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Preliminary communication

THE IMPACT OF LHP POSITION TO REMOVE WASTE HEAT FROM THE POWER COMPONENTS

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Given the rapid progress in the electronics industry, the thermal management of electronics components becomes an important and serious issue. Natural and forced cooling are often deficient. One possibility for heat dissipation for high heat flux is using loop heat pipe. A loop heat pipe (LHP) is a two-phase device with extremely high effective thermal conductivity that utilizes pressure difference in wick to circulate working fluid. It was invented in Russia in the early 1980's. LHP is composed by an evaporator, a condenser, a compensation chamber (reservoir) and a vapor and liquid lines. Only the evaporator and part of the compensation chamber are equipped with a wick structure. The use of the wick structure in the evaporator provides a stable physical interface between the liquid and the vapor phases in the LHP. This work deals with the design of LHP for cooling of Insulated gate bipolar transistor and impact of tilt angle of LHP on temperature of transistor. The LHP position is changed from the vertical position (90°) to the horizontal position (0°) during the measurement. The LHP evaporator is made up with copper pipe and alumina saddle. Inside of the evaporator is wick structure and it is made from copper powder. The condenser is made as a tube heat exchanger. The water temperature for cooling is set at 20°C and it is regulated by a thermostat. The temperatures are measured with the thermocouples. As the working fluid was used distilled water. The maximum permissible temperature of transistor is 100°C.
Key words: loop heat pipe, cooling, wick, position.

Utjecaj pozicije LHP-a za uklanjanje otpadne topline strujnih komponenti. Obzirom na brzi napredak u elektroničkoj industriji, toplinsko upravljanje elektroničkim komponentama postaje važan i ozbiljan problem. Prirodna i prisilna hlađenja često su manjkava. Jedna od mogućnosti odvođenja topline s ekstremno visokim toplinskim tokom je korištenje toplinske cijevi u obliku petlje. Toplinska cijev u obliku petlje(*Loop Heat Pipe*- LHP) je dvofazniuređaj s iznimno visoko učinkovitom toplinskom provodljivosti koji koristi razliku tlaka u kapilari za cirkulaciju radnog fluida. Uređaj je izumljen u Rusiji u ranim 1980-im. LHP se sastoji od isparivača, kondenzatora, kompenzacijske komora (rezervoar) ilinije s parom i s kapljevinom. Samo su isparivač i dio kompenzacijske komore opremljeni s kapilarnom strukturom. Upotreba kapilarne strukture u isparivaču daje stabilno fizičko sučelje između faze kapljevine i pare u LHP-u. Ovaj se rad bavi dizajnom LHP-a za hlađenje bipolarnog tranzistora s izoliranom upravljačkom elektrodom i utjecajem kuta nagiba od LHP-a na temperaturutranzistora.Tijekom mjerenja položaj LHP-a se mijenja iz okomitog (90°) u vodoravni položaj (0°). Isparivač LHP-a je izrađen od bakrene cijevi i aluminatnog sjedišta. Unutar isparivača je kapilarna struktura, koja je dobivena od praškastog bakra.Kondenzator je napravljen kao cijevni izmjenjivač topline.Temperatura vode za hlađenje je postavljena na 20°C i regulirana je termostatom. Temperature su mjerene termoparovima. Kao radni fluid se koristiti destilirana voda.Najveća dopuštena temperatura tranzistora je 100°C.
Ključne riječi: toplinska cijev u obliku petlje, hlađenje, kapilara, pozicija.

INTRODUCTION

A two-phase capillary pump loop, as Loop Heat Pipe (LHP), is an efficient heat transfer system based on the liquid-vapor phase change phenomena. It was developed in 1972 by Gerashimov and Maydanik of the Ural Polytechnic Institute. A loop heat pipe consists of an evaporator, a condenser, a compensation chamber, and liquid and vapor line for transport working fluid (Figure. 1). Only the evaporator and part of the compensation chamber contain wicks. The other components could be made of smooth tubing. Like a conventional heat pipe, a two phase capillary loop uses capillary action to circulate the working fluid in a sealed enclosure and, in the process, to transfer waste heat from one location (heat source) to another (heat sink). LHP contains no mechanical moving part to wear out or require electrical power to operate. [1]

