

Study on hydrogen release mechanism of package shell

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Abstract: In this paper, the hydrogen release amount of SiC particle reinforced aluminum matrix composite (SiCp/Al) base plate, titanium alloy enclosure and its packaging shell was studied, the influence of substrate surface morphology on the hydrogen storage state of the coating was analyzed, and the hydrogen release mechanism of the packaging shell was discussed. The results show that the gold-plated SiCp/Al composite is the main source of hydrogen release from the package shell, and its complex surface morphology leads to different hydrogen storage states of the coating. At the early stage of baking, the hydrogen storage release is mainly due to micropores and interface defects, which is the main reason for the large amount and dispersion of hydrogen release from the package shell. Continuous baking is mainly stable release of lattice hydrogen storage, resulting in stable and discrete release of hydrogen.

Keywords: SiCp/Al composites; Package shell; Electroless nickel plating; Hydrogen release mechanism

1. Introduction

In recent years, packaging shells composed of high volume fraction SiCp/Al composites / titanium alloys have been widely used in aerospace products. The silicon carbide particle reinforced aluminum matrix (SiCp/Al) composite in the packaging shell has excellent properties such as light weight, low expansion, high thermal conductivity and high specific strength, and the titanium alloy has excellent properties such as light weight and high strength, providing a solution for light weight, high strength, high power and high heat dissipation microwave functional components [1]. A large number of studies and engineering practices have proved that the hydrogen in the module can cause the "hydrogen effect" of GaAs bare chips, resulting in the degradation of device performance and the reduction of module reliability [2-4]. It is generally believed that the generation of "hydrogen effect" is related to the hydrogen resistance of GaAs bare chips and the hydrogen content in components [5-7]. Therefore, in order to ensure the long-term reliable operation of the module, a lot of work has focused on improving the hydrogen resistance of GaAs bare chips and controlling the hydrogen content in the module.

The research shows that [5-7], there are many factors affecting the hydrogen content in the module, and the coating of packaging material is an important source of hydrogen release. In terms of controlling the internal hydrogen content of components, the main work focuses on the screening of hydrogen release sources and reducing the internal hydrogen content of components through baking. However, the research on the hydrogen release mechanism of the package shell is insufficient, which seriously restricts the hydrogen control effect of the module and brings hidden dangers to the reliability of the module.

In this paper, the SiCp/Al composite / titanium alloy packaging shell is taken as the research object. Through the research and analysis of the relationship between the hydrogen release amount and dispersion of the packaging shell and the baking times, the hydrogen release mechanism of the packaging shell is tried to reveal, which provides a theoretical basis for the application of hydrogen removal engineering of the packaging shell.

2. Experimental materials and methods

The packaging shell is composed of a bottom plate and a frame by gold tin welding. The bottom plate is made of SiCp/Al composite material, which is prepared by pressureless infiltration method.

The brand is SiCp/Al-dz8, and the volume fraction of SiCp is 52%-60%; The enclosure is made of titanium alloy and the brand is TC4 (m); The basic process of gold plating is electroless nickel plating + gold plating. The nickel layer contains about 10% phosphorus, with a thickness of about 10 μ m, and the thickness of gold layer is about 2.5 μ m[8]. By placing the sample in a sealed aluminum alloy box for baking, the hydrogen content in the aluminum alloy box represents the hydrogen release of the sample. Detect the hydrogen content in the aluminum alloy box according to gjb548b-1018.1 standard.

3. Results and discussion

The internal hydrogen content of the packaging shell produced by the same process is tested after it has been used for half a year at a temperature not higher than 45 °C, and the results are shown in Table 1. It can be seen from table 1 that the hydrogen content inside the package shell is 700ppm at least and 30500ppm at most, indicating that the package shell can release hydrogen and accumulate in the shell at low temperature, and the hydrogen release amount is obviously discrete.

Table 1. Test results of hydrogen content inside the package shell

Sample No	0504	0596	0667
Hydrogen release (ppm)	700	30500	12500

To further investigate the source of hydrogen release from the packaging shell, the gold-plated titanium alloy enclosure and SiCp/Al composite base plate were baked at 150 °C for 96 hours, and the hydrogen release was detected. The test results are shown in Table 2. It can be seen from table 2 that the hydrogen release from the gold-plated titanium alloy enclosure is 1165ppm to 1924ppm, and the dispersion is small, while the hydrogen release from the gold-plated SiCp/Al composite base plate is 1485ppm to 14200ppm, and the dispersion is large.

Table 2. Hydrogen release test results of gold plated titanium alloy enclosure and SiCp/Al composite base plate test pieces

Sample No	Gold-plated titanium alloy enclosure			Gold-plated SiCp/Al composite base plate		
	B3 #	B4 #	B5 #	11 #	16 #	17 #
Hydrogen release (ppm)	1907	1165	1924	1485	14200	13700

It can be seen from table 1 and table 2 that the hydrogen release from the gold-plated SiCp/Al composite bottom plate is dominant to the hydrogen content in the packaging shell, and the dispersion of its hydrogen release is the main reason for the dispersion of the hydrogen release from the packaging shell.

