EFFECT OF DIFFERENT MICRO STRUCTURES ON HEAT DISSIPATION OF CPU SURFACE HEAT SINK

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ABSTRACT: In order to discuss the heat dissipation performance of CPU heat sink, based on the commonly used CPU Aluminum Alloy heat sink ,experiment simulation device of CPU heat sink and wind tunnel experiment platform are established. On the basis of comprehensively considering convection heat dissipation and radiation cooling, the effect of surface micro structure and radiation coating on the CPU thermal performance is studied. The results show that after the surface treatment and coating, the degree of rough surface increases, and the surface temperature of heat sink reduces about 5 DEG C. By using the composite treatment by oxidation after spray coating, the cooling effect is significant. Compared with the direct spray, when the input power is 90W, the cooling rate is nearly 10 DEG C, which can be a good solution to the CPU heat problem. As a result, it is concluded that it is of great significance in improving the electronic equipment reliability and safety performance.

KEY WORDS: CPU heat sink; surface processing; roughness; radiation rate.

1 INTRODUCTION

With the rapid development of integrated circuit technology, all kinds of electronic equipment have been developed to high frequency and high integration. The volume of electronic devices and products is getting smaller and smaller, and the heat flux around the integrated devices is becoming larger and larger. With the computer CPU as an example, the chip volume decreases constantly, and its integration rapidly increases. At last, it results in that in the running process, CPU chip heat flux increased sharply, while the electronic device is highly sensitive to temperature. If the chip heat has not dissipated in time, it will affect the life and the working reliability of electronic devices [1]. Therefore, the effective solution to the problem of heat dissipation can promote the extensive application of high-density integrated technology and accelerate the integration of micro electronics industry.

2 LITERATURE REVIEW

The common way to dissipate heat is to add heat sinks to the CPU, and how to optimize the heat sink to dissipate the heat of the CPU through the heat sinks so as to ensure the CPU work at normal temperature has become the focus of the scholars. Sohel and his partners [2], through the experiment, proved that applying Al_2O_3 nano fluid spraying the surface of the heat sink can significantly improve the performance of heat transfer. Moraveji [3] made use of CFD fluid dynamics modeling method to characterize the thermal performance of Al_2O_3 nano coating from a single and whole stage. In addition, Bahiraei proposed a new bio nano fluid, so as to improve the cooling rate of the heat sink fins, to ensure the normal operation of equipment [4]. Based on this, this paper uses chemical grinding, chemical oxidation, chemical polishing, shot peening, surface spraying and other processing methods for the aluminum heat sink surface treatment. And then the micro structure with different roughness can be obtained. The surface radiation rate and heat measurement effect are measured after the surface treatment, and factors affecting the cooling performance of the radiator are analyzed, so as to improve the reliability and safety of operation of electronic equipment.

3 METHOD

3.1 Heat dissipation mechanism of heat sink

Heat dissipation way of heat sink is usually forced convection and heat radiation. The forced convection uses fan driven force to form the wind field to strengthen air convection, which is the main way for heat dissipation. The heat radiation is that the heat dissipates to the surrounding environment from the heat sink by way of infrared radiation. The main way of heat transfer includes heat conduction, heat convection and heat radiation three kinds. In this study, CPU transfer the heat produced to the heat sink in the heat conduction method. The aluminum heat sink transfers the heat to the space

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mainly by way of thermal convection and thermal radiation.

The formula of heat exchange is considered when convection heat [5] is considered separately:

$$Q_d = \alpha_c A \Delta t = \alpha_c A (t_w - t_f)$$

In the above formula, tw suggests the object surface temperature (℃); tf indicates the temperature (℃) of fluid; Δt refers to the temperature difference (℃) between the object surface and the fluid; A represent the surface area (m2) of the object involved in heat transfer (); and means convective heat transfer coefficient (W/m2·℃). When the volume of heat sink is determined, if the contact volume with the fluid is increased, the heat exchange can be increased.

When the radiation heat radiation is considered separately, the heat emitted by the radiating surface of the radiating fin can be expressed by the following formula [6]:

$$Q_r = \varepsilon \delta A (t_w{}^4 - t_f{}^4)$$

In the above formula, ε refers to radiation rate of an object surface, whose value is related to material temperature, surface area and surface roughness; δ is Stepan - Boltzmann constant, whose value is 5.67032×10-8W/(m-2×K-4).

