Flat Plate Loop Heat Pipe with a Novel Evaporator Structure

Meng-Chang Tsai [1],Chun-Sheng Yu, Shung-Wen Kang
Department of Mechanical and Electro-Mechanical Engineering, Tamkang University
151 Ying-Chuan Rd., Tamsui, 25137, Taiwan, R.O.C.
Tel: 886-2-26215656 Ext.2613; Fax: 886-2-26209745
[1] 691340383@s91.tku.edu.tw

Abstract

This paper proposes that fabrication and test of flat plate loop heat pipe (FPLHP) with a novel evaporator structure. IC industry of Taiwan, R.O.C. is one of the competitive industries in the world. With the increasing of electric heat dissipation and miniaturization, we need advanced cooling systems to solve the high temperature problems. We describe the evaporator design and a new design stretched. Finally, the testing results show that the new design of FPLHP works very well.

Keywords

Flat plate loop heat pipe, Loop heat pipe

1. Introduction

Computer chip always accompanied by the increase of heat dissipation and miniaturization. In 2003, due to the increasing of power density the computer processor is higher than 2G Hz, the heat dissipation is higher than 45 watt in notebook computer, and the estimate approach 80 watt in the future. Loop heat pipes can resolve the high heat dissipation problems, and take heat away from the heat source. Loop heat pipe (LHP) technology was first developed in the former Soviet Union in the mid 1980's [1], and has since been employed in the thermal design of numerous spacecraft systems worldwide. The system of a loop to transport heat used a working fluid has been around for a long time. Refrigeration (invented around the turn of the century) has used this technique for years. The distinction between a loop heat pipe and a refrigeration unit is that a loop heat pipe does not use any sort of power input. Due to this restriction, heat pipes must transport heat with a thermal gradient. It is similar to the Capillary Pumped Loop (CPL), which was invented at the NASA Lewis (now Glenn) Research Center in 1966 by Stenger [2], but it has some distinct difference of design that makes the LHP more suitable for terrestrial applications [3].

Pastukhov et al. [4] used the loop heat pipe for electronic cooling research. The paper is devoted to the development of miniature loop heat pipes (mLHPs) with a nominal capacity of 25 – 30 W and a heat-transfer distance up to 250 mm intended for cooling electronics components and CPU of mobile PC. Eric Golliher and Jake Kim [5] construct a steady state model of micro loop heat pipe. Developments at the NASA Glenn Research Center and the University of Cincinnati have produced micro-machining techniques for silicon that will be used to manufacture microchip scale LHP (μLHP) with application potential for cooling of individual chips as an integrated package.

In this paper, we developed a FPLHP used copper mesh with some special channels. It can let the vapor generation and spoliation more quickly along a constant vector. We try to make a FPLHP of low cost, and provide a new idea for the evaporator of the FPLHP.

2. Design and Ffabrication

The configuration of a FPLHP is shown in Figure 1. We make a evaporator to produce the vapor, and let it through the fluid channel into condenser. At the last, the working fluid cooling becomes the under cooling liquid fluid and comes back to evaporator. Following we will describe the design of FPLHP and a extend design. Figure 2 is the complete picture of FPLHP.

