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Research on Reliability of Heavy Copper Wire Bonding for IGBT Module

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Abstract

In the advanced application of power electronic modules, the design and manufacture of power modules must meet the requirements of high frequency switching rate, high power density, high junction temperature, etc. With the increase of power density, the current carrying capacity of the terminal interconnection is required to be higher, and the traditional aluminum wire will have a higher temperature rise under a large current. Therefore, the use of copper terminal through-flow technology can support the establishment of higher power platforms. In this paper, we focus on the relationship between the properties of copper wire bonding and their reliability in IGBT module applications.

1 Introduction

In the design and manufacture of power modules must meet the requirements of high frequency switching rate, high power density, high junction temperature, etc., and the lead interconnection technology of traditional power electronic modules usually uses aluminum wire bonding. But due to the limitations of aluminum wire resistivity, low yield strength material itself, this connection has become the key to limit the development of high-power power electronic modules[1]. With the continuous increase of chip power density, the device power density is increasing, and the application current is also increasing. The same package and process system can no longer meet the increasing power density of devices.

Compared with aluminum wire, copper wire has higher electrical and thermal conductivity, as well as higher yield strength and mechanical stability[2]. Copper wire terminal through-flow technology can support the establishment of higher power platform by applying boundary forward research terminal through-flow technology[3].

In this paper, we focus on the relationship between terminal copper wire bonding properties and its reliability in power device applications. The selection of copper wire bonding wire is the key point in the design of power module. We study to control the grain size of copper wire by controlling the temperature and time of heat treatment in the process of copper wire production. Bond line grain size plays an important role in the reliability of power module terminals. By refining the grain, the bottleneck problem of the bonding point neck after warm flushing can be solved, and the number of reliability cycles can be increased.

2 Copper wire terminal performance

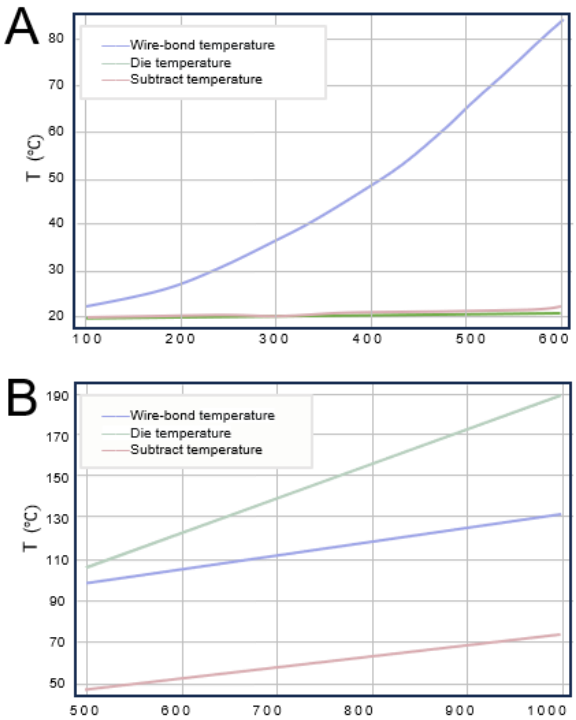

Fig.1. Bond-wire/chip/substrate temperature changes with chip loss(A) and no chip loss(B).

Compare the relationship between chip temperature rise and terminal temperature rise in the same current

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power module. As can be seen from Figure 1, the terminal temperature is proportional to the square of the current, and the terminal temperature has very little effect on the chip temperature because the heat loss of the terminal is very low; The heat loss of the chip is proportional to the terminal temperature, and the chip temperature has a great influence on the terminal temperature. For every 50W increase in chip power dissipation, the terminal temperature rise increases by 5℃.

Comparing the temperature rise of aluminum wire and copper wire in a current power module of the same specifications, the actual test results show that the highest temperature of aluminum wire bonding at the busbar can be reached to 158.7℃, while the highest temperature of copper wire bonding is 113℃, and the temperature rise of copper wire is 29% lower than that of aluminum wire. And modules that use copper wire have a more consistent temperature rise in different phases.

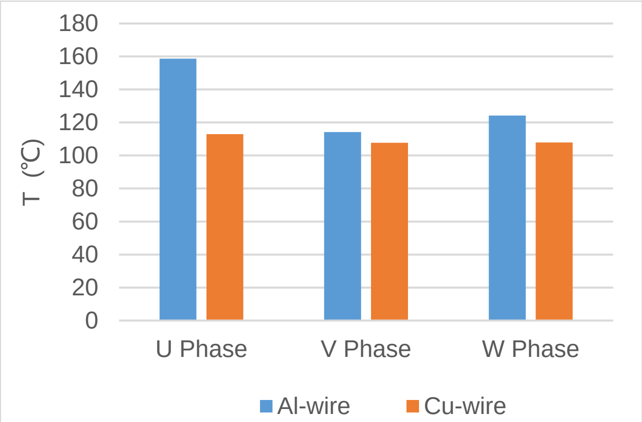

Fig.2. Comparison of temperature rise of different phases of copper wire and aluminum wire.

3 Experiment and analysis

By using copper wire with different material properties, packaged in same specification power module to compare its reliability.

