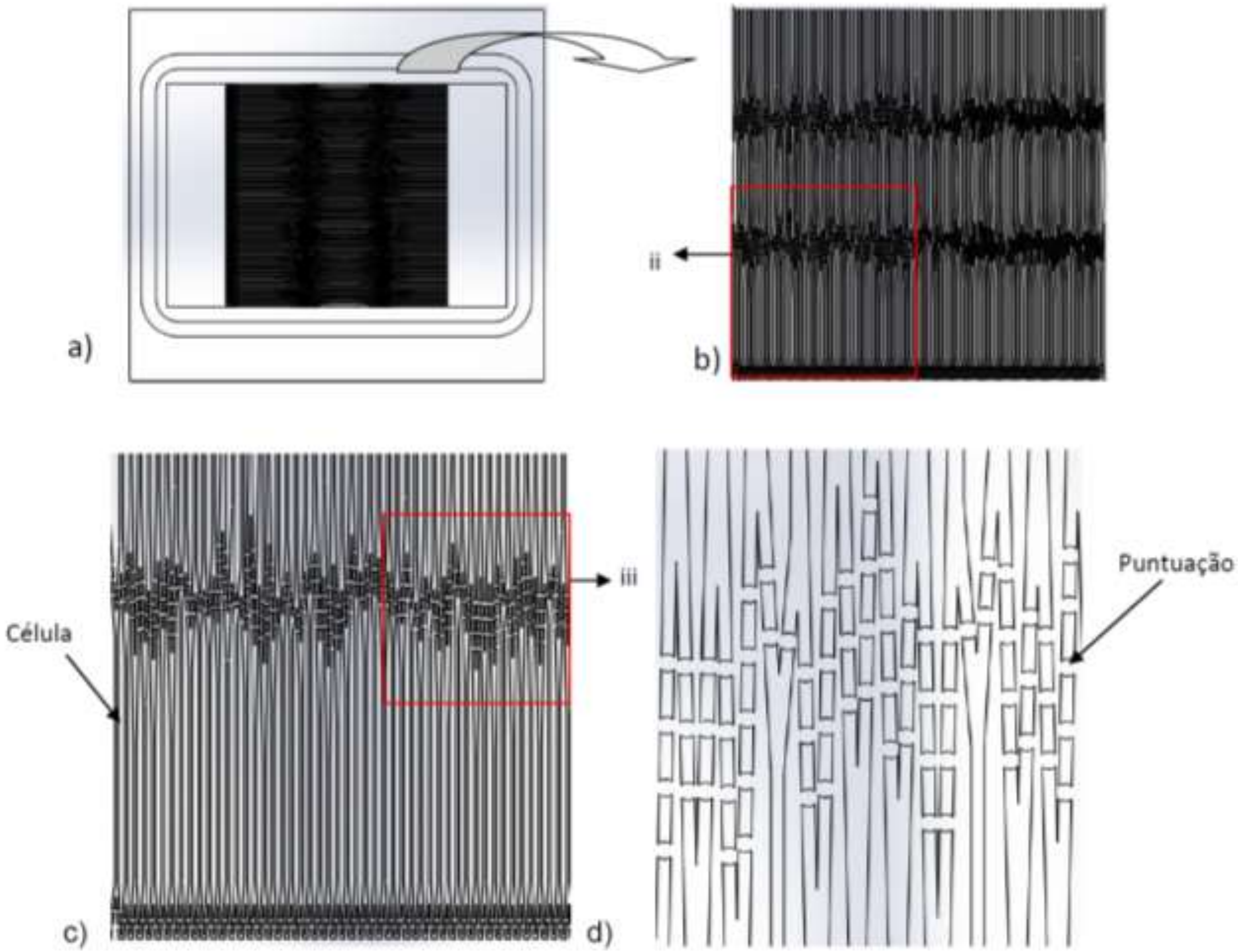


Koga et al. (2013)

Microstructured heat sinks

- Novel designs

Chávez and Ribatski (2014)



