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AN INVESTIGATION OF POROUS STRUCTURE CHARACTERISTICS OF HEAT PIPES MADE BY ADDITIVE MANUFACTURING

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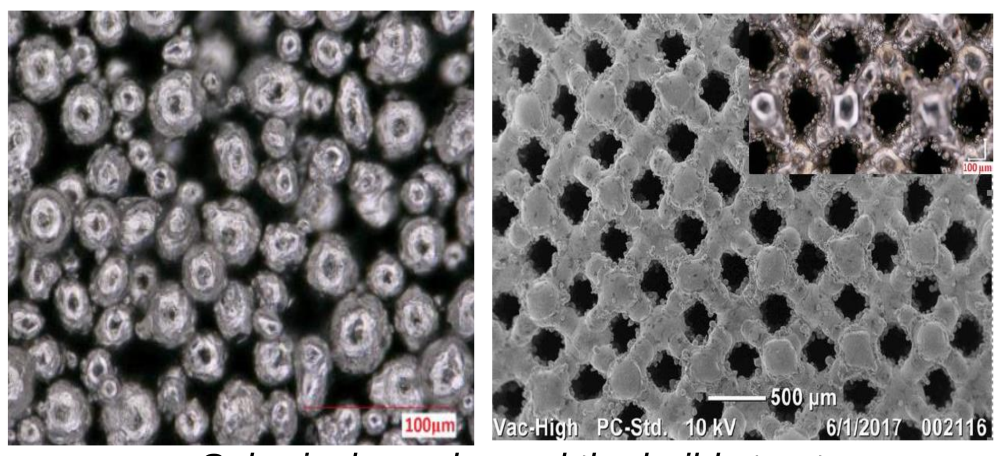
Highlights

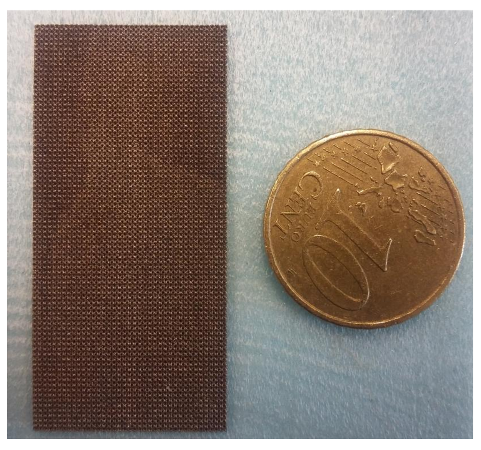
- ✓A rectangular-shaped stainless steel 316L porous structure is additively manufactured by selective laser melting (SLM).
- ✓Effective thermal conductivity and wicking of liquid into the porous structure have been experimentally analyzed.
- ✓The experimentally obtained values of thermal conductivity do not correspond well with correlations available in the literature.
- ✓The experimental results show that SLM technology can be used to fabricate porous structures for heat pipes technology.

Fabrication & Morphology analysis

- ✓The porous sample is manufactured using a Concept Laser Mlab Cusing 90, 3D metal printing machine.
- ✓The porous structure of 1 x 20 x 40 mm^3 is manufactured with a 500 µm octahedral unit cell size.
- ✓SS 316L powder size is in the range of 15-20 µm and pore sizes in the fabricated sample are around 160µm.
- ✓The porosity of the sample, measured by the Archimedes method, is 0.461.