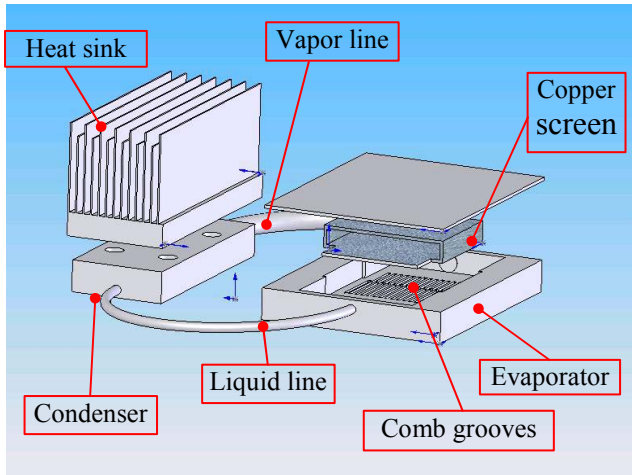

Figure 1. Schematic of flat plate loop heat pipe

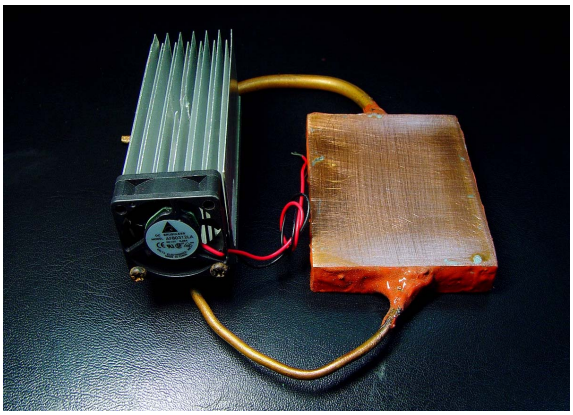

Figure 2. The flat plate loop heat pipe

2.1. Flat Plate Loop Heat Pipe's Evaporator Design

A FPLHP separate into three parts, evaporator, condenser and transport line. Evaporator is the most important factor effects FPLHP works or not.

The evaporator uses a copper structure including a comb grooves inside. The design characteristics are shown in figure 3. Evaporator center put in a special copper screen is shown in figure 4. In order to observation, we cover the evaporator with a piece of glasses. This mesh structure can let the vapor move away and absorb working fluid quickly. Figure 5 shows a partial cross sectional view of the evaporator. The liquid is return from the liquid transport line then goes into the liquid side of mesh in the evaporator. The liquid volume (pump core) is contained with the hollow center of a rectangular copper wick structure. The liquid flows to the outer of wick surface, where the liquid absorb the heat then vaporization. The vapor moves through comb grooves to the vapor line.