Microstructured heat sinks

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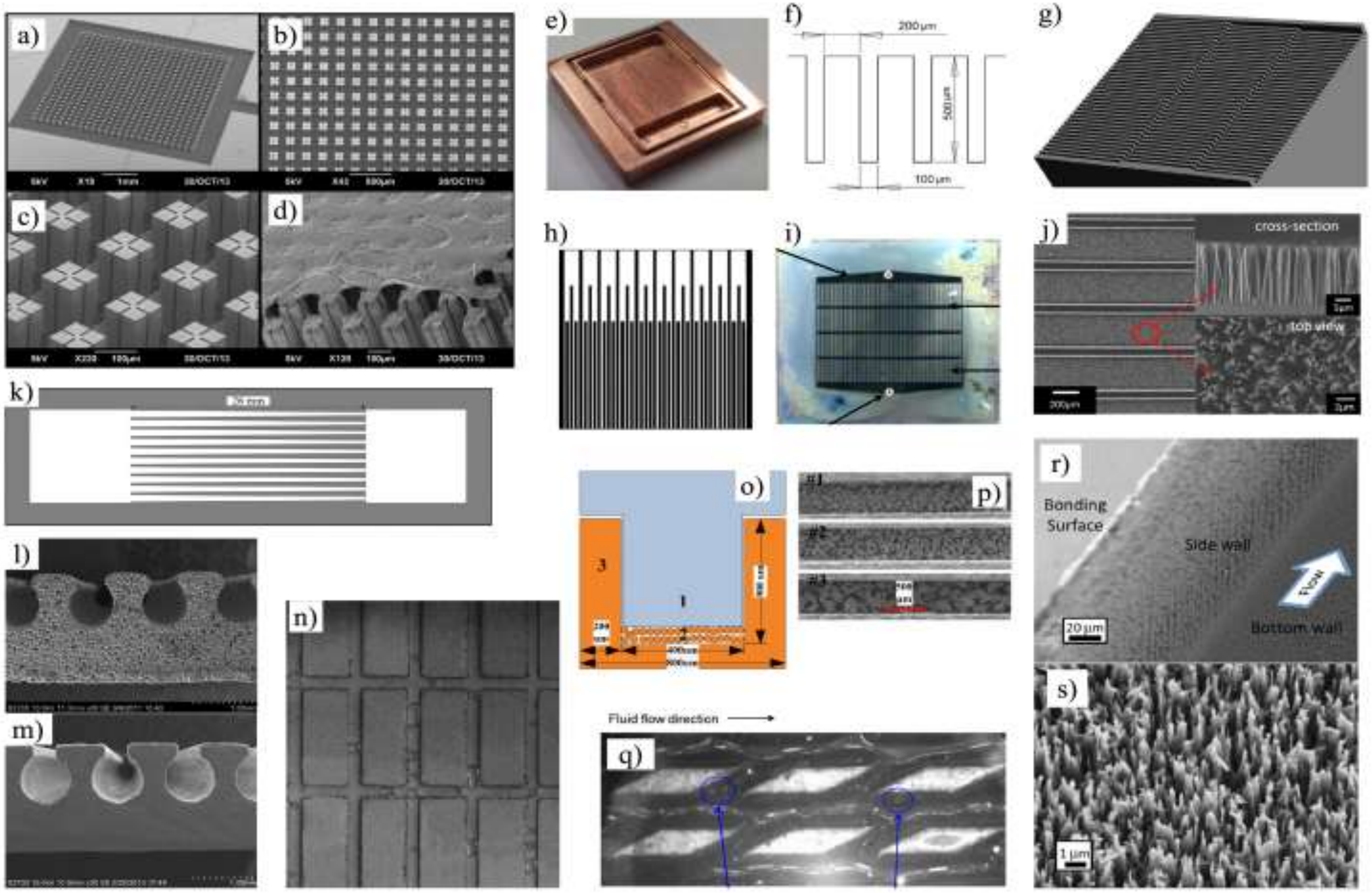

