Proceedings of the 11th World Congress on Mechanical, Chemical, and Material Engineering (MCM'25)
Paris, France - August, 2025
Paper No. HTFF 222
DOI: 10.11159/htff25.222

Thermographic Mapping and Wettability Alteration of Mini-Channel Heat Sinks: Impact on Fluid Flow and Heat Transfer

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Extended Abstract

Effective thermal management in compact electronic devices requires innovative cooling solutions that enhance heat transfer while minimizing pressure drop. Mini-channel heat sinks (MCHS) [1], [2] are widely used due to their high surface area and efficient convective heat transfer. This study presents a two-step investigation: initially, detailed thermographic mapping of an uncoated mini-channel heat sink was performed alongside numerical simulations to understand temperature distribution and flow characteristics; subsequently, the channel surface was modified by applying a hydrophobic coating to analyse its effect on thermohydraulic performance. In the first phase, experiments were conducted on aluminium mini-channels with hydrophilic surfaces using deionized water as the working fluid in laminar flow conditions. Infrared (IR) thermography was employed to capture high-resolution spatial temperature distributions along the channel walls. Numerical simulations using COMSOL Multiphysics were performed in parallel to solve the conjugate heat transfer problem and validate the experimental data. The close agreement between thermographic and simulated temperature profiles confirmed the reliability of the experimental setup and numerical model.

Following the baseline characterization, the internal surfaces of the mini-channels were treated with a commercial hydrophobic coating [3], [4] to alter surface wettability. Contact angle measurements indicated a significant increase from hydrophilic (<90°) to hydrophobic (>120°), confirming successful surface modification. Using the same test conditions, the thermohydraulic performance of the coated mini-channel was evaluated. The hydrophobic coating resulted in a substantial reduction in pressure drop due to decreased wall friction and the promotion of slip flow near the channel walls. However, infrared thermography revealed a slight decrease in heat transfer efficiency compared to the uncoated case. This reduction is attributed to decreased liquid-solid contact and the formation of bubbles adhered to the hydrophobic surface. These bubbles, observed during flow visualization, intermittently disrupted the thermal boundary layer, leading to localized decreases in heat transfer. Such bubble formation was absent in the hydrophilic channels, indicating a direct effect of surface wettability on interfacial fluid behaviour.

References

[1] K. An, Z. Su, M. Zhang, and Y. Deng, "Liquid metal-based micro/mini-channel heat transfer: Progress, challenges, and opportunities," *Appl. Therm. Eng.*, vol. 250, p. 123551, Aug. 2024, doi: 10.1016/j.applthermaleng.2024.123551.

[2] H. Xiao, Z. Liu, and W. Liu, "Conjugate heat transfer enhancement in the mini-channel heat sink by realizing the optimized flow pattern," *Appl. Therm. Eng.*, vol. 182, p. 116131, Jan. 2021, doi: 10.1016/j.applthermaleng.2020.116131.

[3] H. Babar, H. Wu, and W. Zhang, "Investigating the performance of conventional and hydrophobic surface heat sink in managing thermal challenges of high heat generating components," *Int. J. Heat Mass Transf.*, vol. 216, p. 124604, Dec. 2023, doi: 10.1016/j.ijheatmasstransfer.2023.124604.

[4] A. Khan, F. Hadi, N. Akram, M. A. Bashir, H. M. Ali, M. M. Janjua, A. Hussain, R. A. Pasha, A. B. Janjua and F. Farukh, "Review of micro and mini channels, porous heat sinks with hydrophobic surfaces for single phase fluid flow," *J. Taiwan Inst. Chem. Eng.*, vol. 132, p. 104186, Mar. 2022, doi: 10.1016/j.jtice.2021.104186.