Proceedings of the 3rd IASME/WSEAS Int. Conf. on HEAT TRANSFER, THERMAL ENGINEERING AND ENVIRONMENT, Corfu, Greece, August 20-22, 2005 (pp118-121)

Study on Heat Transfer Performance of Flat Plate Heat Pipe based on Experiment

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Abstract: - In this study, we have manufactured the flat plate heat pipe with different inner square modules ; different height(10mm, 5mm) and width(30mm, 20mm). We investigated the operating characteristics of flat plate heat pipe experimentally. Water was used as a working fluids, fill charge ratio and heat flux was changed(10-40 vol.%, 10-40W). Surface temperature, inner saturated temperature and pressure was measured. Optimal inner module which suitable for the temperature uniformity was considered, minimum temperature difference of upper surface ranged 0.3-1.1℃ when average surface temperature ranged 70-150℃.

Key-Words: - Flat plate heat pipe, Heat transfer performance, Surface temperature uniformity, Thermal resistance

1 Introduction

Hot and cool plate systems are used to heat and cool the wafer after the HMDS(a kind of wafer surface cleaning), Soft bake, Post exposure bake and Hard bake in the photolithographic process which is one of the semiconductor manufacturing processes. A large number of plate are used in this photolithography process, and the general function of these plates is to increase the adhesive strength of photoresist, stabilize the components of it before and after the photoresist coating and help to control the critical dimension (0.09~0.13μm) easily while the patterns are formed by this process.

In this process, thermal control becomes a vital factor of affecting quality, reliability of semiconductor wafer, therefore temperature uniformity of total wafer area and the accuracy of temperature control are very important to formed the critical pattern dimension.

Because the plate used in this process is usually made of an aluminum solid, thickness increase to obtain isothermal characteristics, so heat capacity, weight and cost increase.

Heat pipe is heat transfer devices which transfer large quantities of heat with minimum temperature gradient without any additional power. Also, it is easy to design and manufacture, it has merit to apply to various temperature condition. Especially, heat pipe has good thermal response characteristics and produce an entirely isothermal surface. So, heat pipe is used in field with high thermal load such as electronic cooling, etc.

In this study, we have manufactured the flat plate heat pipe with different inner square modules and investigated the operating characteristics, isothermal characteristics and heat transfer performance of heat pipe based on experiment.

2 Experiment and procedures

Fig. 1 shows experimental apparatus to evaluate heat transfer performance and operating characteristics of flat plate heat pipe. Experimental apparatus consists of heating section to supply the evaporating part(bottom) with input power, isothermal test chamber and data acquisition system.

Test section consist of aluminum flat plate heat pipe with 9 number of square modules, square flat plate heater with same size and working fluid. Bottom plate side is the evaporating part which is mounted on the heater to absorb heat and the other side is the condensing part from which heat is transferred to air.

Plate heater was controlled by the digital power meter and DC voltage regulator.

To measure the surface temperature, saturation temperature and pressure, 4~9 pieces of thermocouples, 1 piece of sheath type thermocouple and pressure sensor are installed in the heat pipe. The specification of test section used in this study was shown in Fig. 2 and Table 1.

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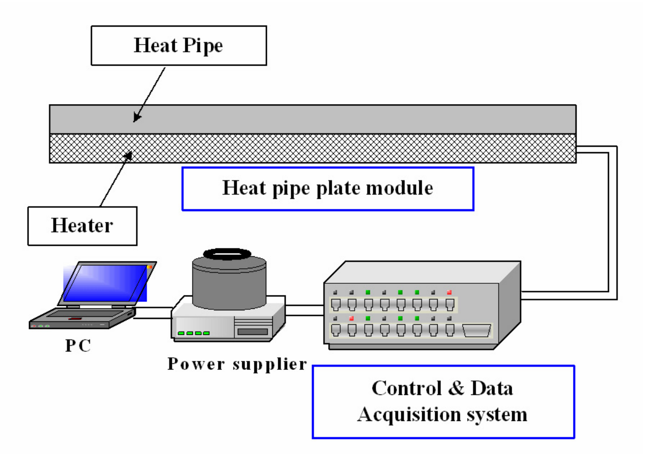

Fig. 1 Schematic diagram of experimental apparatus.

Test section with the exception of bottom and side was insulated with fireproof and insulation materials(creak wool and urethane foam)

Test section was evacuated to the 1×10^{-3} torr by the vacuum system.

Working fluid was charged using charge cylinder for small amount injection(HPG-10, 96, Taistsu). Inner volume of heat pipe was calculated to find out the optimal fill charge ratio of working fluid which shows the good results. We changed fill charge ratio from 10 to 40(vol.%) and input power was varied from 10 to 40W.