Microstructured heat sinks

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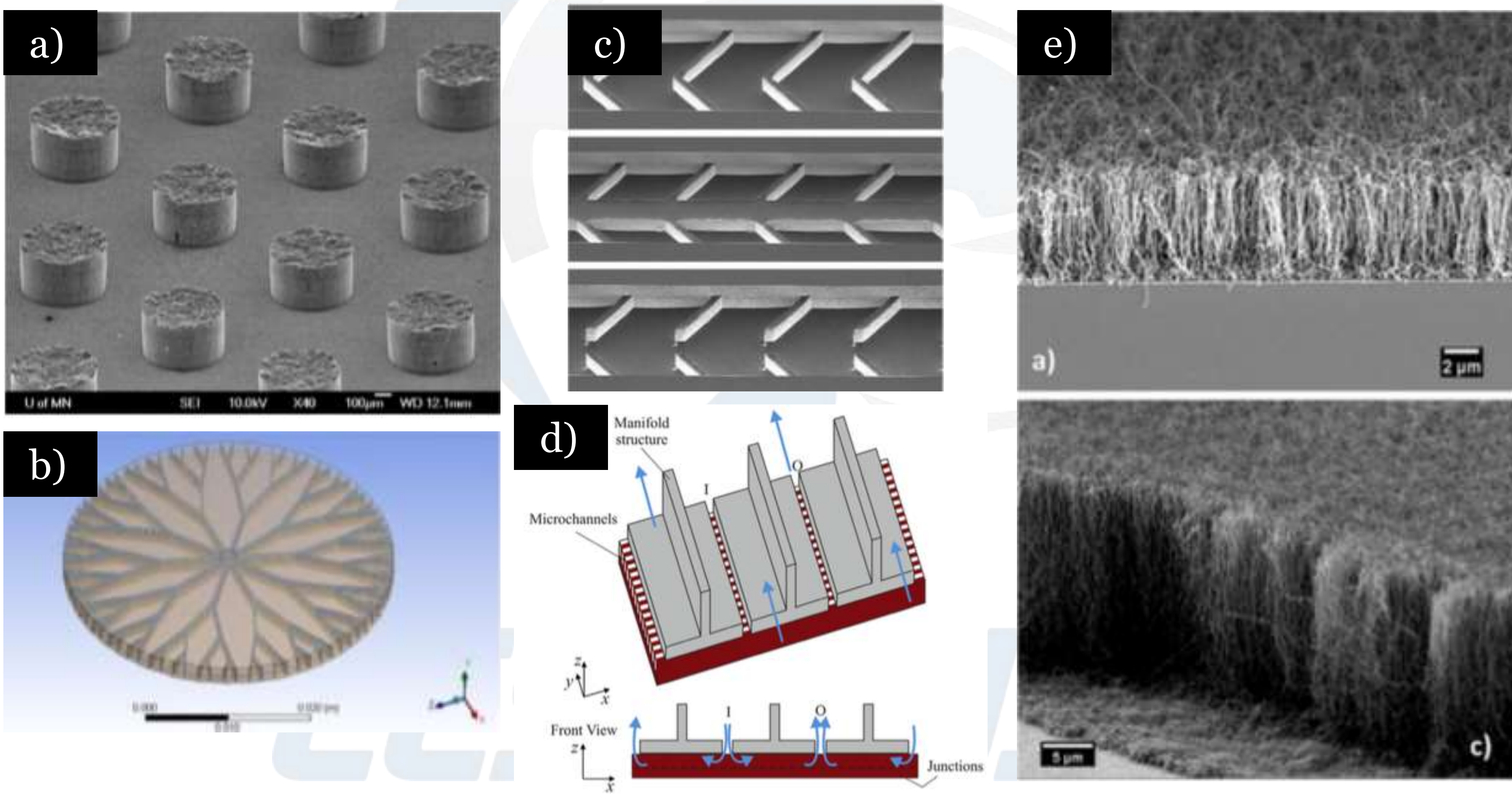