In order to further study the hydrogen release law of the package shell, the package shell was baked at 250 °C for 48 hours, and the hydrogen release was detected. The relationship between the hydrogen release amount of the package shell and the baking times is shown in Figure 1. It can be seen from the above that the hydrogen release and its dispersion of the package shell first decrease sharply and then tend to be stable with the increase of baking times, which shows that, on the one hand, baking can effectively reduce the hydrogen release and its dispersion of the package shell; on the other hand, the hydrogen release of the package shell can be divided into two stages, namely, the rapid hydrogen release stage and the stable hydrogen release stage, with the second baking as the dividing point.

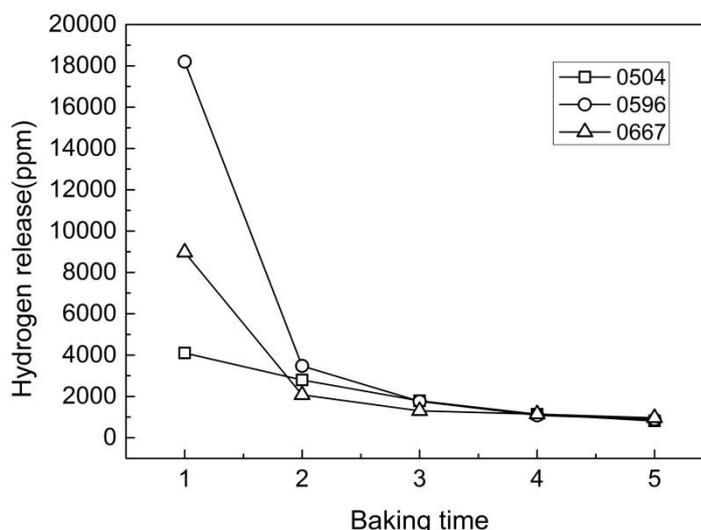


Figure 1. Relationship between hydrogen release of package shell and baking times

The research shows that [9-11], in the process of electroless nickel plating, with the deposition of nickel layer, phosphorus, hydrogen and other impurities can be "wrapped" into the coating. Due to the mismatch between nickel and matrix lattice, the nickel lattice is stretched to provide a storage place for hydrogen. The greater the lattice mismatch, the more hydrogen will be stored. The coating obtained by electroless nickel plating has an amorphous structure, the morphology is composed of cells, the cell wall surface is smooth, there is a certain gap between the cells, and there are no structural imperfections such as grain boundary, sub grain boundary, phase boundary, dislocation and stacking fault in the crystalline structure. For the coating, the surface morphology and surface defects of the substrate material seriously affect its internal structure, and then affect the internal hydrogen content and hydrogen storage state of the coating.

In this project, electroless nickel plating is used as the transition layer in the gold plating process of titanium alloy enclosure and SiCp/Al composite base plate. For the hydrogen storage state of the coating of the packaging shell, the hydrogen release amount and dispersion phenomenon can be analyzed based on the different coating states caused by the substrate state. For the titanium alloy enclosure, due to its dense structure and less surface defects, the coating is also dense. The hydrogen in the coating is mainly stored in the mismatched lattice, which is the reason for the small amount of hydrogen release and discrete type of the titanium alloy enclosure; For SiCp/Al composite base plate [12], on the one hand, SiCp is pulled out, cut off, crushed by rolling or SiCp/Al interface cracks during machining, forming surface defects, providing a large number of storage places for hydrogen; On the other hand, according to the growth mechanism of nickel layer [10-11], its surface defects can lead to the existence of porous structural defects such as micropores in the coating, which can wrap a large amount of hydrogen. Therefore, there are three states of hydrogen storage in the composite coating: lattice hydrogen storage, microporous hydrogen storage and interface defect hydrogen storage. Microporous hydrogen storage and interface defect hydrogen storage are easier to release in large quantities and have greater randomness, and lattice hydrogen storage release is more stable.

It is proved that [5], the hydrogen in the coating can be released in a wide temperature range. In a low temperature environment, when the micropore is close to the coating surface, even at a low temperature, its internal hydrogen can break through the micropore and release, which is the reason why the internal hydrogen content of the 45 °C storage packaging shell reaches 10000 ppm. When the temperature is high, more micropores and interface defects release hydrogen, which is the main reason for the large amount of hydrogen released from the packaging shell at the initial stage of baking. After baking, on the one hand, hydrogen is released outward, which reduces the hydrogen

content in the coating; on the other hand, it promotes the diffusion of some hydrogen into the lattice. Therefore, when baking is continued, the hydrogen storage is released completely due to micropore and interface defects, and the hydrogen release from the coating gradually changes to the lattice hydrogen storage release, resulting in the reduction of hydrogen release. With the increase of baking times, the hydrogen content in the coating decreases, and the lattice hydrogen storage becomes more uniform, which increases the difficulty of hydrogen release, resulting in the stabilization of hydrogen release and dispersion of the package shell.

4. Conclusions

Baking can effectively promote the release of hydrogen from the package shell, and increasing the baking times can effectively reduce the amount of hydrogen released from the package shell and its dispersion. The gold-plated SiCp/Al composite is the main hydrogen release source of the packaging shell. On the one hand, its surface defects provide a storage place for hydrogen, on the other hand, they induce microporous defects in the coating, which increases the hydrogen content of the coating. The storage state of hydrogen in the coating determines the hydrogen release mechanism. In the early baking stage, the hydrogen storage release of gold-plated SiCp/Al composite micropores and interface defects is the main reason for the large amount and dispersion of hydrogen release from the packaging shell. The continuous baking is mainly due to the release of lattice hydrogen storage, resulting in the stable and discrete hydrogen release of the package shell.

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