



Heat transfer enhancement of phase-change materials (PCMs) based thermal management systems for electronic components: A review of recent advances

Ibtissam Afaynou^a, Hamza Faraji^{b,*}, Khadija Choukairy^a, Adeel Arshad^{c,*}, Müslüm Arıcı^d

^a Laboratory of Computer and Mathematical Process Engineering, National School of Applied Sciences, Moulay Elmhaj University, Khourfiga, Morocco

^b USA Laboratory, National School of Applied Sciences, Cadi Ayyad University, Marrakech, Morocco

^c Environment and Sustainability Institute (ESI), Faculty of Environment, Science and Economy, University of Exeter, Penryn Campus, Cornwall TR10 9FE, United Kingdom

^d Mechanical Engineering Department, Engineering Faculty, Kocaeli University, Kocaeli 41060, Turkey

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ABSTRACT

Thermal control of electronic components using phase-change materials (PCMs) in heat sinks is an efficient method that has attracted the attention of numerous researchers. However, because of its poor thermal conductivity restrict their usage for cooling electronic components. Hence, to overcome this issue, thermal conductivity enhancers (TCEs) are used. The aim of this article is to conduct a review of different TCEs techniques applied on the PCM-based heat sinks. Included are recent papers on experimental and numerical works with an emphasis on analysing the impact of using TCEs such as *fin*, *foam* and *nanoparticles* for improving the thermal performance of the PCM-based heat sinks. According to the literature, few studies have been conducted on PCM-based heat sink under intermittent conditions. In addition, there is a lack of numerical works on hybrid heat sinks that showed great thermal cooling than conventional heat sinks. Furthermore, it seems that the interesting heat transfer capabilities of nanoparticles systems, as passive solutions for electronic thermal management are preferable. Because of their high thermal conductivity, high heat storage and with light weight than *fin* and *foam* as TCEs techniques. Other conclusions and future perspectives are introduced.

1. Introduction

In recent years, the rate of progress in the requirements for electronic devices in various applications such as aerospace, transport and communications are increasingly high due to the rapid growth of society's demand. With the development of integrated circuits technologies that still follow the classical Moore's law, there is a continuous increase of the power density and the miniaturization of electronic components from micro to nanometre increasing circuit speeds and high performance. According to Taiwan Semiconductor Manufacturing company, electronic chips of 3 nm were putting into production in 2021, and chips of 2 nm factory is being built [1]. In addition, the number of electronic components (transistors) that can be embedded on the integrated circuit continues to grow according to Moore's law [1]. For example, the number of transistors mounted in Corei7 was >731 million transistors on a surface of 270 mm², which increased its thermal power rating to

140 W [2]. That makes their peak temperature higher, shortens its life and reduces their performance. However, the electronic component (transistors) working reliability and its operating temperature are closely related and depends exponentially. As estimated by Black's correlation [3], the median time to failure (MTTF), in hours is calculated as follows:

$$MTTF = \frac{1}{A_p} \exp\left(\frac{E_a}{K_B T}\right) \quad (1)$$

Eq. (1) demonstrated that a slight increase in working temperature could significantly increase the device failure rate. Experimental observations revealed that the electronic components operating, under high-temperature situations can result in failure. At any temperature compared to that of 75 °C, the failure factor increases exponentially with rising the device operating temperature [3], as illustrated in Fig. 1.

Besides failure, a high temperature rise of electronic components will creates inevitable challenges in the thermal management area and

* Corresponding authors.

E-mail addresses: hamza.faraji@uca.ac.ma (H. Faraji), a.arshad@exeter.ac.uk, adeel_kirmanski@hotmail.com (A. Arshad).

Recent Advances In Heat Mass Transfer

**Sendhil Kumar Natarajan, Rajiv
Prakash, K. Sankaranarayanasamy**



Recent Advances In Heat Mass Transfer:

