EFFECT OF DIFFERENT SURFACE PRETREATMENT METHOD ON VACUUM BRAZING JOINT PROPERTIES OF ALSI50 ALLOY

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Abstract:

In this paper, the effect of different surface pretreatment method on properties of vacuum brazed joint of AlSi50 alloy was investigated. The surface pretreatment methods of specimen before brazing include sanding, NaOH corrosion, HCl corrosion, H_2SO_4 corrosion and nickel plating. The experimental results indicate that the width of brazing joint varies with different surface pretreatment methods. The joint with sanding pretreatment, has the largest brazing seam width of 20 μm. Meanwhile, joint with H_2SO_4 corrosion has the narrowest brazing seam width. The brazing filler metal can wet and spread on different pretreated specimen very well. Spectrum analysis indicates that nickel-plate on AlSi50 surface, can interact with brazing filler metal, which increases mechanical property of brazing joint. For brazing of AlSi50 alloy, the optimal pretreatment method is nickel plating. After nickel plating pretreatment, brazing joint has the maximum shear strength 82.05 MPa by using brazing filler metal Al52-Cu33-Mg12-Ni3 and following technological parameters: brazing temperature 580 ℃, soaking time 30 min and pressure 3 MPa.

1 Introduction

At present, high-end equipment manufacturing areas need a lot of new materials, which must have excellent strength, ductility, toughness, corrosion resistance and thermal conductivity [1-4]. Compared with the conventional materials, high-silicon aluminum alloy has excellent performances, such as light weight, high strength, high thermal conductivity, small coefficient of linear expansion, good dimensional stability and so on, which makes this kind of material widely used in the fields of aerospace electronic packaging [5, 6]. At the same time, high-silicon aluminum alloy also can be plated by copper, nickel and other materials to produce a good plating effect [7, 8].

In recent years, researchers have done a lot of research about high-silicon aluminum [9, 11]. But very little research has been done on its welding technology and property. This makes the welding problem the main factor for the promotion and application of high-silicon aluminum. At present, the welding methods of high-silicon aluminum are mainly solid phase welding and brazing [12, 13]. High-silicon aluminum is easy to be oxidized at elevated temperature and room temperature to produce refractory alumina film. However, the oxide film seriously affects the welding

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process and quality. For further wide application of high-silicon aluminum, an efficient and high-quality welding technology has to be investigated [14]. Vacuum brazing is a kind of precise and effective welding method, which is appropriate for high-silicon aluminum welding since it can provide an oxygen-free environment preventing formation of aluminium oxide. For vacuum brazing, some factors such as brazing temperature, soaking time, pressure on specimen, as well as brazing filler metal have influence on joint performance, and researchers have already done a lot of work in that direction [15]. Besides those factors, the surface pretreatment method of specimen before brazing has also significant influence on joint performance [16-18]. In this paper, the effects of different surface pretreatment methods on performance of vacuum brazing joint are discussed in detail.

2 Experiment material and procedure

The base material used in this experiment is AlSi50 alloy manufactured by pressure casting. The chemical composition, performance and microstructure of AlSi50 are shown in Table 1, Table 2 and Figure 1, respectively. Each specimen was cut into dimension of 20 mm × 10 mm × 4 mm. Brazing filler metal used in this research was Al52-Cu33-Mg12-Ni3, which was prepared by melt-spinning technology and proved to be an applicable filler metal for AlSi50 alloy joining by previous research [19].

Table 1. Chemical composition of AlSi50 (wt%)

Element	Si	Fe	Zn	Ca
Content	50.6	0.02	0.015	0.01
Element	Sn	Pb	Al	
Content	0.015	0.015	Balance	

Table 2. Physical and mechanical performance of AlSi50

Thermal expansivity (ppm/℃)	Thermal conductivity (W/mK)	Density (g/cm^3)	Tensile strength (MPa)
11.5	140	2.5	220
Yield strength (MPa)	Poisson ratio	Elongation	Elasticity modulus (GPa)
210	0.25	<1	105

