



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

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ARTICLE INFO

Keywords:
Phase-change material
Electronic components
Thermal management
Thermal conductivity enhancers
Heat sink

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:

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

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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