Recent Advances in Heat and Mass Transfer, 1961 Recent Advances in Analysis of Heat Transfer for Fin Type Surfaces Bengt Sundén, P. J. Heggs, 2000 Description of the editor This volume is concerned with the heat transfer from extended surfaces such as fins attached to a primary transfer surface These are used extensively within heat exchangers and on heat transfer equipment to ensure that a specified rate of heat transfer is achieved between a heat source and sink All of the chapters come from invited contributors and follow a unified outline and presentation Contents Overview of Extended Surface Heat Transfer Fins Coupled Forced Convection Conduction and Thermal Radiation of a Rectangular Fin in a Confined Space Mechanistic Investigation of the Performance of a Triangular Fin Conjugate Free and Mixed Convection Heat Transfer from a Vertical Fin Embedded in a Porous Medium About Fin Performance and Optimization Two Dimensional Effects in Extended Surface Assessment Steady State Heat Transfer and Performance Assessment Multi Louvred Fin Surfaces Methodology for the Design of Multi Stream Plate Fin Heat Exchangers Incorporation of a Consideration of Operability into the Design of Multi Stream Heat Exchangers WIT Press *Recent Advances in Heat and Mass Transfer* James P. Harnett, 1961 Recent Advances in Heat Pipes Wael I.A. Aly, 2019-09-18 Heat pipes are considered as an effective thermal solution particularly in high heat flux applications and in situations where there is a combination of nonuniform heat loading limited airflow over the heat generating components and space or weight constraints This book is intended to explore some of the recent advances in heat pipes and their applications in thermal systems The first chapter is an introductory chapter about the recent advances in heat pipes in general The second chapter is about thermosyphon heat pipe technology working principles advantages and disadvantages application ranges and using computational fluid dynamics in modeling thermosyphons The third chapter is about recent research into loop heat pipes LHPs The last chapter presents a novel liquid vapor separator incorporated gravitational LHP Recent Advances in Liquid-Liquid Extraction C. Hanson, 2013-10-22 *Recent Advances in Liquid liquid Extraction* focuses on the applications of liquid extraction The selection first discusses solvent extraction Concerns include organic and inorganic separations mass transfer process solvent extraction economics and coalescence in liquid liquid systems The book focuses on the chemistry of solvent extraction Extraction by acidic organophosphorus compounds extraction by phosphorus bonded oxygen donor solvents extraction by high molecular weight amines and synergistic extraction are elaborated The book also focuses on industrial organic processes industrial contacting equipment response characteristics and control of extraction processes and calculation of contactors with longitudinal mixing The selection presents the study of longitudinal mixing in liquid liquid contactors Rotating disc contactors packed columns vibrating plate extractors and Oldshue Rushton columns are described The text also discusses heat transfer by direct liquid liquid contact and the coalescence of liquid droplets and liquid dispersion The selection is a vital source of data for readers interested in liquid extraction *Recent Advances in Finite-time Thermodynamics* Chih Wu, 1999 Finite time

thermodynamics FTT is one of the newest and most challenging areas in thermodynamics The objective of this book is to provide results from research which continues at an impressive rate The authors make a concentrated effort to reach out and encourage academic and industrial participation in this book and to select papers that are relevant to current problems and practice The numerous contributions from the international community are indicative of the continuing global interest in finite time thermodynamics All represent the newest developments in their respective areas Recent Advances in Heat Transfer and Micro-structure Modelling for Metal Processing Remn-Min Guo,James J. M. Too,1995 A balance of contributors from the metal industry and academia share theoretical and practical information relevant to meeting the need for conserving energy and resources and the increasing high quality and cost effectiveness demanded by world market competition by applying newly developed modelin **Recent Advances in heat and mass transfer** JP Hartnett (Ed),1961