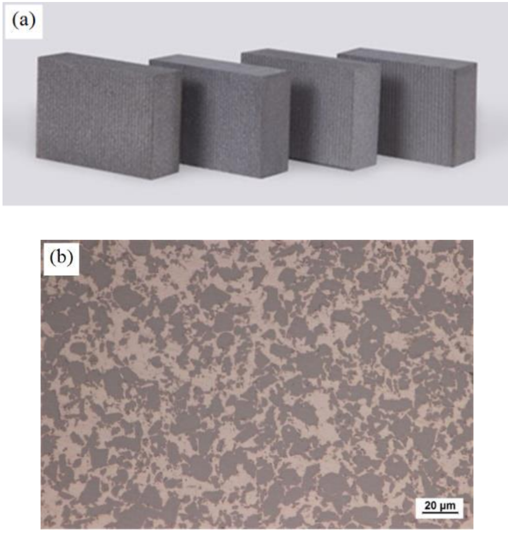

Figure 1. AlSi50 alloy: (a) macrospecimen and (b) microstructure

Vacuum brazing experiment was performed on OTL1200 vacuum tube furnace. The process parameters were set as following in experiment: the vacuum degree 6.5 × 10^{-3} Pa, brazing temperature 580 ℃, soaking time 30min and welding pressure 3 MPa. Before vacuum brazing, AlSi50 surface was pretreated by five different methods: sanding with #120 paper, H_2SO_4 corrosion (0.3 mol/L and etching time 30 seconds), HCl corrosion (0.3 mol/L and etching time 30 seconds), NaOH corrosion (0.3 mol/L and etching time 30 seconds) and nickel plating (electroless plating). In order to study the effect of surface pretreatment on joint properties, vacuum brazing was also performed on a non-pretreated AlSi50 specimen with the same process parameters. A specific specimen number and pretreatment method is presented in Table 3.

Table 3. Different surface pretreatment method of specimen

Specimen number	Surface pretreatment method	Specimen number	Surface pretreatment method
1#	Sandpaper polished	4#	H_2SO_4 corrosion
2#	NaOH corrosion	5#	Nickel plating
3#	HCl corrosion	-	-

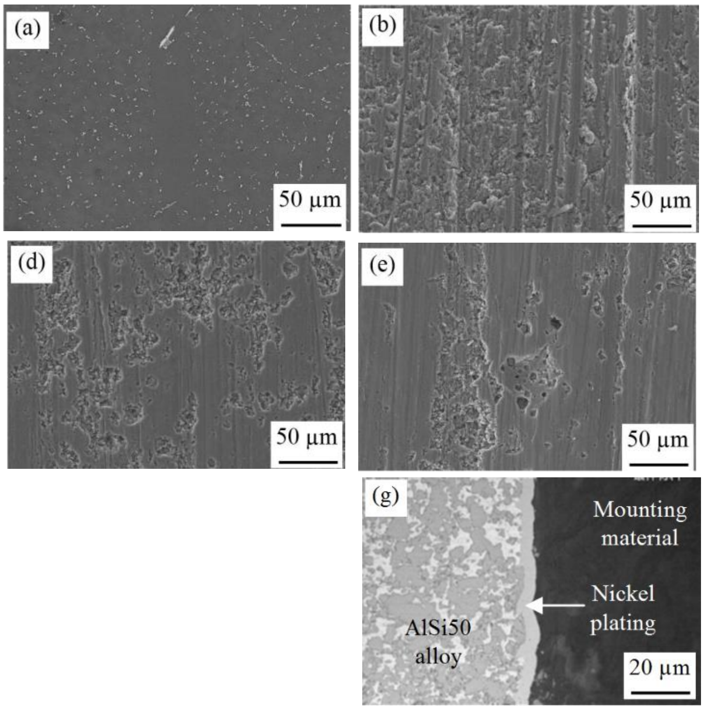

Figure 2. Surface microstructure of specimen after different pretreatments: (a) Non-pretreatment, (b) Sanding with #120 paper, (c) NaOH corrosion, (d) HCl corrosion, (e) H_2SO_4 corrosion, (f) Nickel plating and (g) Nickel plating cutting from the cross section

Microstructure of the specimen was analyzed by optical metallographic microscope OLYMPUS - CK40M, and the shear strength was tested on electronic universal testing machine CMT5105. Joint morphologies were observed by Merlin Compact scanning electron microscopy and local analysis was performed on OXFOED spectroscopy.

3 Results and discussions

3.1 Surface microstructure of specimen after different surface pretreatment

Figure 2 shows surface microstructure of the specimen after different surface pretreatments.