Spherical powder and the build structure



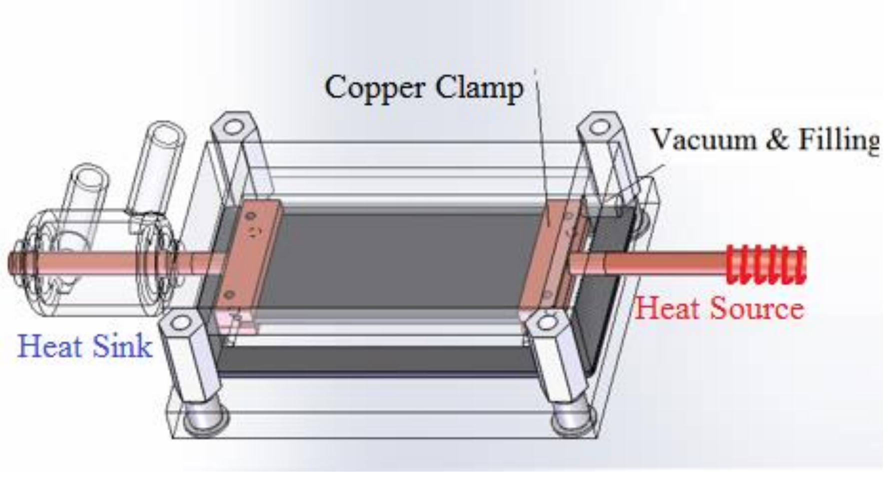
The fabricated sample

Development of experimental devices and results

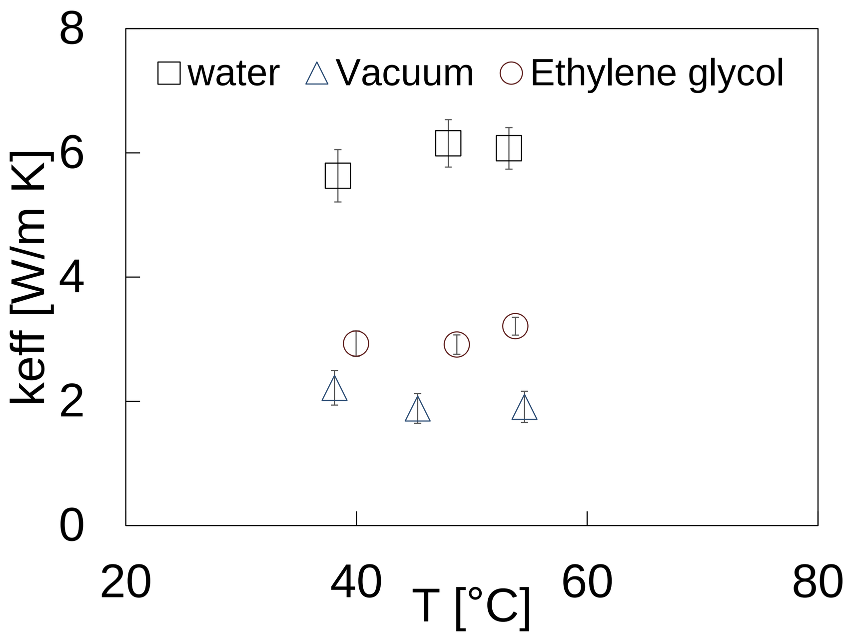
Effective thermal conductivity

- ✓The experimental set-up includes a heating and cooling sections and the test chamber.
- ✓Using the Fourier model the porous media effective thermal conductivity is calculated.

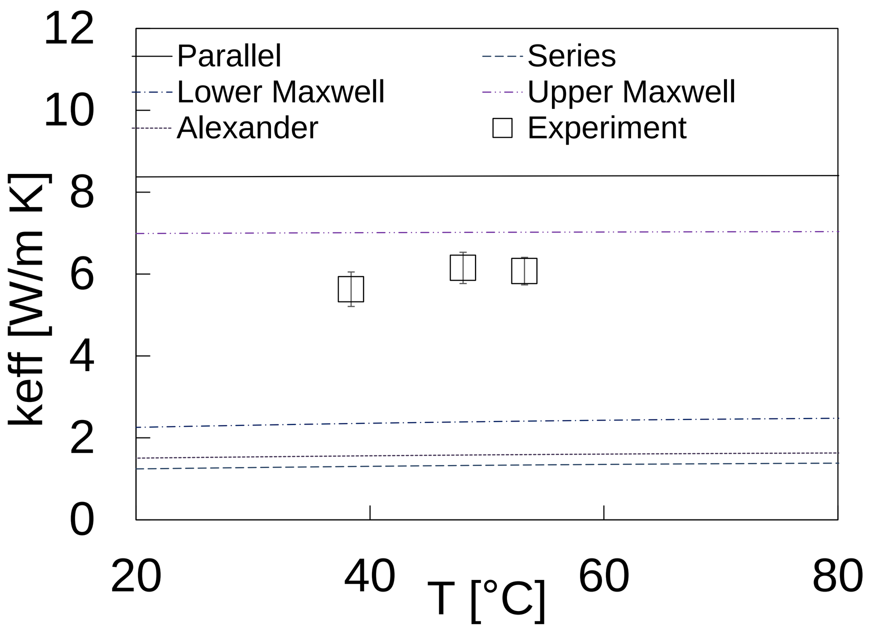
$$k_{eff} = \frac{lQ}{A\Delta T}$$



The thermal conductivity measurement set-up



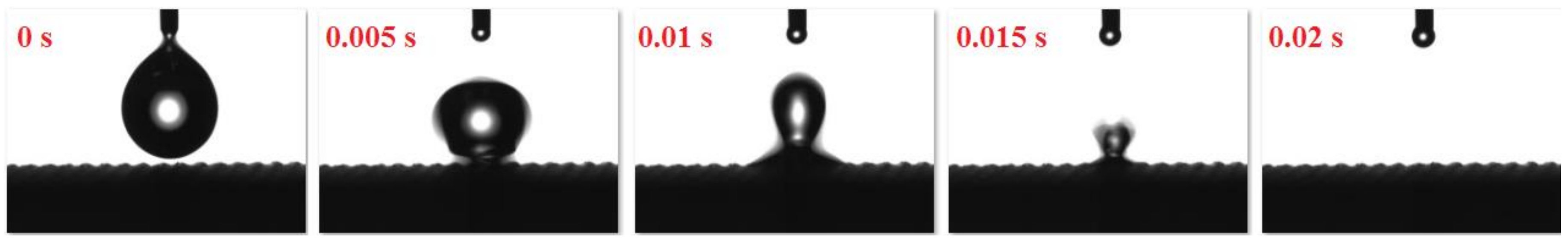
The effective thermal conductivity of the sample for different saturated fluids