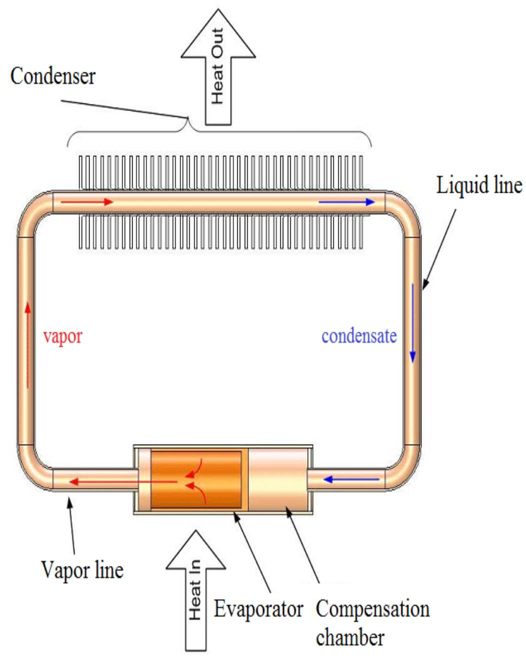

Figure 1. Schematic view of LHP [2]
Slika 1. Shematski prikaz LHP-a [2]

OPERATION ANALYSIS OF LHP

A major part of heat input Q_{imput} is used for the liquid vaporization on the outer surface of the wick structure (Q_V). The vapor generated in the evaporator is transferred along the vapor line to the heat exchanger where heat is transmitted to the ambient and turns back to liquid phase. The rest of the heat input, Q_{cc} (called "heat leak") is conducted across the wick and tends to increase the compensation chamber temperature. The amount of heat leak is proportional to the saturation temperature difference between the evaporator and the compensation chamber ΔTw. This temperature difference (ΔTw) is a direct result of the pressure difference across the wick, induced by the vapor, condenser and liquid line pressure drops. The coupling between the pressure drop and the temperature drop across the evaporator wick is responsible for many of the peculiar behaviors found in LHP operation. Thus:

$$Q_{input} = Q_v + Q_{cc} \quad (1)$$

$$Q_v = \dot{m}.L_v \quad (2)$$

$$Q_{cc} = \frac{\lambda_{cc}}{s}.\Delta T_w = \frac{\lambda_{cc}}{s}.(T_e - T_{cc}) \quad (3)$$

where $\dot{m}$ is the mass flow rate, L_v is heat of vaporization, λ_{cc} is the thermal conductance between the evaporator and the compensation chamber, T_e and T_{cc} is the temperature of evaporator and compensation chamber. [3]

In order to correct function of LHP, the wick in the evaporator must develop a capillary pressure in wick to overcome the total pressure drop in the loop:

$$\Delta P_{total} \leq \Delta P_{cap} \qquad (4)$$

One of the advantages of a capillary loop is that the meniscus in the evaporator wick will automatically adjust its radius of curvature such that the resulting capillary pressure is equal to the total system pressure drop. The total pressure drop in the system is the sum of frictional pressure drops in the evaporator grooves, the vapour line, the condenser, the liquid line, and the evaporator wick, plus any static pressure drop due to gravity:

$$\Delta P_{total} = \Delta P_{groove} + \Delta P_{vap} + \Delta P_{con} + \Delta P_{liq} + \Delta P_w + \Delta P_g \qquad (5)$$

The capillary pressure rise that the wick can develop is given by:

$$\Delta P_{cap} = \frac{2\sigma.cos\theta}{R} \qquad (6)$$

where, σ is the surface tension of the working fluid, R is the radius of curvature of the meniscus in the wick, and θ is the contact angle between the liquid and the wick.[4]

DESIGN OF LHP

LHP was made from copper pipes. Model of LHP is shown in the figure 2. As a working fluid was used distilled water. In the evaporator was wick structure of sintered copper powder. There was cooper powder with grain size 50μm and it was sintered at temperature 950°C for 30minutes. The wick structure is shown in the figure 4.

To avoid heat loss (it is also called heat leak) into the compensation chamber was inserted a brass flange with rubber seal between the evaporator and the compensation chamber. On the evaporator was mounted the aluminum block, and on the aluminum block was fixed Insulated gate bipolar transistor (IGBT). IGBT was connected to DC power source. For better heat transport was applied thermal conductive paste on the connection between IGBT and aluminum block and between aluminum block and the evaporator. The condenser was made as a tube heat exchanger. The condenser was cooled by cooling water.The temperature of cooling water was set at 20°C and it was regulated by a thermostat. The temperatures were measured with the thermocouples. The schematic diagram of measuring device can be observed in the figure 3. During the measurement position of LHP was changed from horizontal to vertical (figure 5).