The heat sink fins can be approximately considered as a rectangular structure. The heat dissipation of the heat sink is deducted by using the infinitesimal method. The heat conduction along the rib elongation direction, the temperature of rib is t_0. The temperature of heat sink at a certain place is t, the thermal conductivity coefficient is λ, and the perimeter of cross section is U. The quantity of heat can be calculated by the following formula:

$$Q = \lambda A \alpha_c U (t_0 - t_f) + \left[2\lambda A U \varepsilon \delta \left(\frac{1}{5} t_0{}^5 - t_f{}^4 t_0 + \frac{4}{5} t_1{}^5\right) \right]^{\frac{1}{2}}$$

According to this formula, it is known that, the heat dissipation of the radiating fin is related to the temperature difference, the surface area of the radiating fin, the radiation rate and the coefficient of thermal conductivity.

3.2 Surface processing

In general, in the CPU radiator, heat sink is made by aluminum alloy by extrusion technology. The aluminum radiator is made by die casting process, and the surface treatment must be done unified with the surface pretreatment. The heat sink with the same size of 19 copies is made, and divided into 6 groups. The first five groups have three blocks, used for micro structure processing. And the last group has four blocks, applied for radiation coating thickness test. The first step of the surface pretreatment is to make use of alkaline cleaning agent (compositions are shown in table 1) for oil removal. Followed by, nitric acid or phosphoric acid is used for pickling, and finally, the samples are washed and dried in the flowing water, which can form the clean and uniform surface.

Table 1 Surface cleaning formula and process

Solution composition	Content (g/L)	Response time (min)	Temperature (℃)
Na_2CO_3	40~60		
Na_2CrO_4	10~20	3~5	80~100
NaOH	2~3		

Chemical oxidation treatment [7]: weigh 50g Na_2CO_3 and 15g Na_2CrO_4 to fill in the beaker with boiling water, place the sink into the 90~100 DEG C solution, and continuously shake for 5~10min. After a layer of gray film is formed on the surface, the specimen is removed. In the weak acid solution, the surface residual oxide is cleaned, and then it is flushed in the cold water, for drying in the air.

Chemical grinding processing: weigh 300~320g/L NaOH, 40~50g/L Na_3PO_4, and 15~25g/L NaF, respectively. Add into the boiling water, and the control solution temperature is 60~70 DEG C. When the sample surface appears obvious sand surface effect, the specimen is removed for cleaning in the weak acid. After it is cleaned, the sample is rinsed with cold water until the surface is cleaned, for drying in the air.

Chemical polishing treatment: place the aluminum alloy material in the polishing liquid with reasonable ratio of corrosion agent, oxidizing agent, and additives. The time is controlled in 10~120s, and the sample surface has a series of chemical reactions, which induce the morphological changes.

Mechanical shot peening treatment: use stainless steel bullet in compressed air to blow the surface of the radiator, to make the material surface appear cyclic plastic deformation. Generally, it requires sample surface coverage rate more than 100%.

Spraying treatment: by using the manual cold spraying technology, the double volatile coating is coated on the surface of the heat sink, forming a layer of bright, clean and uniform coating. In order to explore the effect of different thickness of the coating of radiation coatings on the cooling effect, in the experiment, 0.1, 0.15, 0.2, and 0.25 four kinds of coating thickness are chosen.

3.3 Measurement of surface roughness of samples

The surface roughness refers to the micro geometrical characteristics composed of the smaller spacing and peaks and valleys on the machined surface. The smaller the surface roughness is, the smoother the surface of the sample is [8]. The roughness measurement uses the middle line system, which takes the contour middle line as the measuring datum line. The sampling length L is used for distinguishing a base line length with the surface roughness characteristics, taking the horizontal direction. The assessment length of Ln is applied for assessing a section length required for the contour assessment. In general, within an assessment length, 5 sampling lengths are chosen. The surface roughness of the central system commonly uses three ways, including the arithmetic average deviation of the contour Ra, the micro roughness height Rz and the maximum height of the contour Ry.