Recent Advances in Thermal Engineering C. V. Chandrashekara,N. Rajesh Mathivanan,K. Hariharan,K. H. Jyothiprakash,2024-07-12 This book presents the select proceedings of 21st ISME conference on Advances in Mechanical Engineering It covers the latest research and technological advancements in the area of thermal engineering Various topics covered in this book are multi phase flow alternative fuels fluid mechanics combustion and IC engines fluid machinery heat and mass transfer refrigeration and air conditioning renewable sources of energy thermal systems simulation heat exchangers flow measurements etc The book is useful for researchers and professionals working in thermal engineering and allied fields **Recent Advances in Fluid Dynamics** Jyotirmay Banerjee,Rupesh D. Shah,Ramesh K. Agarwal,Sushanta Mitra,2022-09-24 This book presents select proceedings of the International Conference on Advances in Fluid Flow and Thermal Sciences ICAFFTS 2021 and summarizes the modern research practices in fluid dynamics and fluid power The content of the book involves advanced topics on turbulence droplet deposition oscillating flows wave breaking spray structure and its atomization and flow patterns in mini and micro channels Technological concerns relevant to erosion of steam turbine blade due to droplets influence of baffle cut and baffle pitch on flow regime bubble formation and propagation in pool boiling design optimization of flow regulating valves are included in the book In addition recent trends in small scale hydropower plant and flow stability issues in nanofluids solar water heating systems and closed loop pulsating heat pipes are discussed Special topics on airflow pattern in railway coach and vortex tube are also included This book will be a reliable reference for academicians researchers and professionals working in the areas of fluid dynamics and fluid power Recent Advances in Applied Mathematics and Applications to the Dynamics of Fluid Flows Suripeddi Srinivas,Badeti Satyanarayana,J. Prakash,2022-10-15 This book presents select proceedings of the 5th International Conference on Applications of Fluid Dynamics ICAFD 2020 organized by the School of Mechanical Engineering Science VIT AP University India in association with the University of Johannesburg Auckland Park Kingsway Campus South Africa It identifies the existing challenges in the area of applied mathematics and mechanics of solids and fluids and emphasizes the importance of

establishing new methods and algorithms to address these challenges The topics covered include diverse applications of fluid dynamics in aerospace dynamics and propulsion atmospheric sciences compressible flow environmental fluid dynamics control structures viscoelasticity and mechanics of composites Given the contents the book will be a useful resource for researchers as well as practitioners working in the area of mechanical engineering and applied mathematics **Challenges**

and Recent Advances in Sustainable Oil and Gas Recovery and Transportation Sanket Joshi, Prashant Jadhawar, Asheesh Kumar, 2023-03-10 Challenges and Recent Advances in Sustainable Oil and Gas Recovery and Transportation delivers a critical tool for today's petroleum and reservoir engineers to learn the latest research in EOR and solutions toward more SDG supported practices Packed with methods and case studies the reference starts with the latest advances such as EOR with polymers and EOR with CCS Advances in shale recovery and methane production are also covered before layering on sustainability methods on critical topics such as oilfield produced water Supported by a diverse group of contributors this book gives engineers a go to source for the future of oil and gas The oil and gas industry are utilizing enhanced oil recovery EOR methods frequently but the industry is also tasked with making more sustainable decisions in their future operations Provides the latest advances in enhanced oil recovery EOR including EOR with polymers EOR with carbon capture and sequestration CCS and hybrid EOR approaches Teaches options in recovery and transport such as shale recovery and methane production from gas hydrate reservoirs Includes sustainability methods such as biological souring and oil field produced water solutions **Recent Advances in Manufacturing, Automation, Design and Energy**

Technologies Sendhil Kumar Natarajan, Rajiv Prakash, K. Sankaranarayanan, 2021-10-11 This book comprises the proceedings of the 1st International Conference on Future Technologies in Manufacturing Automation Design and Energy 2020 The contents of this volume focus on recent technological advances in the field of manufacturing automation design and energy Some of the topics covered include additive manufacturing renewable energy resources design automation process automation and monitoring etc This volume will prove a valuable resource for those in academia and industry *Recent Advances in Pyrolysis* Hassan Al- Haj Ibrahim, 2020-01-22 Pyrolysis is an irreversible thermochemical treatment process of materials at elevated temperatures in an inert atmosphere It is basically a carbonisation process where an organic material is decomposed to produce a solid residue with high or higher carbon content and some volatile products The decomposition reactions are accompanied in general with polymerisation and isomerisation reactions The end products of pyrolysis can be controlled by optimizing pyrolysis parameters such as temperature and residence time Pyrolysis is used heavily in the chemical industry to produce many forms of carbon and other chemicals from petroleum coal wood oil shale biomass or organic waste materials and it is the basis of several methods for producing fuel from biomass Pyrolysis also is the process of conversion of buried organic matter into fossil fuels *Recent Advances in Material, Manufacturing, and Machine Learning*

Rajiv Gupta, Devendra Deshmukh, Awanikumar P. Patil, Naveen Kumar Shrivastava, Jayant Giri, R.B. Chadge, 2023-05-26 The

role of manufacturing in a country's economy and societal development has long been established through their wealth generating capabilities. To enhance and widen our knowledge of materials and to increase innovation and responsiveness to ever increasing international needs more in depth studies of functionally graded materials, tailor made materials, recent advancements in manufacturing processes and new design philosophies are needed at present. The objective of this volume is to bring together experts from academic institutions, industries and research organizations and professional engineers for sharing of knowledge, expertise and experience in the emerging trends related to design, advanced materials processing and characterization and advanced manufacturing processes.

