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Research on hydrogen release control process of package shell

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Abstract. In this paper, through the influence of baking temperature and time on the hydrogen release of silicon carbide particle reinforced aluminum matrix composite (SiCp/Al) base plate, titanium alloy enclosure and its package shell, the hydrogen control process of package shell is proposed. The results show that increasing the dehydrogenation temperature and prolonging the dehydrogenation time can reduce the hydrogen release from the package shell. By using this hydrogen control process, the internal hydrogen release of the package shell under the baking condition of 250℃ and 48 hours cannot be greater than 2000ppm, which can effectively improve the consistency of the hydrogen release of the product, and the impact on the appearance quality, adhesion and weldability of the coating is acceptable, meeting the product use requirements.

Keywords: SiCp/Al composites; Package shell; Hydrogen release; Hydrogen control process

1. Introduction

The internal atmosphere of the package shell has an important impact on the functional stability and long-term reliability of components [1]. The previous research mainly focused on the control of internal water vapor, oxygen and carbon dioxide, and made great achievements. Recently, the components represented by GaAs are sensitive to hydrogen, causing the "hydrogen effect" problem, resulting in the decline of component functions, seriously affecting the project progress and causing huge economic losses [1-7].

The "hydrogen effect" is the result of the mismatch between the hydrogen resistance of components and the hydrogen content in the package shell. According to research reports [6], the hydrogen resistance of components can be improved through the optimization of component circuit design and manufacturing process, so as to effectively alleviate the problem of "hydrogen effect", but other indicators of components may be reduced. Controlling the hydrogen content in the package shell has become an important research direction to alleviate the "hydrogen effect". The research data show that [3], the hydrogen release from the package shell is distributed from hundred degree ppm to ten thousand degree ppm, which has obvious discreteness, and has a great impact on the selection of hydrogen release control process path and hydrogen control effect. R.Z. Ding et al. [1] carried out vacuum hydrogen removal at 200 ℃ for 12 hours and 24 hours on the solder cover plate with Au80Sn20. After 1000 hours at 125 ℃, the hydrogen content fluctuated between 4000-13000ppm; H.B. Li et al. [7] realized that the internal hydrogen content after high-temperature storage was not greater than 2000ppm by baking the 4J29 kovar alloy package shell at high temperature. These studies provided a favorable support for solving the problem of "hydrogen effect".

With the rapid development of aerospace and Avionics products, the demand for lightweight microelectronic package shell is becoming more and more urgent. The package shell composed of high volume fraction SiCp/Al composite / titanium alloy has excellent properties such as lightweight and high thermal conductivity, and is widely used in aerospace products [8]. However, there is little research on the internal hydrogen content control of this kind of package shell, which limits its wide application. Therefore, this paper takes this kind of package shell as the research object, from the perspective of economy and reliability, studies the influence of baking temperature and baking time on the hydrogen release of the package shell, formulates the hydrogen removal

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process of the package shell, and studies the influence of the hydrogen removal process on the reliability of the package shell.

2. Experimental materials and methods

The package shell studied in this paper is composed of three parts: base plate, enclosure and cover plate. The base plate material is 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 and cover plate are made of titanium alloy, and the brand is TC4 (M); In order to meet the welding requirements, the surface of the bottom plate and the enclosure is treated with gold plating. 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 μm, and the thickness of the gold layer is about 2.5 μm.

The bottom plate, enclosure and its shell are placed in the closed aluminum alloy box for baking, and the hydrogen content in the aluminum alloy box represents the hydrogen release of the sample. The bottom plate and the enclosure form a package shell through gold tin welding. The titanium alloy cover plate and the package shell are sealed by laser welding to form a sealed component shell. After baking, the hydrogen content in the shell is detected. All atmosphere tests shall be conducted according to GJB 548b-1018.1 standard.

3. Results and discussion

3.1 Dehydrogenation temperature

After a certain time of installation of a T/R component (the temperature is not higher than 45℃, and the duration is about 500 hours), the internal hydrogen content test results are shown in Table 1. It can be seen that the internal hydrogen content of the module is as high as 23400ppm, which is consistent with the previous research results. The results show that hydrogen released from the coating in the module and accumulated in the sealed shell is the main reason for the increase of hydrogen content in the module.