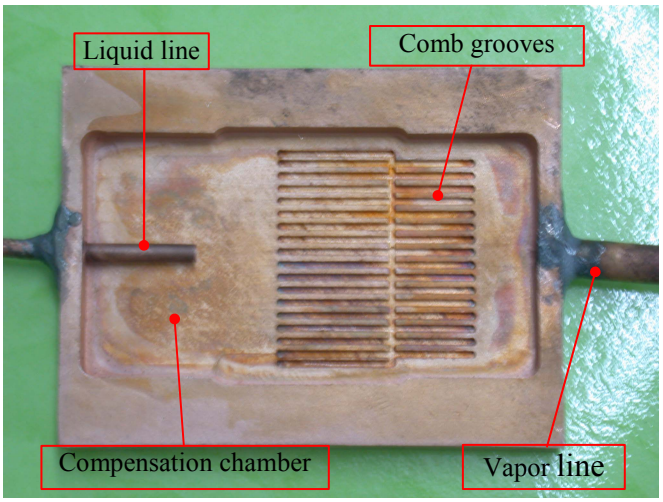

Figure 3. The evaporator structure of flat plate loop heat pipe

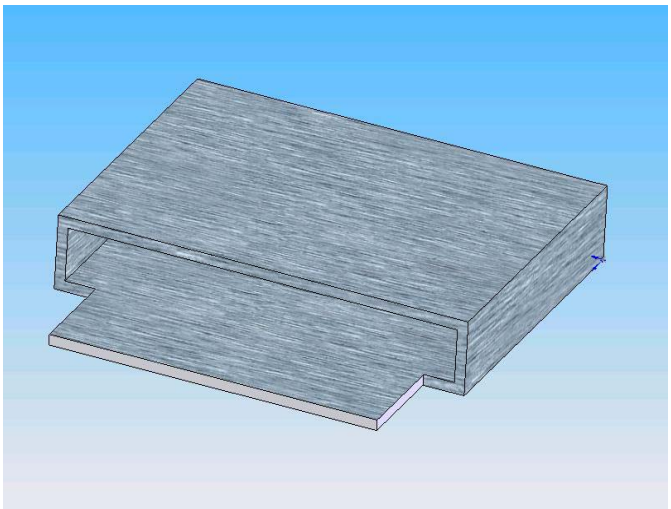

Figure 4. The special copper mesh

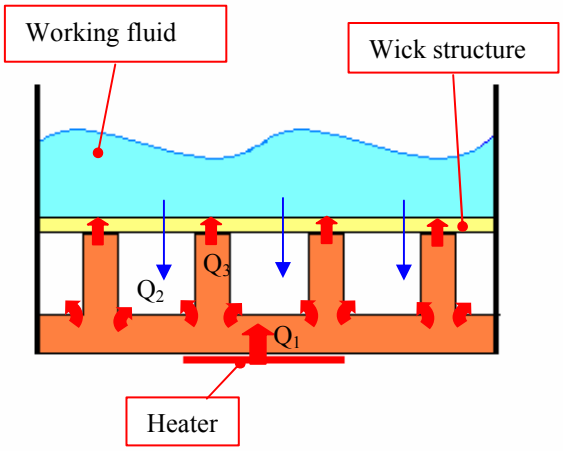

Figure 5. Part of evaporator pump cross-section

2.2. A Extend Design of Evaporator

The first evaporator just design by concept. In order to do a quantitative analysis, a new design stretched as follows. There are five factors that effect the FPLHP's evaporator.

(1) The Porosity of the mesh structure.
(2) The size and seat of compensation chamber.
(3) The wide and depth of the comb grooves.
(4) The slope of diversion slug.
(5) The filling rate and property of the working fluid.

By the design, preliminary we fasten the four factors, (1) to (4), and change the filling rate of working fluid. The new design is shown in figure 6. This design is smaller and thinner than first design. We increase the size of vapor chamber and decrease the compensation chamber. Furthermore, the diversion slug was used to smooth the streamlines of vapor. The diversion slug slope is ($\tan 30° = 1/\sqrt{3}$).

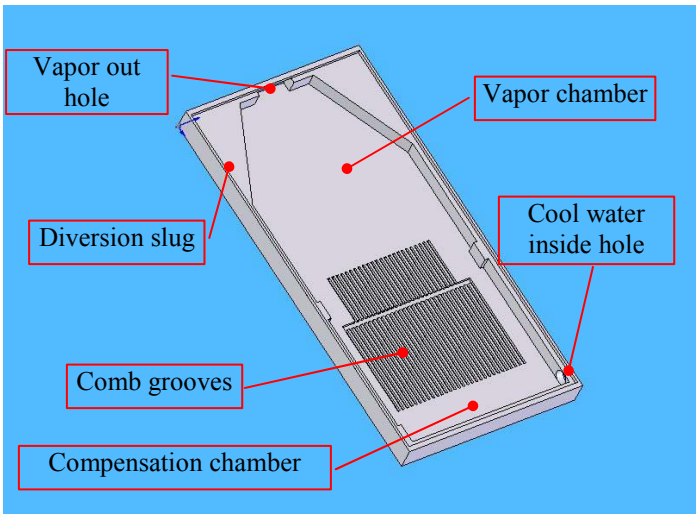

Figure 6. The new evaporator structure of FPLHP

2.3. New Flat Plate Loop Heat Pipe

A new FPLHP is shown as Figure 7. The left pencil length is 16 cm compared with FPLHP. The length of vapor line is 12 cm and liquid line is 23 cm. The thickness of evaporator is 0.5 mm. The working fluid is pure water.