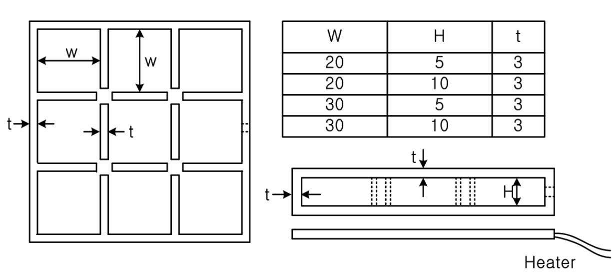

Fig. 2 Schematic diagram of test section.

Table 1 Specification of test section.

Spec.	Description
Material	Al-6061
Size	72mm×72mm×11mm(W20H5) 72mm×72mm×16mm(W20H10) 102mm×102mm×11mm(W30H5) 102mm×102mm×16mm(W30H10)
Working fluid	Distilled water
Inclination angle	0° (Horizontal mode)

Temperature and pressure data acquired by PC via data logger(HR2500E, YOKOGAWA). All data were gained at the stable states, mean value which measured over 10 times was used for data reduction.

3 Results and discussion

Fig. 3~6 show surface temperature variation at each side according to the operating time when the fill charge ratio of working fluid is 10(vol.%). In all test sections, as input power increase, the mean surface temperature difference between bottom side and top side. In particular, temperature deviation of bottom side is larger than that of top side in the test section with wide inner space. Also, In case of wide inner space condition with thin thickness, temperature difference was reduced. On the contrary, in case of test section with relatively narrow inner space, temperature deviation of each side decrease when heat pipe thickness is increase, but mean temperature

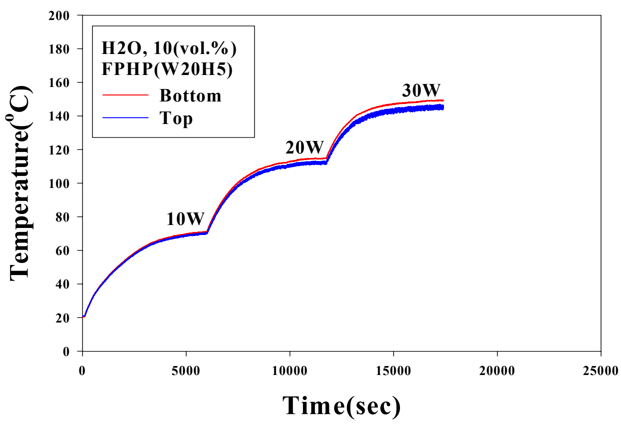

Fig. 3 Temperature variation vs. time(W20H5).

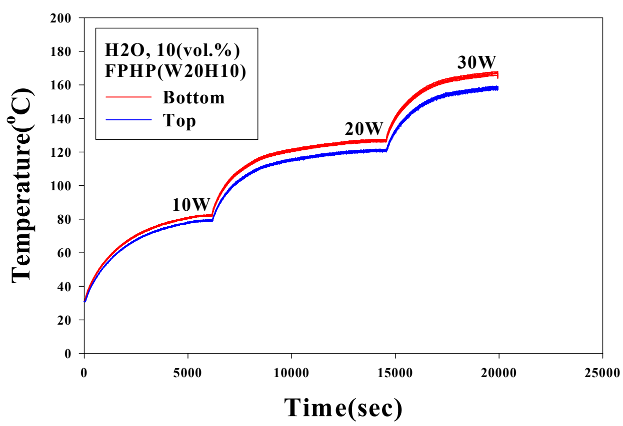

Fig. 4 Temperature variation vs. time(W20H10).

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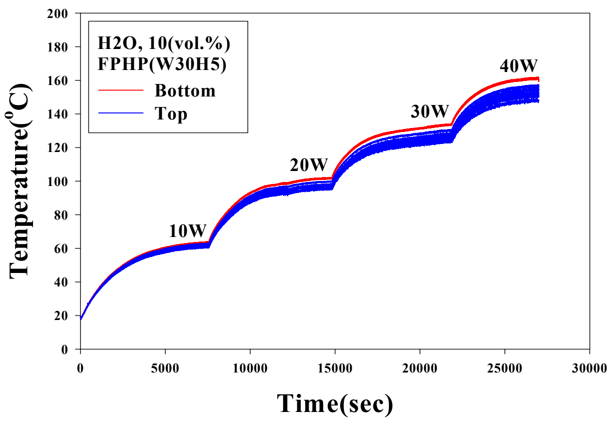

Fig. 5 Temperature variation vs. time(W30H5).

