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Editorial

Special Issue on Thermodynamics, Flow, and Heat Transfer in MEMS

Microelectromechanical systems (MEMS) equipment and products have gradually penetrated into modern life due to recent advances in fabrication processes. Accompanied with the fast-growing power consumption and increasing integration, requirement for miniaturization, compactness, and high performance have become more and more remarkable, resulting in problems such as higher heat loads and higher thermal resistance. Thermal management has emerged as one of the critical bottlenecks for further development of diverse, robust, and ultracompact MEMS. Thermodynamics, fluid flow, and heat transfer are important physical processes in advanced MEMS and affiliated parts. A better understanding of the mechanisms of thermodynamics, fluid mechanics, and heat transfer in MEMS is desired for advanced MEMS thermal management.

Extensive efforts have been directed toward advanced cooling schemes for removing high heat fluxes, e.g., direct and indirect liquid cooling, jet impingement, liquid-vapor phase change cooling, etc. MEMS thermal management demands high heat transfer coefficient, low pressure drop penalty, and low load-driven temperature nonuniformity. Besides, junction temperature rise and hot spots should be carefully manipulated. The main problems for single-phase cooling are temperature nonuniformity and relatively low heat transfer coefficient, while two-phase cooling is challenged by flow instabilities and possible associated large pressure drop penalty. Therefore, enhancement techniques might be incorporated in present cooling approaches for further heat transfer augmentation and flow stabilization. In an effort to synthesize recent development in MEMS thermal management and to improve our fundamental understanding of the involved scientific issues related to thermodynamics, fluid mechanics, and heat transfer, invitations were sent to a group of researchers, who have been actively involved in the research and development of MEMS thermal management, to submit their articles for the special issue of *Journal of Electronic Packaging* (JEP). After careful reviews of all the submissions following the standard reviewing process for regular JEP papers, 11 articles were finally accepted for this special issue.

These articles address a variety of topics, including enhancement of single-phase cooling (e.g., enhancement by offset strip fins, pin-fins, grooves and obstacles, and dimples and protrusions), analytic and numerical models from microchannel heat sink level to system level (e.g., resistance-capacity network modeling of multicomponent systems, and porous media modeling of two-phase cooling with nonuniform power distribution), development of three-dimensional multicavity microprocessor chip stacks, a three-stage design approach for microchannel systems of multi-core processors, on-chip power generation using ultrathin thermoelectric generators, etc. Recent advances and suggestions in integrated cooling systems were presented for three-dimensional integrated circuit. Besides, advances of wafer level packaging were reviewed.

Although a wide range of topics are touched upon, it is not possible to cover the entire field of MEMS thermal management in a single journal issue. Some other important topics on thermodynamics, flow and heat transfer in MEMS, such as junction temperature rise, evaporative instability, two-phase cooling enhancement and thermodynamics of advanced electronic packaging, are not considered in this issue. However, no attempt was taken to make it a comprehensive review either. Instead, it is hoped that this special issue presents the readers with a snapshot of the recent trends and developments in thermodynamics, flow and heat transfer in MEMS. Most likely, these papers will generate and stimulate more interests and discussions, and consequently lead to more innovations and technology advances in MEMS thermal management and to promote the development of the next generation cooling schemes for MEMS.

Finally, all the contributors of this special issue are gratefully acknowledged for their support and cooperation. I really appreciate the JEP Editor Professor Bahgat Sammakia for giving me the opportunity to edit a special issue on very timely topics. I also thank the assistant Editor Dr. Gary Miller for help to manage the process of the special issue. The present volume is the first special issue on thermodynamics, flow, and heat transfer in MEMS, and it is hoped that it forms the beginning of a series that will periodically stimulate researchers to publish the highlights and original articles reporting new advances in MEMS.

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