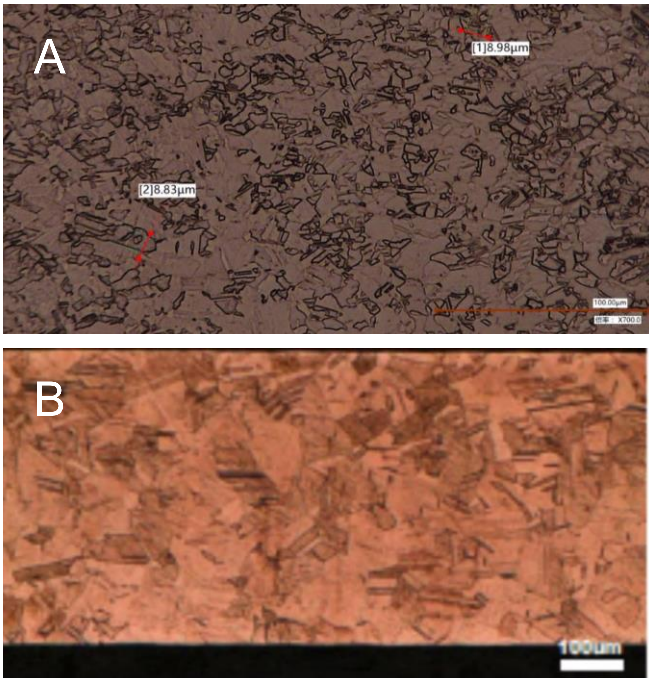

Fig.3. The samples with different grain sizes.

The selection of copper bonding wire is important to the package design of power module. The samples with different grain sizes were obtained by different heat treatment methods (see Fig. 3). The sample with the grain size of 20-40um is named A, and the sample with the grain size of 40-70um is named B. The weak point of the terminal bond line is reflected in the internal stress caused by thermal expansion and contraction during the high and low temperature cycle. After 1000 temperature cycles, it can be seen that the copper wire with the finer grain resists the temperature shock, while the sample with the larger grain develops cracks in the heel zone of wire bond after the temperature shock (see Fig. 4). In addition, the toughness of samples with different grain bonding wire has tested by bending test. The test method and results were shown in Fig. 5. Fine-grain copper wires could withstand more bending tests.

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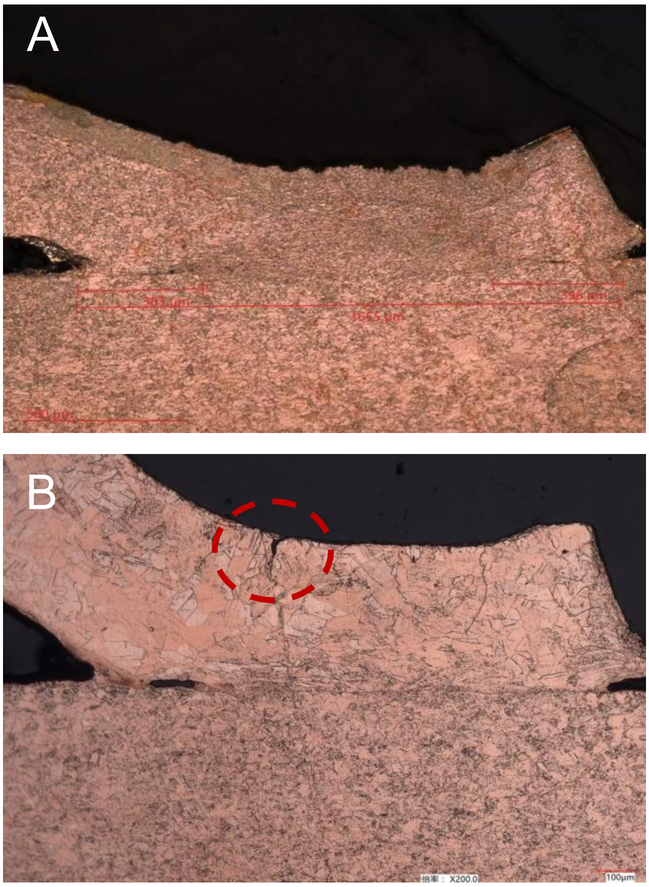
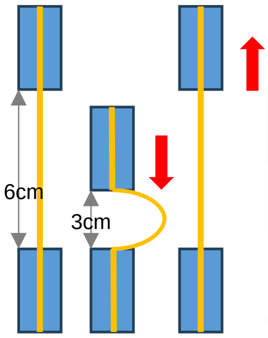


Fig.4. The cross section between wire bond and DBC.



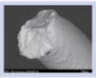
sample	Number of bending cycles	Appearance of bending fracture
A	181	
B	124	

Fig.5. The diagram of bending test and the result of bending cycles between two samples.

This is because when the grain size is small, the material in the unit volume has more grains and grain boundary number, while producing greater grain boundary energy, and the grain boundary as a place to hinder the movement of dislocation, so that the dislocation continues to accumulate and gradually tangled, so that the deformation resistance increases, the overall strength of the material continues to improve. With the grain thinning and the increase of grain boundaries, the dislocation movement is hindered, and the dislocation is accumulated at the grain boundaries. The grain boundaries are used as a way to hinder the growth of cracks, and the purpose of improving the reliability of the modules is achieved.

4 Summary

In this research we find that the desired grain size of copper wire is obtained by controlling the heat treatment in the process of copper wire production. And the grain size of bonding wire plays an important role in the reliability of power module terminals. The reliability of terminal copper wire can be improved by refining the grain.

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