



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

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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 (MTF), in hours is calculated as follows:

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

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

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1. Understanding the eBook Recent Advances In Heat Mass Transfer
 - The Rise of Digital Reading Recent Advances In Heat Mass Transfer
 - Advantages of eBooks Over Traditional Books
2. Identifying Recent Advances In Heat Mass Transfer
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Recent Advances In Heat Mass Transfer
 - User-Friendly Interface
4. Exploring eBook Recommendations from Recent Advances In Heat Mass Transfer
 - Personalized Recommendations
 - Recent Advances In Heat Mass Transfer User Reviews and Ratings
 - Recent Advances In Heat Mass Transfer and Bestseller Lists

5. Accessing Recent Advances In Heat Mass Transfer Free and Paid eBooks
 - Recent Advances In Heat Mass Transfer Public Domain eBooks
 - Recent Advances In Heat Mass Transfer eBook Subscription Services
 - Recent Advances In Heat Mass Transfer Budget-Friendly Options
6. Navigating Recent Advances In Heat Mass Transfer eBook Formats
 - ePub, PDF, MOBI, and More
 - Recent Advances In Heat Mass Transfer Compatibility with Devices
 - Recent Advances In Heat Mass Transfer Enhanced eBook Features
7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Recent Advances In Heat Mass Transfer
 - Highlighting and Note-Taking Recent Advances In Heat Mass Transfer
 - Interactive Elements Recent Advances In Heat Mass Transfer
8. Staying Engaged with Recent Advances In Heat Mass Transfer
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Recent Advances In Heat Mass Transfer
9. Balancing eBooks and Physical Books Recent Advances In Heat Mass Transfer
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Recent Advances In Heat Mass Transfer
10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
11. Cultivating a Reading Routine Recent Advances In Heat Mass Transfer
 - Setting Reading Goals Recent Advances In Heat Mass Transfer
 - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Recent Advances In Heat Mass Transfer
 - Fact-Checking eBook Content of Recent Advances In Heat Mass Transfer
 - Distinguishing Credible Sources
13. Promoting Lifelong Learning

- Utilizing eBooks for Skill Development
- Exploring Educational eBooks

14. Embracing eBook Trends

- Integration of Multimedia Elements
- Interactive and Gamified eBooks

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