In this experiment, the surface roughness of the sample is measured by Time Inc TR200 hand-held roughness tester. The working flow chart is shown in Figure 1. The nine points with uniform distribution are selected on the sample surface, so as to reduce the measurement error.

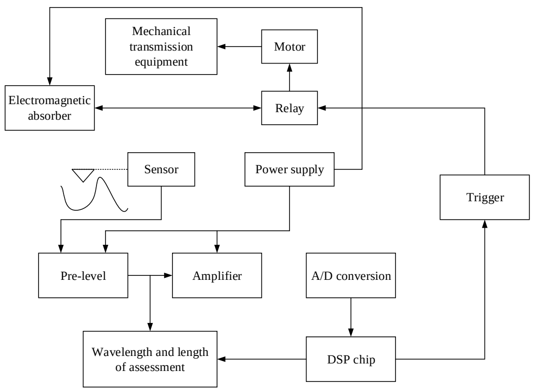

Figure 1 Flow chart of roughness instrument

3.4 Heat sink performance test

The radiation rate is a measurement of the ability of object surface to release the energy in the form of radiation. The object radiation ratio is equal to the ratio of black body radiation energy and energy of the object radiation at a certain temperature at the same temperature. The radiation rate of actual object is related to the surface state of the object, including surface temperature, surface roughness, surface oxide layer and so on [9].

In order to measure the influence of surface treatment on the performance of CPU heat sink, a wind tunnel test platform was built to test the surface temperature of the radiator under the forced convection. In the experiment, the heating rod is used as the heat source to simulate the CPU chip to provide heat for the heat sink. A simple wind tunnel is made of a high-power fan and an aluminum alloy plate, and the wind speed at the exit of the wind tunnel is about 15m/s. The heat radiation simulation device is arranged in a wind tunnel, the distance to the fan is about 300mm, and the airflow is evenly distributed through the heat sink to take away heat. When the input power is changed, the heat sink is used to collect the surface temperature of the heat sink. Each point is measured several times and the average is at last taken.

4 RESULTS AND DISCUSSION

4.1 Test results of sample surface radiation rate

In the experiment, the radiation rate of the sample after surface treatment is measured. The surface temperature of each sample is about 40 degrees centigrade, the ambient temperature is 26.5, and the humidity is 50%. The surface radiation rate of each sample is shown in figure 2. After the surface treatment, the surface roughness of the sample increases, and the radiation rate increases with the increase of the surface roughness. Compared with the original surface, the radiation rate increases 1.5 times after oxidation and the change is obvious.

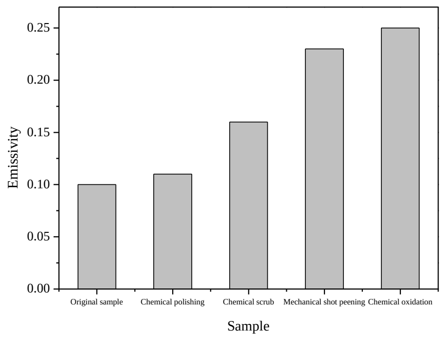

Figure 2 Surface radiation rate of each sample

The coating thickness is about 70μm in the experiment. The coverage rate reached 100%, the surface brightness sample increases obviously after coating, and the surface radiation rate calibrated at 40 DEG C is about 0.98, close to the black body. The surface spraying significantly increased the sample radiation rate. After surface treatment, the surface of specimen is also coated with a radiation dissipation coating, and the radiation rate is measured. The results show that the radiation rate of the surface of the sample is close to 1. That is to say, when the coating thickness is large enough that the coverage rate is over 100%, the substrate surface morphology of the sample has little effect on radiation rate.

4.2 Influence and its correction of environmental temperature on the experimental results

When the heat sink enters the stable temperature, as the temperature increases by 2 degrees centigrade for the same sample, the data measured twice is about 4~5 DEG C, which seriously affects the accuracy of the experiment, so it is necessary to correct the experimental data. With a certain linear relationship with environmental temperature and heat sink temperature at the bottom, so the linear fitting can be used to the linear equation of heat sink temperature changing with the ambient temperature. The temperature of all test points is corrected as that in the benchmark ambient temperature of 25 DEG C, and then comparative analysis is made. A represents the spray not coated, and B refers to the heat dissipation coating with the surface heat coating thickness about 70μm. The experimental data before the amendment is shown in figure 3.