Microstructured heat sinks

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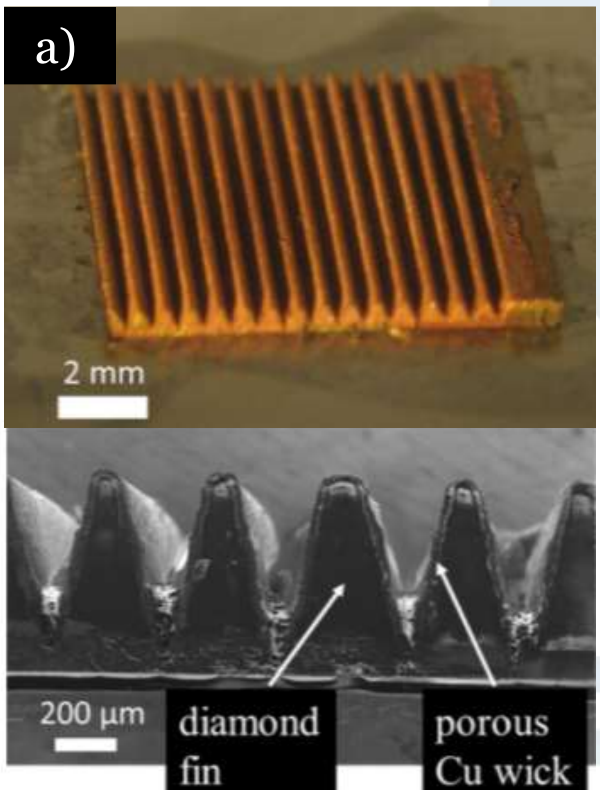
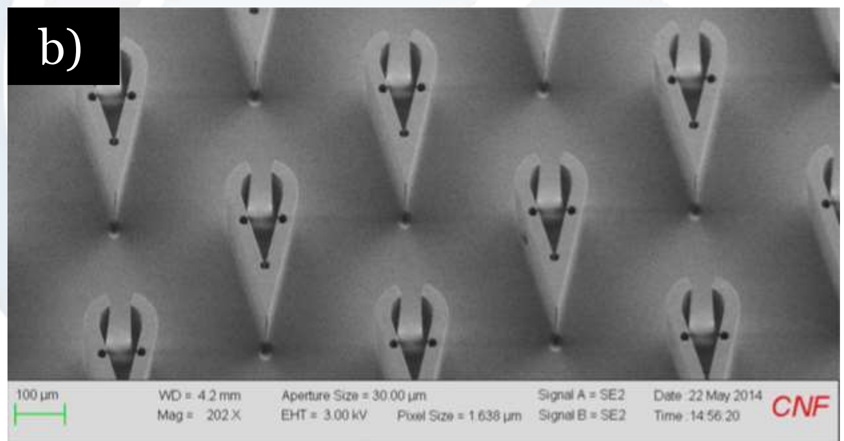
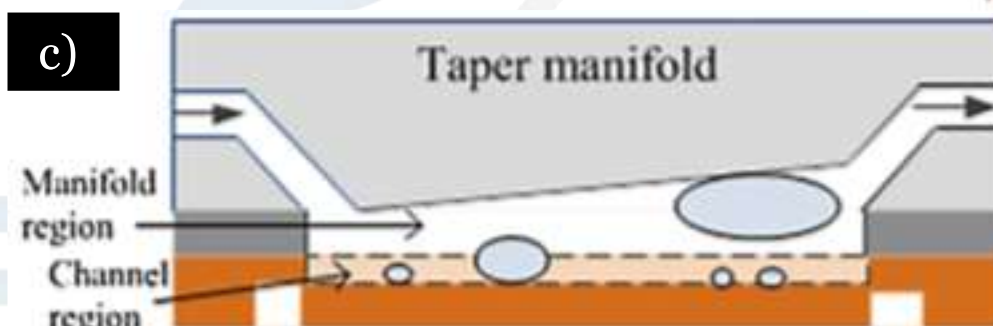
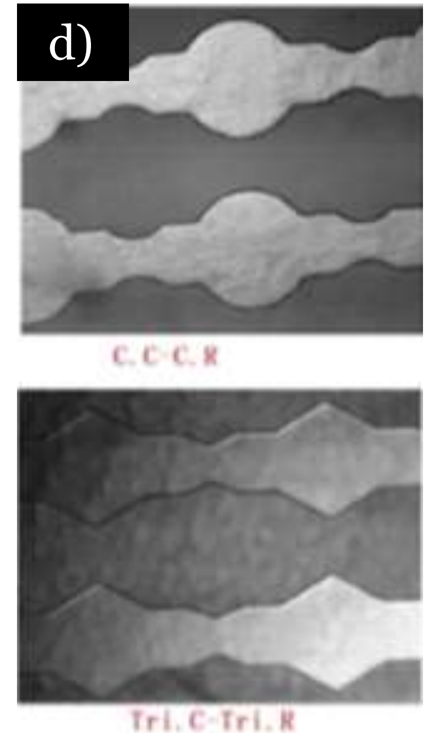