Figure 2 (a) shows the surface microstructure of AlSi50 alloy without pretreatment. It can be seen that AlSi50 alloy is free from the brazing defects such as void. Meanwhile, Si particles distribute uniformly on Al matrix. Figure 2 (b) presents a groove-like surface morphology after sanding with #120 paper. Theoretically, grooves on AlSi50 surface will benefit joint brazing performance because it will lead the filler metal to the faying surface effectively. Figure 2 (c), Figure 2 (d) and Figure 2(e) present surface morphologies of AlSi50 after corrosion with NaOH, HCl and H_2SO_4, respectively. The oxide on AlSi50 surface is removed during the corrosion. Figure 2 (f) shows that AlSi50 surface is covered by defect-free nickel plating totally. Figure 2 (g) shows the microstructure of nickel-plating specimen cutting from the cross section. It can be seen that the nickel-plate on AlSi50 is very well with the thickness around 10 μm. Theoretically, nickel plating on AlSi50 surface will improve joint performance because it can change joint status. Before nickel plating, two kinds of bonding interfaces exist in brazing seam: interface between filler metal and aluminum, interface between filler metal and Si particle. However, the strength of interface between filler metal and Si particle is quite weak. After the nickel plating, the weak combination between filler metal and Si particle will be replaced by the nickel.

3.2 Microstructure of vacuum brazed joint

Figure 3 shows microstructure of brazed joints. As can be seen, the combinations between brazing filler metal and base metal with different surface states are all quite well. The reason for that is that the base material and brazing filler metal have the same matrix element aluminum. Therefore, the defects in joint such as pore, unwetted area, slag inclusion and so on have not appeared. As presented in Figure 3 (a), joint has the largest brazing seam width of 20 μm due to the existence of groove produced during sanding process. From Figure 3 (b) to Figure 3(d), joint width decreases gradually due to the increasing of solution's acidity. In all of the pretreatment solutions, H_2SO_4 has the strongest acidity and it can quickly destroy alumina on AiSi50 surface as well as aluminum in matrix. Hence, more silicon phase exposed to AlSi50 surfacewill promote cross-link in joint and narrow the joint, as shown in Figure 3(d). Figure 3 (e) shows some black particles appear in brazed joint. The EDS analysis indicates that black particles are mainly composed of phosphorous compound. Brazing filler metal can wet nickel-plate very well. Basically, the specimen after nickel plating and the specimen after NaOH corrosion have the same joint width.

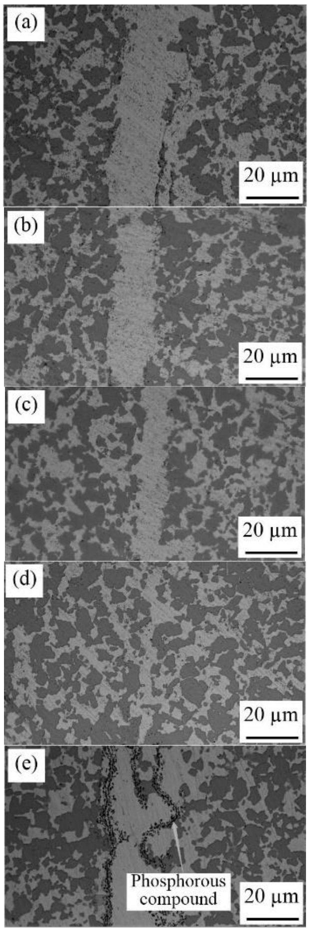

Figure 3. Metallographic photograph of vacuum brazed joint after different surface pretreatment: (a) Sanding with #120 paper, (b) NaOH corrosion, (c) HCl corrosion, (d) H_2SO_4 corrosion, (e) Nickel plating

3.3 Effect of surface pretreatment methods on mechanical properties of the brazed joints

Using Al_{52}-Cu_{33}-Mg_{12}-Ni_3 foil as filler metal, the shear strengths of brazed joints are quite different with different surface condition of specimen, as seen in Figure 4.

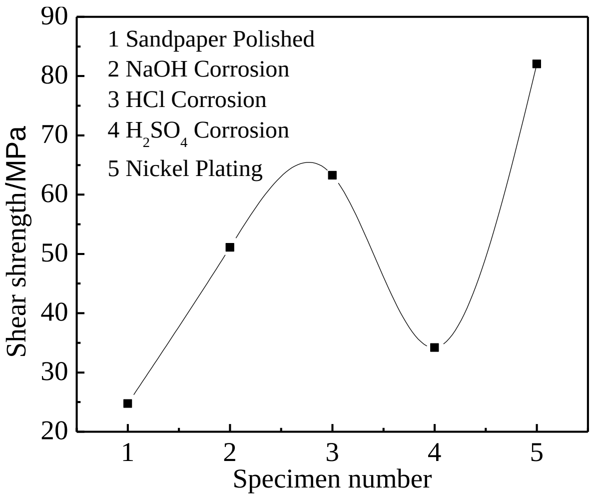

Figure 4. Relationship between joint shear strength and surface pretreatment methods