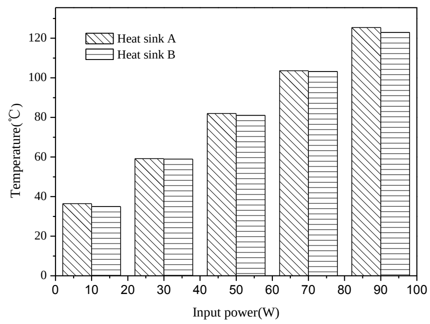

Figure 3 The temperature data before the correction

The software origin is used for fitting of the experimental data after being corrected, and the results are shown in figure 4. The regression equation distribution is shown as follows:

$$Y_A = 28.54 + 0.88\,X_A$$

$$Y_B = 23.36 + 0.88\,X_B$$

The absolute coefficient R^2 is close to 1, and the fitting degree is optimal. The curve showed that: after spraying the heat radiation coating, the surface temperature of the heat sink is reduced by about 5 DEG C. The slope of two regression models is basically equal, and the surface cooling effect is basically stable with the increase of input power.

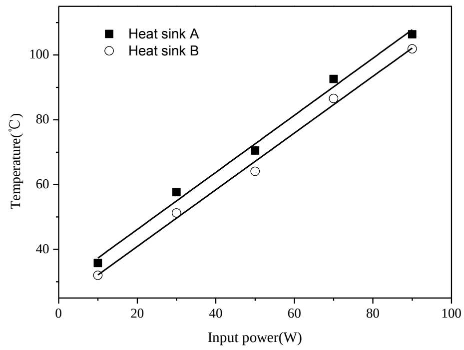

Figure 4 The experimental data of heat sink after the correction

4.3 Effect of coating thickness on heat dissipation result

In the experiment, four kinds of coatings with different thickness are sprayed on the surface of the heat sink. The coating thickness is control in 0.1mm, 0.15mm, 0.2mm, and 0.25mm, respectively. In the experimental device, the highest ground temperature of heat sink is measured. The radiating simulation device is arranged on the wind tunnel. After repeated measurements, the measured data are corrected to the reference ambient temperature of

25 DEG C. The measured temperature value is shown in figure 5, and the linear fitting confidence is set to 95%. From the fitting curve, it can be seen that, the increase of the coating thickness limits the cooling of the heat sink, increases the thermal resistance, and increases the temperature.

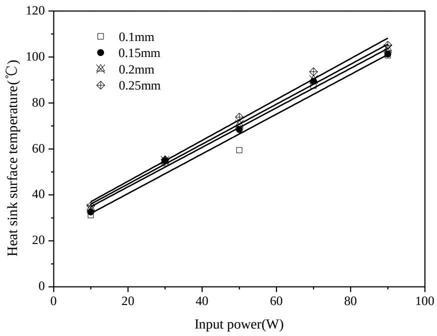

Figure 5 The surface temperature of the heat sink varies with the thickness of the coating after the correction

4.4 Influence of surface roughness on temperature of heat sink

Different micro morphologies were processed on the surface of the sample and their roughness was measured. The results are shown in figure 6, and it can be seen that, the roughness was increased obviously after surface treatment.

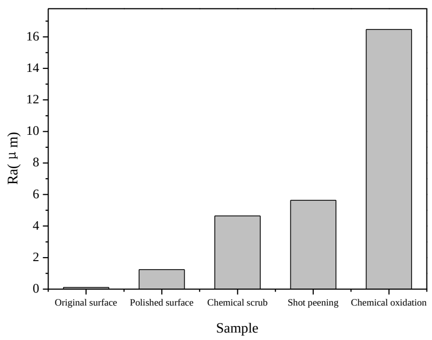

Figure 6 Ra value of surface of heat sink after different surface treatments

Any object is able to make infrared radiation to the space. The physical parameter for the measure of the object size is the radiation rate. That is the ratio of electromagnetic energy radiated outwards through the surface to the electromagnetic energy of black body under the same conditions. The radiation rate is related to the material structure, physical and chemical properties, the temperature and so on, to a great extent, it also depends on the surface state of the object. The CPU chip transfers heat to the fins, which dissipate heat into the space in the form of forced convection and infrared radiation. For the infrared radiation, the sample after surface treatment, the surface roughness increases, which showed irregular topography with uneven surface, namely the surface roughness. Such kind of irregular surface structure has a great effect on the radiation rate.