Table 1. Test results of internal hydrogen content of components

Sample No	0215	1106	1354
Hydrogen release（ppm）	19100	23400	22100

After the gold-plated titanium alloy enclosure and the gold-plated SiCp/Al composite base plate are baked at 150℃ for 96 hours, the hydrogen release test results are shown in Table 2. It can be seen that the hydrogen release of the gold-plated titanium alloy is not more than 2000ppm, and the hydrogen release of the gold-plated SiCp/Al composite base plate is as high as 10000 ppm.

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

Sample No	Gold-plated titanium alloy enclosure(150℃、96h)			Gold-plated SiCp/Al composite base plate(150℃、96h)		
	B6＃	B7＃	B8＃	4＃	18＃	19＃
Hydrogen release（ppm）	1439	931	1371	8031	11200	12500

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By analyzing the results in Table 1 and table 2, it can be concluded that the hydrogen in the package shell in this study mainly comes from the gold-plated SiCp/Al composite base plate. This provides an experimental basis for the subsequent dehydrogenation of the package shell.

After the gold-plated SiCp/Al composite base plate is baked at 250℃, 48 hours and 72 hours respectively, the hydrogen release test results are shown in Table 3. It can be seen that the hydrogen release of gold-plated SiCp/Al composite base plate is as high as 33200ppm after 48 hours of baking. After 72 hours of baking, the hydrogen release is as high as 59400ppm. The hydrogen release increases by nearly 30000ppm after 24 hours. This indicates that extending the baking time is conducive to the release of hydrogen gas.

Table 3. Hydrogen release test results of gold plated SiCp/Al composite base plate

Sample No	Gold-plated SiCp/Al composite base plate(48h)			Gold-plated SiCp/Al composite base plate(72h)		
	236	271	154	0357	0853	0316
Hydrogen release（ppm）	25400	33200	30900	28000	49700	59400

It can be seen from the results in Table 2 and table 3 that the hydrogen release from the gold-plated SiCp/Al composite bottom plate increases by nearly 20000ppm when the temperature increases by 100 ℃ , which indicates that increasing the baking temperature is conducive to hydrogen release. The research shows that when the temperature is higher than 250℃, with the increase of temperature, on the one hand, the coating changes from amorphous state to polycrystalline state or even crystalline state, resulting in the release of internal stress in the coating and the generation of microcracks [9]; On the other hand, Ni in the coating intensifies the diffusion to the gold layer, affecting the weldability of the coating [7]. Therefore, combined with the results of this study, the dehydrogenation temperature of the package shell should not be higher than 250℃.

3.2 Dehydrogenation time

The package shell was baked at 250℃ for 48 hours for multiple rounds, and the hydrogen release test results are shown in Table 4. It can be seen that with the increase of baking times, the hydrogen release from the package shell decreases. After 96 hours of baking, the hydrogen release drops below 2000ppm. After 192 hours of baking, the hydrogen release drops to 1000ppm. This shows that prolonging the baking time can effectively reduce the hydrogen release, but when the baking time exceeds a certain extent, the hydrogen removal effect is weakened. This is because when the hydrogen content in the coating is reduced to a certain extent, the hydrogen released by the coating is at a considerable level with the hydrogen adsorbed, resulting in the hydrogen removal effect. Therefore, considering the project development cycle and cost control, the dehydrogenation time of the package shell in this study should not exceed 192 hours.

Table 4. Hydrogen release test results of package shell

Sample No	Baking time				
	1	2	3	4	5
0504	4100	2797	1787	1138	815
0596	18200	3474	1760	1083	882
0667	8974	2074	1302	1145	961

3.3 Dehydrogenation process

According to the discussion in chapters 3.1 and 3.2, the process flow of package shell dehydrogenation is developed in combination with the product realization process, as shown in Figure 1. The gold-plated titanium alloy enclosure is baked at 250℃ for 48 hours to remove

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hydrogen, the gold-plated SiCp/Al composite base plate is baked at 250℃ for 120 hours to remove hydrogen, and the package shell is baked at 250℃ for 48 hours to remove hydrogen. The hydrogen removal atmosphere is vacuum.