Figure 4 presents joint shear strength of AlSi50 after sanding with #120 paper has only 24.76 MPa. Though grooves on surface can promote wetting behavior of brazing filler metal, the micro grooves in joint reduce bonding performance. The joint shear strength of AlSi50 after HCl corrosion has a relatively high value of 63.28 MPa compared with the specimen after NaOH corrosion and H_2SO_4 corrosion. The reason for that is HCl solution can get rid of alumina film but not so strong to break aluminum matrix. The joint shear strength of AlSi50 after nickel plating achieves the maximum value of 82.05 MPa as can be seen in Figure 4. It indicates that bonding force between brazing filler metal and nickel-plate is much higher than that between brazing filler metal and AlSi50. The nickel-plate can improve joint mechanical property significantly.

3.4 Spectrum analysis

Mechanical analysis indicates that the specimen with nickel plating has the largest shear strength. In this research, the spectrum analysis mainly focuses on nickel plating specimen. Figure 5 shows SEM image of the brazed joint.

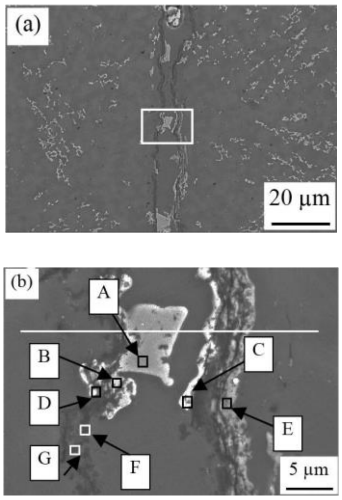

Figure 5. SEM image of brazed joint pretreated by nickel plating: (a) joint appearance and (b) zoom in at the white area

Figure 5 (a) shows that nickel plate on AlSi50 is quite uniformed. The nickel plate will eliminate the weak connection such as silicon particle-particle connection. That will be very helpful for the increasing of joint strength. Interaction at interface between filler metal and base material is a very important factor for brazing. As shown in Figure 5 (b), interaction occurred between filler metal and nickel plating. In order to study the interaction in joint, the EDS analysis was performed in several places as defined in Figure 5 (b). The EDS results can be found in Table 4.

Table 4. The EDS results at defined places

Region	C	O	Al	P	Ni	margin
A	2.26	0.00	51.89	0.00	38.48	0.00
B	7.54	6.74	53.48	0.62	30.45	0.00
C	0.00	12.69	55.72	4.06	26.19	0.00
D	13.36	6.98	52.22	0.98	24.08	0.00
E	11.57	5.46	60.74	1.82	16.08	3.51
F	6.46	29.73	59.74	3.52	0.00	
G	23.29	24.78	47.32	2.16	0.00	

Light white region such as regain A, B, C and D, mainly compose of Al and Ni, which means nickel-plate on AlSi50 surface, interacts with the filler metal during brazing effectively formed intermetallic compound of Al and Ni such as Al_3Ni and Al_3Ni_2. The interaction between nickel plating and filler metal will increase mechanical property of the joint, as can be seen in shear strength test.

4 Conclusion

With different surface pretreatment methods, AlSi50 alloy was brazed together using vacuum brazing technology and Al_{52}-Cu_{33}-Mg_{12}-Ni_3 foil as filler metal. Based on this research, the following conclusions can be drawn:

(1) The width of brazing joint varies with different surface pretreatment methods. The joint with sanding pretreatment, has the largest brazing seam width of 20 µm. Meanwhile, the joint with H_2SO_4 corrosion has the narrowest brazing seam width, which can not be found nearly in light microscope.

(2) Nickel-plate on AlSi50 surface, can interact with the filler metal during brazing effectively, which increases mechanical property of the brazing joint.

(3) For brazing of AlSi50 alloy, the optimal pretreatment method is nickel plating. After the nickel plating pretreatment, brazing joint has the maximum shear strength 82.05 MPa with the following technological parameters: brazing temperature 580 ℃, soaking time 30 min and pressure 3 MPa.

Acknowledgments

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