Different surface roughness sample temperatures, after repeated measurements and corrections, the average value is shown in figure 7. After the surface treatment, the heat sink temperature decreased slightly, and the biggest drop is about 5 DEG C. With the increase of surface roughness, the heat sink temperature decreases slightly. In the figure, the slope of the regression models have no great change. If the input power continues to increase, the temperature change amplitude will not be too big.

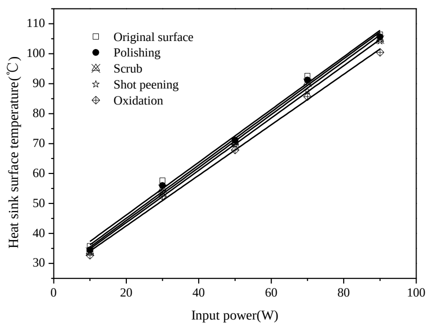

Figure 7 impact of surface roughness on the heat sink temperature

4.5 Influence of spraying treatment after substrate roughening on the performance of heat sink

The heat sink after surface treatment, the radiation heat dissipation coating with the thickness about 70μm is coated on the surface. The surface temperature in the wind tunnel is tested. After correction, the data is shown in figure 8. The linear regression is made in origin, and the confidence is 95%. The absolute coefficients R^2 of each curve are all close to 1, and the fitting degree is optimal. As can be seen from the diagram, the surface treatment has certain influence on the heat radiation coating, and the higher the input power is, the more obvious the effect is. When the input power is 90W, the temperature can be reduced by nearly 10 degrees at most. After treatment, the surface radiation rate of the sample does not increase, but the surface roughness increases the surface area between the radiator surface and the heat radiation coating, which is beneficial for the heat transferring from the heat sink to the coating.

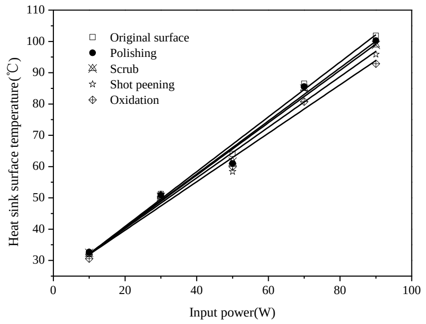

Figure 8 The heat sink surface temperature fitting curve after the correction

5 CONCLUSION

This paper, in terms of aluminum alloy CPU heat sink, uses the way of combining theoretical analysis and experimental study, to explore the effects of surface treatment technology on heat sink performance. With chemical polishing, chemical mechanical grinding, chemical oxidation, and shot peening, the surface of the samples is processed. Changing the micro structure of specimen surface, the surface roughness is measured. The original sample is 0.27μm, chemical polishing is 1.24μm, chemical scrub is 4.6μm, mechanical shot peening is 5.63μm, and the surface roughness is 16.5μm after chemical oxidation. The regression analysis is used for correcting the influence of environmental temperature. All temperature data are corrected to the reference ambient temperature of 25 DEG C for analysis and comparison. The greater the surface roughness is, the greater the emission rate is, and the lower the surface temperature is. Compared with the original sample, after chemical oxidation, the surface temperature of heat sink is reduced by about 5 DEG C. The spraying surface radiation coating can effectively increase the radiation rate of the heat sink surface, so the surface temperature is reduced about 5 DEG C. The surface roughness will strengthen the radiation dissipation cooling performance of coatings. The greater the surface roughness is, the higher the temperature is, and the more obvious the strengthening effect is. After oxidation, the most obvious the cooling effect of the spraying coating is, and the cooling rate is nearly 10 degrees.

In this paper, the characterization of sample surface structure after the surface treatment is limited to the surface roughness. The further comprehensive analysis of the change of the sample is not carried out. And the external environment will greatly affect the measurement precision and structure. It is necessary to further design high precision measurement platform, for eliminating interference factors. In addition, a detailed theoretical analysis of the factors influencing the radiation rate and coating performance is made, so as to play an important guiding role in the optimization design and actual application of radiator.

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