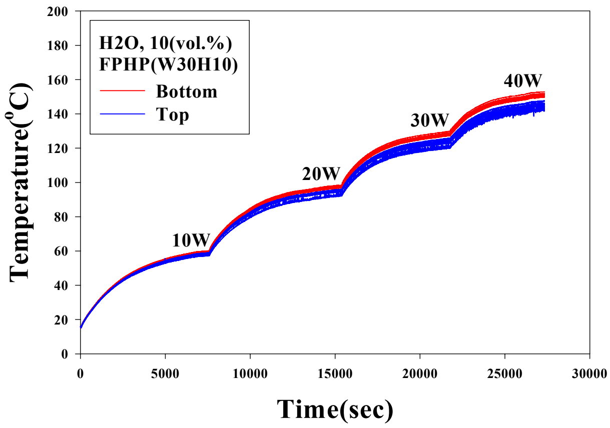

Fig. 6 Temperature variation vs. time(W30H10).

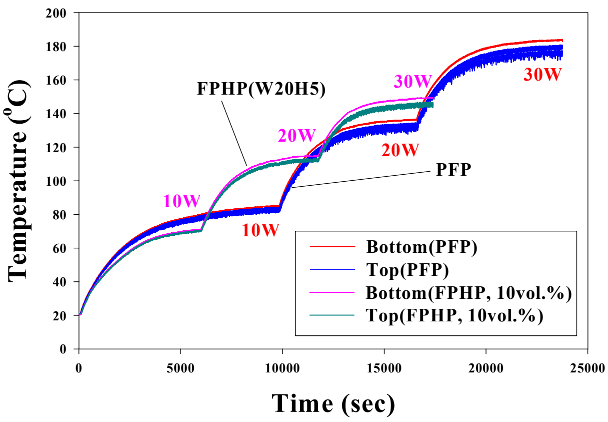

Fig. 7 Comparison between heat pipe and solid plate.

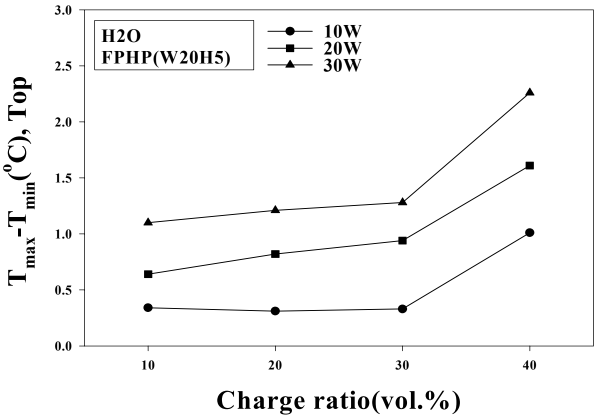

Fig. 8 Temperature difference of top surface as function of fill charge ratio of working fluid.

difference between bottom and top increase. This results represent that phase-change heat transfer can be enhanced in a narrow space under the certain combination of heat flux, gap size or geometry, working fluid and operating temperature.

Fig. 7 shows comparison of operating characteristics between heat pipe with wide space, thin thickness and aluminum solid plate with same size at the same test condition. The temperature deviation in the top surface of aluminum solid plate is larger than that of heat pipe, the time which get to the stable state increase for same input power. Also, surface temperature at each side of heat pipe is lower than that of aluminum solid plate.

Fig. 8 shows the surface temperature difference at top side of thin test section with wide space according to the fill charge ratio of working fluid and input power. Minimum temperature difference was shown at the condition of 10(vol.%) fill charge ratio, that value was ±0.3℃. This mean that isothermal purpose can be achieved by the heat pipe having the phase change heat transfer inside it.

4 Conclusion

We manufactured flat plate square heat pipe and investigated operating characteristics, heat transfer performance and isothermal characteristics through the experiment. Conclusions are as follows.

1. When inner space and thickness of heat pipe is narrow and thin respectively, surface temperature difference at top side was smaller, operating characteristics was better than that of other condition.

2. Optimal fill charge ratio of working fluid which show good operating characteristics exist around 10(vol.%).

References:

[1] S. W. Chi, *Heat Pipe Theory and Practice* : *A Source Book*, Hemisphere Publishing Corporation.
[2] Amir Faghri, *Heat Pipe Science and Technology*, Taylor & Francis.
[3] Yimin Xuan, Yuping Hong and Qiang LI, Investigation on transient of flat plate heat pipes, *Experimental Thermal and Fluid Science*, Vol. 28, 2004, pp. 249-255.
[4] M. J. Rightley et. al., Innovative wick design for multi-source, flat plate heat pipes, *Microelectronics Journal*, Vol. 34, 2003, pp. 187-194.