Simulation of Heat Transfer on Periodic Microstructured Surfaces for Evaporation Cooling

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Abstract

The growing power density of electronic devices requires the development of new cooling methods and systems by which large heat fluxes can be dissipated. In this respect, evaporative cooling is an innovative and promising method [1, 2]. In addition to convective heat dissipation, the boiling fluid absorbs vaporization heat. Beside the operation by natural circulation, in which the fluid flow arises by natural convection, there is the possibility to apply a forced circulation. In this case the fluid flow is created by applying an external pressure difference what allows high flow velocities. Thus resulting vapor bubbles are removed quickly from the cooler surface and a high convective cooling performance can be achieved. In order to increase heat transfer microstructures can be machined into the cooler surface. That increases the heat transfer coefficient by enlarging the cooler surface and manipulates the fluid flow as well as the boiling process [1].

In this study the influence of cylindrical micro-structures with an aspect ratio of 0.5 on the heat transfer has been investigated analyzing conductive and convective components. Using COMSOL Multiphysics® a 3D model applying the Non-Isothermal Flow interface was created. The model exploits the symmetry of the steady flow field. Fluid with defined initial temperature and velocity flows over a micro-structured cooler segment where the undersurface is heated to a defined temperature. The investigated micro-structure arrangements are shown in Figure 1.

As an example for the results, Figure 2 shows heat flux streamlines through one of the investigated microstructure arrangements. An evaluation was carried out regarding the formed fluid flow and heat flow fields. In addition the results of a Richardson-Extrapolation of the achieved heat fluxes respectively heat transfer coefficients are analyzed.

Reference

[1] Schubert, A. et al.: Design and realization of micro structured surfaces for thermodynamic applications. Z. Microsystem Technology, (2011), Nr. 17, P. 1471-1479.
[2] Schubert, A. et al.: Energy-efficient cooling using microstructures for nucleate boiling. Z. Proceedings of the PCIM EUROPE ,(2013), P. 1036-1041, ISBN 978-3-8007-3505-1.

Figures used in the abstract

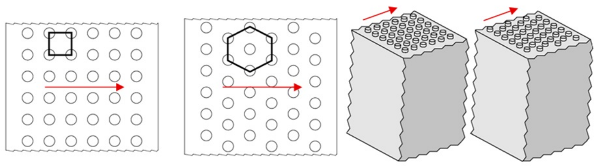

Figure 1: Investigated micro-structure arrangements (left: top views; right: 3D views)

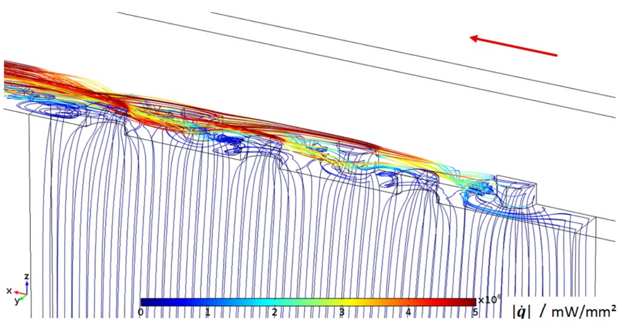

Figure 2: Heat flux streamlines through the hexagonal micro-structure arrangement