Comparison of the experimental values of the effective thermal conductivity of the water-saturated porous sample

Droplet test

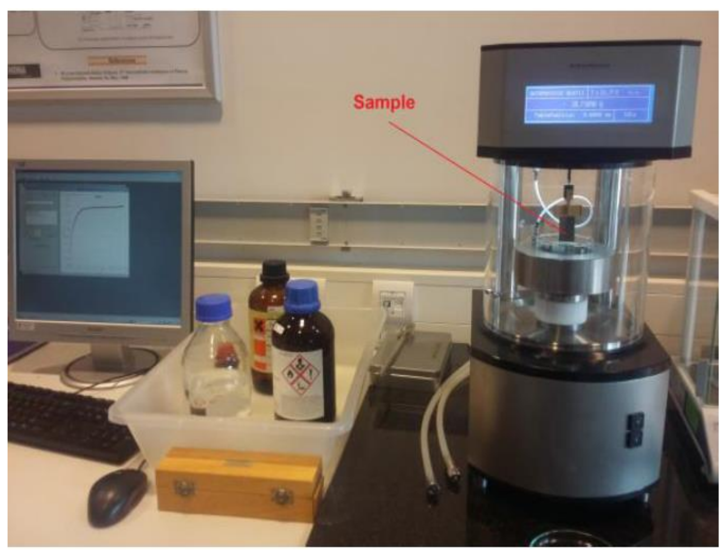
- ✓A water droplet (4.5 µL) is deposited into the wick structure.
- ✓The droplet infiltrates the porous layer in <0.02 s confirming excellent wetting.



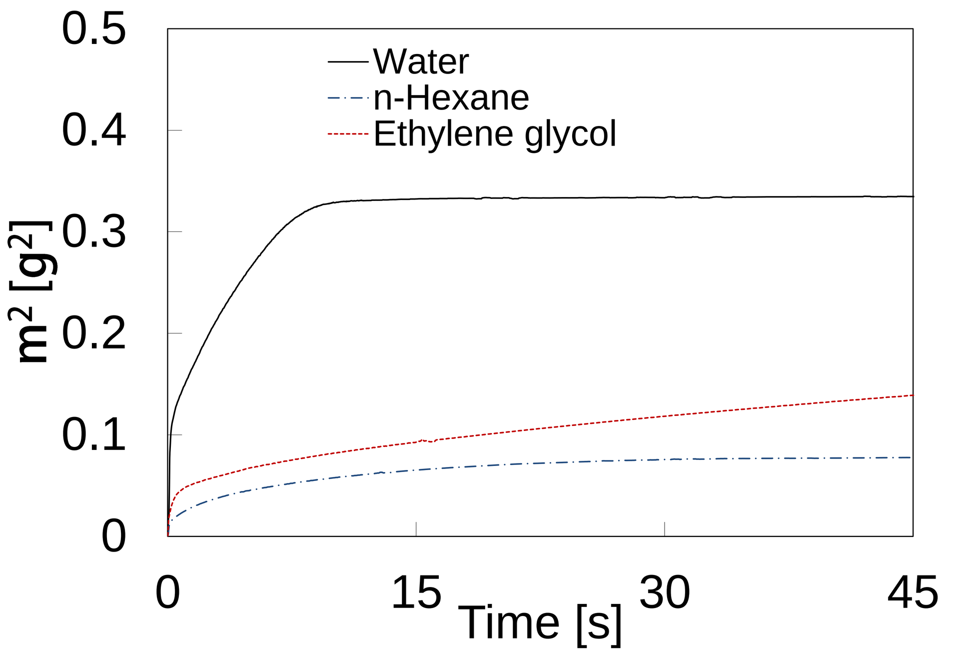
Instantaneous state photos of a deionized water droplet released onto the porous sample

Rate-of-rise method

- ✓The Washburn capillary rise (WCR) method is used to determine the contact angle.



Washburn capillary rise test set-up



Penetrating profiles of water, n-Hexane and ethylene glycol through the porous sample

Geometric factor C values, liquid penetration rates and contact angles

Liquid	C value [$\times 10^{16}$ m^5]	Contact angle [°]	Penetrating rate [$\times 10^{15}$]
n-Hexane	6.84±0.5	0	4.5±0.7
ethylene glycol	-	27.4±1.2	4,3±2.2
Water	-	56.8±0.8	27.1±1.4

Conclusions

- ✓The effective thermal diffusivity is in the range of 1.8~2.2 W/m·K in vacuum condition, ~3 W/m·K for ethylene glycol and ~6 W/m·K for water, thus observing high sensitivity to the interstitial fluid.
- ✓A comparison of the experimental results with available correlations in the literature shows the effective thermal conductivity is between the upper and lower Maxwell model, albeit with a fairly large margin.
- ✓It is demonstrated that during capillary rise, the contact angle can be measured.

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