Table 1. Main design parameters of the LHP
Tablica 1. Osnovni dizajn parametara LHP-a

LHP evaporator			
Total length (mm)	130	Length (mm)	110
Active length (mm)	89	**Charge mass**	
Outer/inner diameter (mm)	28/26	Distilled water	70%
Material	copper	**Vapor line**	
Saddle		Length (mm)	670
Size (length/ high/ wide)	118/89/40	Outer/inner diameter (mm)	6/4
Material	alumina	**Liquid line**	
Sintered copper powder		Length (mm)	820
Number of vapor grooves	6	Outer/inner diameter (mm)	6/4
Porosity (%)	51	**Condenser**	
Outer/inner diameter (mm)	26/8	Length (mm)	420
Compensation chamber		Outer/ inner diameter (mm)	6/4
Outer/inner diameter (mm)	35/33		

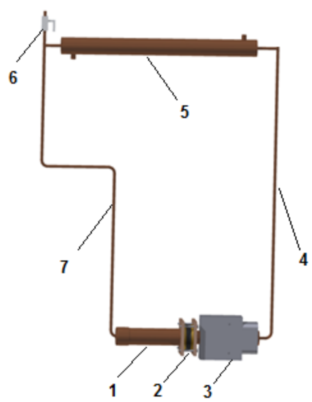

Figure 2. Model of LHP: 1. compensationchamber, 2. rubberseal, 3. aluminablock, 4. vaporline, 5. condenser 6. fillingvalve, 7. liquidline
Slika 2. Model LHP-a: 1. kompenzacijska komora, 2. gumene brtve, 3. aluminatni blok, 4. linija s parom, 5. kondenzator, 6. ventil za punjenje, 7. linija s kapljevinom

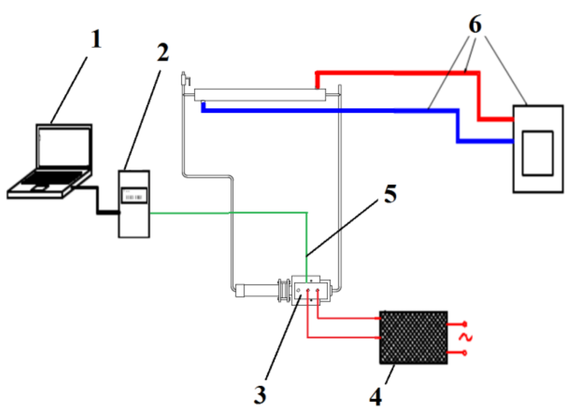

Figure 3. Schematic diagram ofmeasuring device: 1-PC, 2- logger, 3-IGBT, 4- powersupply voltage and current, 5- thermocouple, 6- thermostat
Slika 3. Shematski dijagram uređaja zamjerenje: 1-PC, 2- bilježenje, 3-IGBT, 4- napajanje napona i struje, 5- termopar, 6- termostat

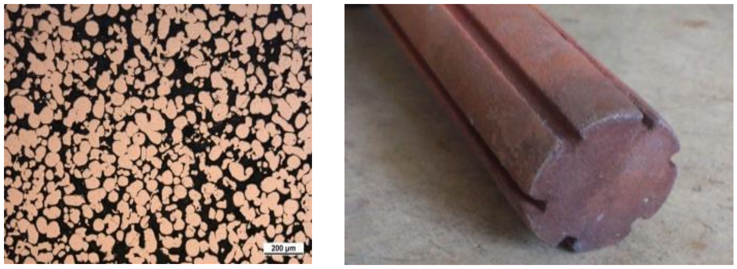

Figure 4. Sintered copper powder with grain size 50. Sintering temperature 950 °C, sintering time 30 min
Slika 4. Sinterirani praškasti bakar s veličinom zrna 50μm. Temperatura sinteriranja 950 °C, vrijeme sinteriranja 30 min

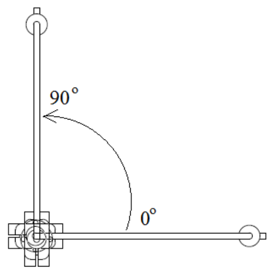

Figure 5. Tilt angle of the LHP
Slika 5. Kut nagiba LHP-a

RESULTS AND DISCUSSIONS

IGBT was connected to DC power (Delta powerSupply SM120-50). Without the use of cooling system the temperature of IGBT exceed 100°C under load 50W. Therefore, it is necessary to cool the IGBT. IGBT was cooled with LHP. The first,IGBT was loaded 150W. The position of LHP was changed from vertical (90°) to horizontal (0°). The result can be seen in figure 5.