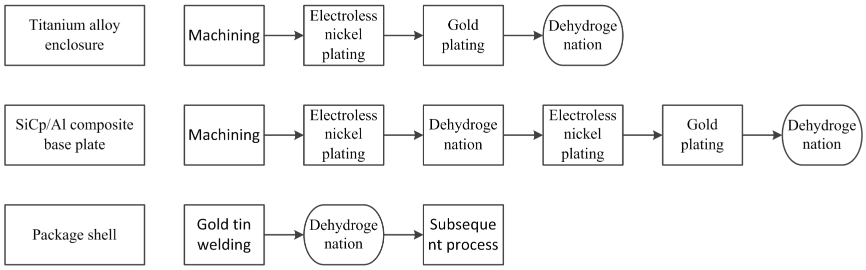

Fig. 1 Process flow chart for dehydrogenation of package shell

3.4 Dehydrogenation result

After baking the titanium alloy enclosure, gold-plated SiCp/Al composite base plate and package shell at 250℃ for 48 hours, test the hydrogen release. The results are shown in Table 5. It can be seen that after the hydrogen removal process is adopted, the hydrogen release from the gold-plated titanium alloy enclosure is not more than 1000ppm, the hydrogen release from the gold-plated SiCp/Al composite base plate is not more than 3000ppm, and the hydrogen release from the package shell is not more than 2000ppm.

Table 5 Hydrogen release test results of titanium alloy enclosure, SiCp/Al composite base plate and package shell after hydrogen removal

Sample No	Titanium alloy enclosure		SiCp/Al composite base plate		Package shell	
	0033	0002	4121	4139	4058	4099
Hydrogen release（ppm）	611	610	2998	2743	1094	1371

3.5 Dehydrogenation effect

The hydrogen removal process increases the long-time high-temperature baking, which may affect the adhesion and weldability of the coating. The appearance quality and adhesion of the coating after hydrogen removal were tested. The results showed that the coating had no rough crystallization, scorching, blistering, peeling, corrosion spots and local bottom exposure.

In order to test the adhesion of gold coating on the surface of carbon silicon aluminum heat sink substrate, select a sample that has been baked at high temperature, and test the adhesion of gold coating by pull-out method, as shown in Figure 2. The maximum strength of the adhesive used in the pull-off test is 15MPa. After the pull-off test, it can be seen that the adhesive breaks and the gold coating does not fall off, indicating that the bonding force of the gold coating on the surface of the SiCp/Al composite base plate is ≥ 15MPa.

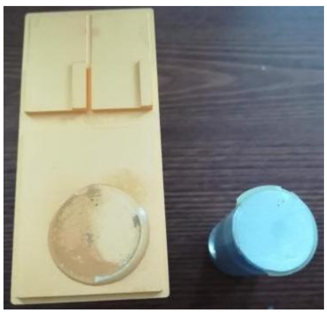
Figure 2. Pull off force test of gold coating on the surface of heat sink substrate

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Carry out micro assembly weldability and reliability verification sample assembly on the assembly shell, and conduct X-ray inspection on the brazing penetration at the welding position of components in the assembly after the screening test. The results are shown in Figure 3.

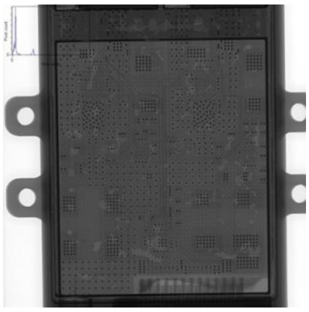

Figure 3. X-ray photo of base plate after welding

It can be seen from Figure 3 that the welding of components and parts is carried out according to the welding process parameters of the product, and the welding penetration rate of components and parts is up to 90%, which shows that the influence of increasing the dehydrogenation process on the solderability of the package shell is within an acceptable range.

4. Conclusions

Increasing the dehydrogenation temperature and prolonging the dehydrogenation time will reduce the hydrogen release of the package shell, but when the time exceeds 192 hours, prolonging the dehydrogenation time will reduce the dehydrogenation effect. Under the condition of 250 ℃ and vacuum, 48 hours, 120 hours and 48 hours of hydrogen removal are respectively carried out for the gold-plated titanium alloy enclosure, the gold-plated SiCp/Al composite base plate and the package shell, so that the internal hydrogen release of the package shell under the condition of 250 ℃ and 48 hours of baking can not be greater than 2000ppm, effectively improving the consistency of product hydrogen control. The addition of hydrogen removal process has an acceptable impact on the appearance quality, adhesion and weldability of the coating, meeting the product use requirements.

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