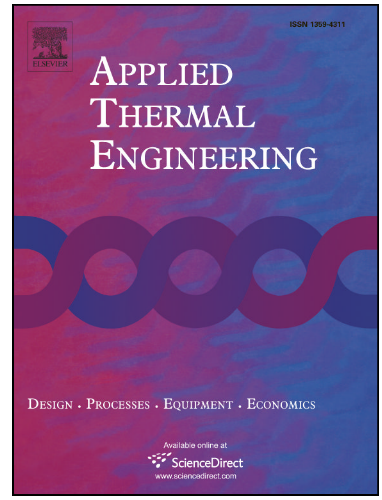

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Numerical parametric study of a hotspot-targeted microfluidic cooling array for microelectronics

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Highlights

- A novel concept for cooling integrated chips based on a cooling array with self-adaptive microvalves is numerically demonstrated
- The cooling scheme tailors the coolant flow rate distribution to the local heat flux passively, without sensors nor control circuitry
- The pumping power is nearly 10 times less than with conventional microchannels, under comparable conditions
- The temperature non-uniformity due to hotspots is practically eliminated due to the adaptive local cooling, even under varying operating conditions

Keywords
Electronics cooling
Hotspots
Self-adaptive cooling
Energy efficient computing
Microfluidics

Abstract

Thermal management in integrated chips is one of the major challenges on advanced microelectronics. The increase in power density is raising the need for microchannel liquid cooling solutions. Although this technology can accommodate high heat rates, it has poor temperature uniformity and may require significant pumping power. In this work, a cooling scheme aiming for high temperature uniformity and low pumping power is numerically studied. The cooling scheme consists in a matrix of microfluidic cells with thermostatic microvalves, fed by an interdigitated manifold. The flow through each cell is controlled with the self-adaptive microvalves to only deliver the flow rate required to maintain a design temperature. This system is assessed with steady state CFD and heat transfer studies of various microfluidic cell designs combined with a time-dependent and non-uniform heat load scenario of a chip with hotspots. The studied cooling scheme practically eliminates chip temperature non-uniformity while also reducing the pumping power by nearly one order of magnitude compared to traditional microchannel configurations for similar applications.

Nomenclature

ΔT	Increase of temperature [ºC]
T	Temperature [K]
ΔP	Pressure drop [Pa]
Q	Flow rate [mL/min]
P	Power [W]
q''	Heat flux [W/cm^2]
R	Thermal resistance coefficient [m^2·K/W]
ΔT_q	Normalized temperature difference [ºC]
COP	Coefficient of performance (Heat removed / pumping power)