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Experimental investigation of a heat switch based on the precise regulation of a liquid bridge

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ABSTRACT

Thermal management is a key issue in various fields of engineering. The effective counterplan has to be come up with for achieving high thermal stability suitable for thermally-sensitive system. Here, the concept utilizing a liquid-based heat switching method was presented as one of the promising solutions in the thermal management, and the proposed system is composed of a hot plate, cold plate, fluid chamber and actuator. The heat switching works by means of controlling the formation of the liquid bridge between the two plates, and it enables to not only control the thermal resistance but also distribute the heat to the surroundings using the liquid bridge. Thus, the thermal performance of the proposed heat switch highly depends on the formation and motion of the liquid bridge. Empirically, the optimal geometry of the heat switch, the diameter of the liquid channel and clearance between two plates, was determined to be suitable for creating and rupturing the liquid bridge. To investigate the effects of its geometry, the pressure analysis and observation of the liquid bridge through CCD were conducted, respectively. The constructed heat switching system was applied to the LED-based testing module to control the LED junction temperature regulation and thermal resistance between the LED plate and the heat sink. As a result, the behavior of the liquid bridge and its effect on the heat switching were empirically understood.

1. Introduction

Recently, thermal management technologies have been becoming indispensable in various applications such as electronic devices, bio-devices, and the light sources of optical systems [1–6], as thermal problems critically affect system performance. However, the requirements of thermal management methods vary from the field of applications based on the operating conditions. The precise and fast temperature regulation, for example, is required in a polymerase chain reaction (PCR) machine [2] while a high cooling capacity and a small volume are essential for electronics packaging systems [7,8]. Indeed, environmental effect has to be taken into account for specific systems such as aircraft experiencing a wide range of working temperatures, from −55 °C to 80 °C [9]. Cooling the hot spot and reducing thermal contact resistance are important issues in the chip packaging [10,11]. Therefore, an effective thermal management method is necessary for achieving its performance in each application.

A heat switching method is one of the solutions available, currently. The heat switch enables to control the heat transfer by making and breaking the thermal contact between the hot and cold parts [12]. Various types of heat switches have been introduced to achieve and improve the heat regulation under different working conditions [13–16]. Most studies were mainly focused on the extremely high or low temperature environment or vacuum conditions. From the literature survey, it was found that the thermal resistance and temperature are key parameters in the heat switching systems [17]. Also, the thermal contact and isolation is equivalently important for those applications [18,19].

In particular, it can be said that a liquid-based heat switch is one of the promising solution for thermal systems because the operation process has to be accomplished under the room temperature conditions. The liquid-based heat switch forms a thermal contact at the desired point by creating and destructing the liquid column between two plates. Thus, the local temperature regulation can be accomplished. Furthermore, its performance can be determined by the choice of the working fluid. In addition, the switch can be available for a small-sized system. Based on the system characteristics, effective thermal management can be achieved with a liquid-based heat switch [20].

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