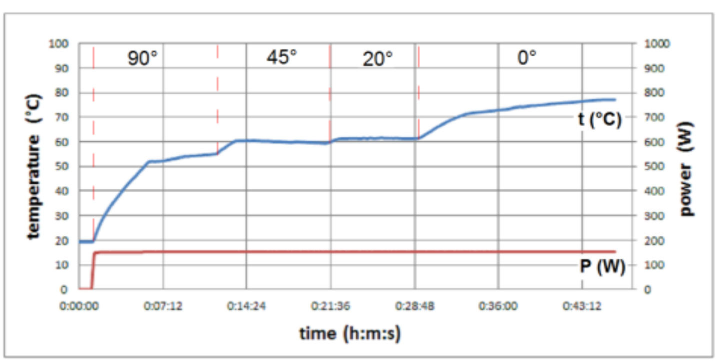

Figure 6. Temperature of IGBT depends on tilt angle of LHP when power of source was 150W
Slika 6. Ovisnost temperature IGBT-a o kutu nagiba LHP-a kada je snaga 150W

The second, IGBT was loaded 200W. The position was changed as in the first case. The result can be seen in figure 7.

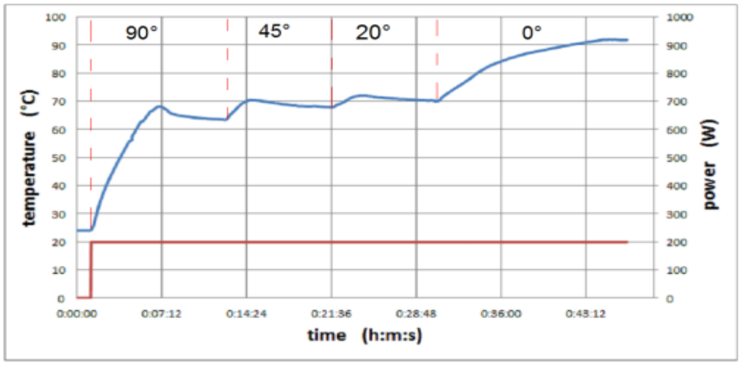

Figure 7. Temperature of IGBT depends on tilt angle of LHP when power of source was 200W
Slika 7. Ovisnost temperature IGBT-a o kutu nagiba LHP-a kada je snaga 200W

The third, IGBT was loaded 250W. The position was changed as in the first and the second case. The result can be seen in figure 8.

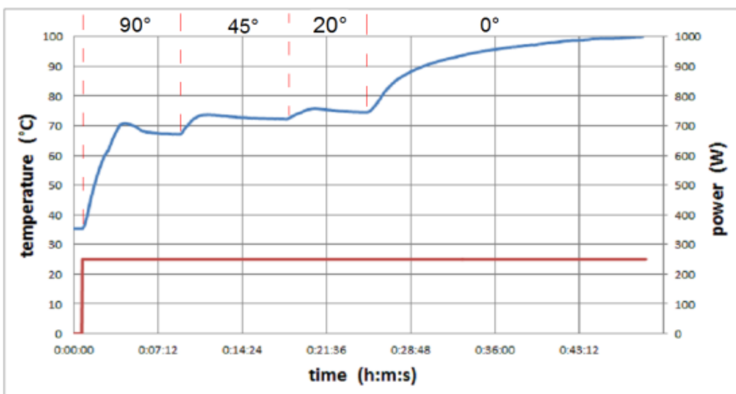

Figure 8. Temperature of IGBT depends on tilt angle of LHP when power of source was 250W
Slika 8. Ovisnost temperature IGBT-a o kutu nagiba LHP-a kada je snaga 250W

CONCLUSION

The aim of this article was to investigate the effect of position LHP to remove waste heat from IGBT. In figures 6-8 it can be seen that cooling capacity of LHP was decreased when position of LHP was changed from vertical (90°) to horizontal (0°). In the vertical position LHP can cool down the IGBT even though IGBT is loaded with high value.In the horizontal position LHP can cool down the IGBT, when it is loaded 200W. It demonstrates good cooling capacity.

The application of LHP for cooling power electronic, especially electronic semi-conductor devices, offers better cooling performance and improved cooling in area of higher power dissipation of about 200 W.

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