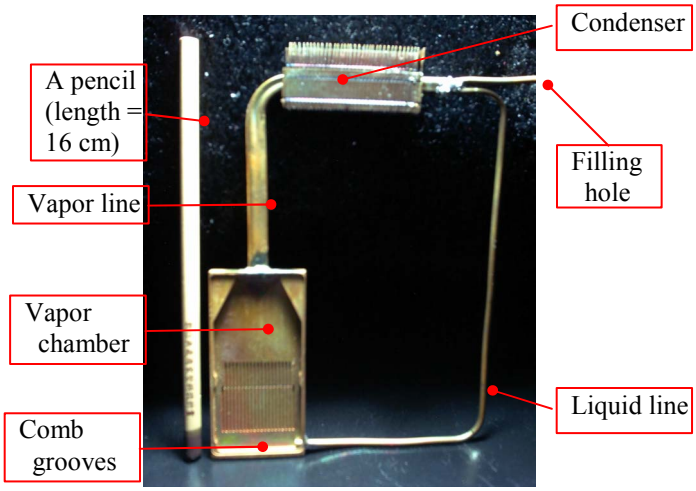

Figure 7. The flat plate loop heat pipe

3. Experiment

A CPU cooler test system is shown in Figure 8 that used to evaluate the performance of the FPLHP. The power input device is showed in Figure 9. The heating die area is 13.97 mm × 13.97 mm (0.55 inch × 0.55 inch). Water, methanol and refrigerant (HCFC 141b) were used as working fluid. Figure 10 shows the Relationship between times and die temperature with different heat input watt. In this picture, the die temperature is between 80 and 90 °C while the power is high than 50 Watt. Preliminary testing results showed that FPLHP filled with methanol could dissipate heat more than 68W. Figure 11 shows the Relationship between die temperature and the heat input with 3 different working fluid (methanol, pure water, HCFC141b) and no fluid filled conditions. In this picture, the action of methanol line is very good, and the water need higher heat flux to get constant. The water line is becoming constant gradually, and the empty one still displayed a straight line. The fluid HCFC 141b has the best effect, but the FPLHP can not handle the high pressure output.

In early experiment, we covered the top of evaporator with glasses. Some phenomenon is observed that the vapor transport along a single vector. The large vapor generated from the comb grooves, and the mesh obstructs the vapor going through the compensation chamber. At the same time, the mesh catches the working fluid and gives the comb grooves vaporizing continuously.

The interrelated experiment of the new FPLHP is proceeding with the new test actively.