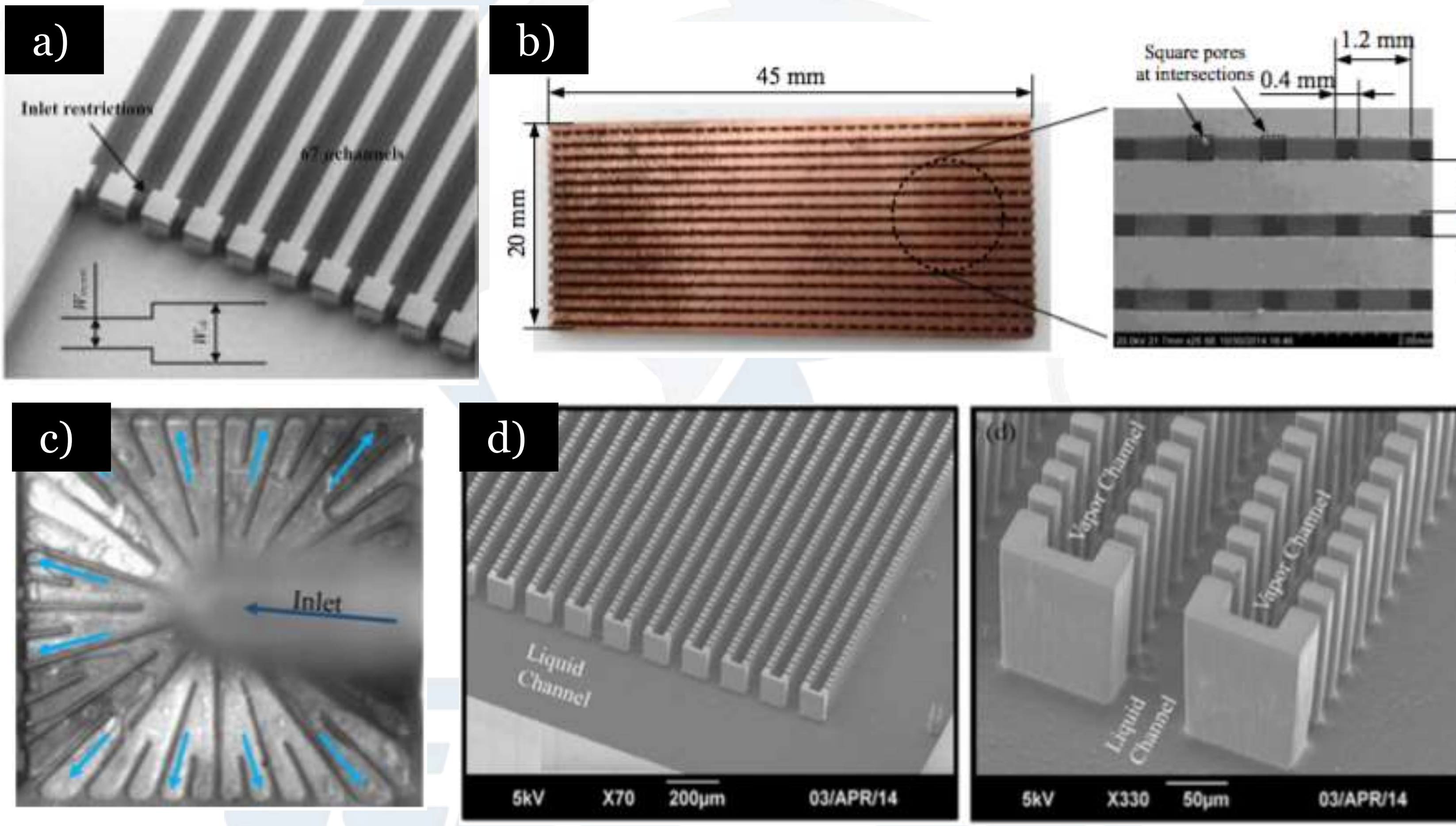






Microstructured heat sinks

- Novel designs



Concluding remarks

- Research needs:
  - Mal-distribution effects
  - Non-uniform heat distribution
  - Dynamic controlling systems
  - Increase CHF
  - Minimize instabilities
  - Cheaper and up-scalable fabrication
  - Design optimization techniques
  - Micro- and nanostructured surfaces
  - Flexible heat sinks


USP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Obrigado!
UDF
Centro
Universitário
UnB Gama
O novo endereço da tecnologia