Recent Advances in Mechanical Engineering Anoop Kumar Shukla, Bhupendra Prakash Sharma, Ahmad Arabkoohsar, Pradeep Kumar, 2023-06-18. This volume comprises the select proceedings of the 3rd Biennial International Conference on Future Learning Aspects of Mechanical Engineering FLAME 2022. It aims to provide a comprehensive and broad spectrum picture of the state of the art research and development in thermal fluids, energy and process engineering, mechatronics, control and robotics, material science and engineering, solid mechanics and structural engineering, dynamics and control engineering, design, manufacturing and industrial engineering, automobile engineering. This volume will prove a valuable resource for researchers and professionals in mechanical engineering and allied fields.

Recent Advances in Material, Manufacturing, and Machine Learning Bjorn Schuller, Rajeev Gupta, Rakesh Mote, Abhishek Sharma, J.P. Giri, R.B. Chadge, 2024-06-17. The main aim of the 2nd international conference on recent advances in materials, manufacturing and machine learning processes 2023 RAMMML 23 is to bring together all interested academic researchers, scientists, engineers and technocrats and provide a platform for continuous improvement of manufacturing, machine learning, design and materials engineering research. RAMMML 2023 received an overwhelming response with more than 530 full paper submissions. After due and careful scrutiny, about 120 of them have been selected for presentation. The papers submitted have been reviewed by experts from renowned institutions and subsequently the authors have revised the papers duly incorporating the suggestions of the reviewers. This has led to significant improvement in the quality of the contributions. Taylor Francis publications, CRC Press, have agreed to publish the selected proceedings of the conference in their book series of Advances in Mechanical Engineering and Interdisciplinary Sciences. This enables fast dissemination of the papers worldwide and increases the scope of visibility for the research contributions of the authors.

Recent Advances in Thermal Sciences and Engineering Hemant B. Mehta, Manish K. Rathod, Rufat Abiev, Müslüm Arıcı, 2023-05-05. This book presents select proceedings of the International Conference on Advances in Fluid Flow and Thermal Sciences ICAFFTS 2021 and summarizes the modern research practices in thermal sciences and engineering. The content of the book involves advanced topics in heat transfer, science, automobile, refrigeration and air conditioning, cryogenics, non conventional systems and energy storage. Topics on cutting edge research in the area of hybrid nano PCM based systems, solar based applications, bio diesel and nano additives based combustion, fuel cell and

thermoacoustic engine are also included In addition this book contains recent research in the area of two phase thermal management of Li Ion Li titanium battery and LED systems using heat sink heat pipe pulsating heat pipe and thermosyphon with next generation refrigerants PCM and nanofluid Some thermal aspects of virus aerosol research advances in volumetric velocimetry and application of artificial intelligence in thermal systems are also covered This book is a valuable reference for academicians researchers and professionals working in the various fields of thermal sciences **Recent Advances in**

Mechanical Engineering Harish Kumar, Prashant K. Jain, 2020-01-24 This book presents the selected peer reviewed papers from the National Conference on Advances in Mechanical Engineering NCAME 2019 held at the National Institute of Technology Delhi India The book covers different areas of mechanical engineering from design engineering to manufacturing engineering A wide range of topics are discussed such as CAD CAM additive manufacturing fluid dynamics materials science and engineering simulation and modeling finite element analysis applied mechanics to name a few The contents provide an overview of the state of the art in mechanical engineering research in the country Given the scope of the topics covered the book will be of interest for students researchers and professionals working in mechanical engineering **Recent Advances**

in Mechanical Engineering, Volume 1 Gujjala Raghavendra, B. B. V. L. Deepak, Manoj Gupta, 2024-04-01 This book presents select proceedings of International Conference on Mechanical Engineering Researches and Evolutionary Challenges ICMech REC 23 It covers the latest research in the areas of mechanical engineering and materials applications Various topics covered in this book are materials composite nano advanced design methodologies Industry 4.0 smart manufacturing thermodynamics mechatronics robotics soft computing and automation The contents of this book are useful to the researchers and professionals working in the different areas of mechanical engineering

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