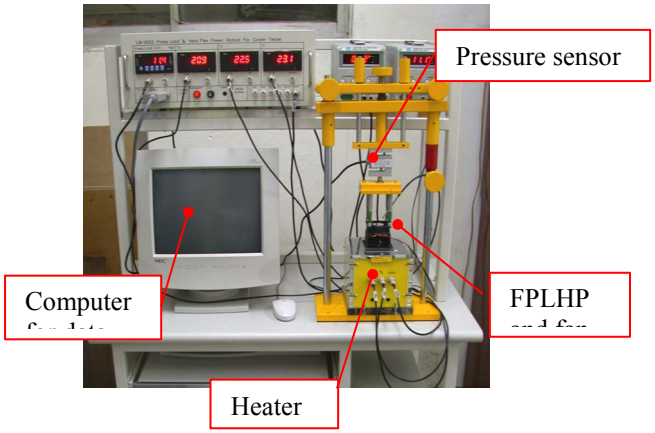

Figure 8. CPU cooler test system

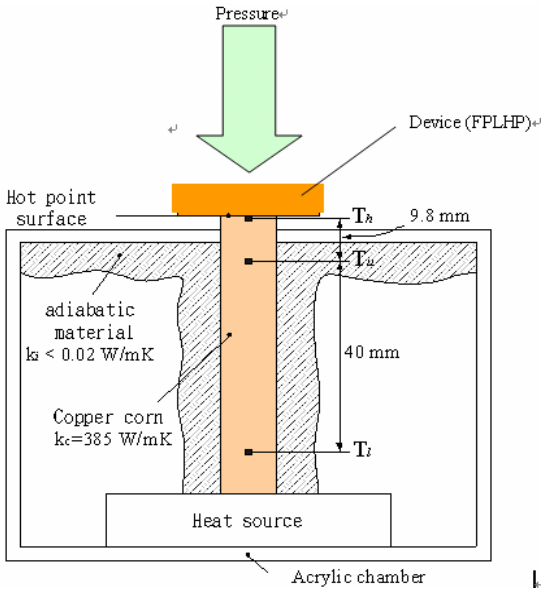

Figure 9. Heat input device

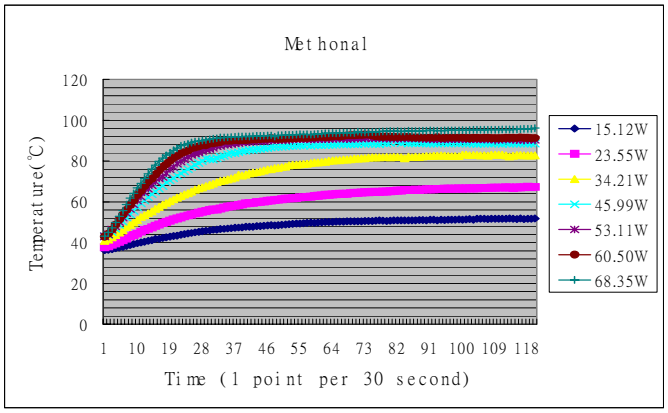

Figure 10. Relationship between times and die temperature with different heat input watt.

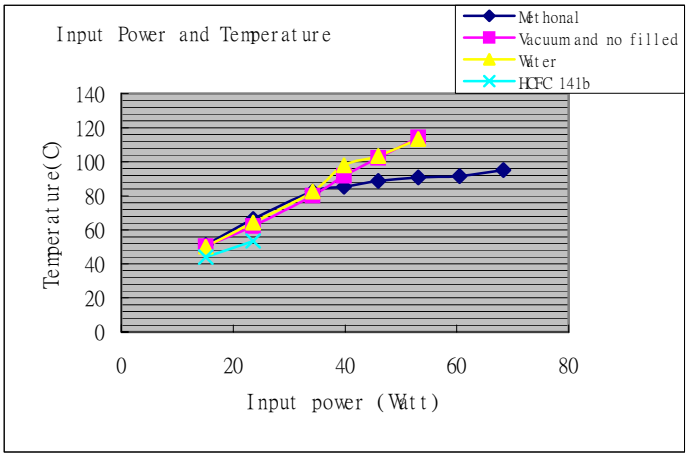

Figure 11. Relationship between die temperature and the heat input with 3 different working fluid and no fluid filled conditions

4. Discussion

Because of the first FPLHP can not handle high pressure output, we improve the weld technology on new device and make it acceptable for higher pressure. The new evaporator has a big vapor chamber and small compensation chamber, because the mesh obstructs the vapor into compensation chamber. For this reason, the compensation chamber is not very important to effort the action of FPLHP and increase the volume of vapor chamber can decrease the start action temperature.

A paper, Miniature Loop Heat Pipe – A Promising Means For Cooling Electronics, submits in 2004 Inter Society Conference on Thermal Phenomena [6]. The MLHPs are capable of transferring of 100–200 W for distance up to 300 mm in the temperature range 50–100 °C at any orientation in 1 g conditions. The thermal resistance for the conditions is in the range from 0.1 to 0.2 K/W. I take a result from the paper shows in figure 12 to compare with my FPLHP. The MLHP1's performance in air cooling is better than mine, but the line appears MLHP is no action. In this research, from figure 11 can show the FPLHP action apparently by the methanol curve line.

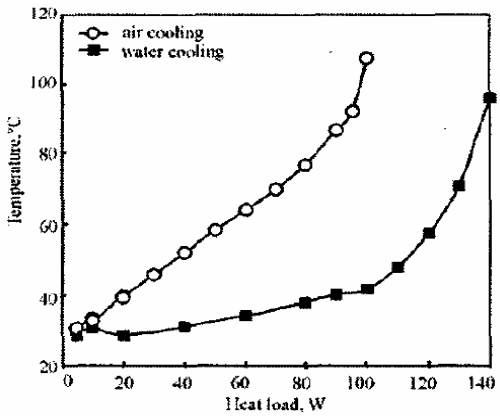

Figure 12. The performance of MLHP1 by different cooling

5. Conclusions

The working fluid in first flat plate heat pipe is methanol. We used the conventional machining and diffusion bonding technology to make the special mesh structure and comb-grooves. The preliminary results show that the FPLHP can dissipate the heat flux more than 50 watt and the die temperature is lower than 85 °C. Primary experiment shows the performance of FPLHP is not the best one in the world, but it proposed a new design of evaporator and action apparently.

By the new design, the experimentation is not fullness. The researching is continuing for the heat transfer limitation, different fluid, slope of diversion slug, mesh structure and optimization of the FPLHP size to improve the cooling performance.

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