Preparation and characterization of Al/Pb Layered Composite Materials

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Introduction

As one of the immiscible alloy systems, Al/Pb has attracted many scientific workers' attentions because of its unique physical, chemical and electrochemical properties [1]. Since the discovery of Al/Pb system, researchers have attempted a variety of ways to prepare Al/Pb alloy, such as mechanical alloying, rapid solidification, and spray deposition methods. Among these methods, the mechanical alloying is desirable due to the capability of improving the controlled uniform distribution of Al and Pb and the performance of Al/Pb materials. However, the brute force employment of mechanical alloying, rapid solidification method, or the spray deposition synthesis leads to only a mixture of bimetallic insert, the interface of Al/Pb still has notable shortcomings. According to the theoretical calculation for mechanical alloying degree of solution, after milling, the solubility of Pb in Al is only 0.19% [2], indicating that mechanical alloying of Pb cannot be substantially expanded in the solubility of Al. As a result, there remains a challenging issue as how to solve the Al, Pb bimetallic interface compatibility. Thereby, successful preparation of Al/Pb composite stands for a key technology.

In this paper, to solve the problem of positive mixing enthalpy of Al/Pb system, we employ an interface energy compensation method. Within this method, the introduction of a transition metal as a third element in the Al/Pb interface allows one to tailor interfacial energy through a third element on both sides of the metal in the interface diffusion, wetting, to generate micro-alloying transition layer. In this way Al and Pb diffuse into the substrates each other, thereby realizing metallurgical-type combination. Although the preparation of Al/Pb alloy technology can be traced back to the 70's of the 20th century, there is no report on Pb on the change of the bonding state of Al-transition-Pb interface. We have advanced the use of solid-liquid method prepared on the Al-the third metal element(Sn)-Pb composition of the product interface to address the interface alone with the structure of energy regulation and reaction mechanism.

Experimental

In the present study, the raw materials used, high purity Al(99.999 %), high purity Sn(99.99 %), high purity Pb(99.9999%), which conformed to the state standards or industrial standards: GB/T 3190-2008, GB/T 728-1998, YS/T 265-1994, respectively, and besides, the thickness of the Al plate was 1.2 mm. The actual experimental procedure is as follows:

1. Heat high purity Pb to 450 ℃, then inject it into a mold which is kept at 230 ℃. Figure 1 shows the preform body of the Al/Pb layered composite material.
2. Cut the Al plate having an inner surface treated into 42mm×100mm and put it into liquid Sn at 350℃ about 15 seconds, naturally cool down the Al plate coated with Sn to room temperature.
3. Put the high purity Sn into the inner cavity of the perform body of the Al/Pb layered composite material when it is heated to 240℃, until the Sn melt and then heat the the system to 250℃, insert the Al plate coated with Sn into the inner cavity, keeping at 250℃ for 15min.,30min.,45min., 60min.,75min., respectively. Naturally cool down the Al plate coated with Sn to room temperature, finally, the Al-Sn-Pb layered composite materials are prepared by this solid-liquid coating method (shown in Fig.2).

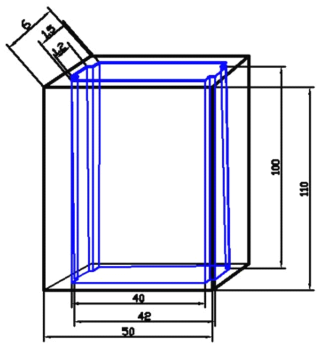

Fig.1 The perform body of the Al/Pb layered composite material

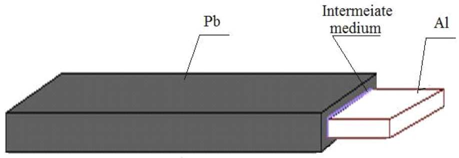

Fig.2 Al-Sn-Pb layered composite sample

Results and Discussion

During the initial research period, a similarly functioning structure in Al-Bi-Pb layered composite electrode materials can be seen in our early publication about the laminated metal composite materials by this method [3].The discovery sparked us to further study. This study further shows that, introducing of Sn reduced the enthalpy heat of mixing of Al/Pb system to be negative, and inter-diffusion of elements in the interface region occurs, and a metallurgical bonding interface between Pb and Al forms. Samples are analyzed surface topography by secondary electron imaging technology by SEM; Microstructure and distribution of the elements are analyzed by EDS. The interface width of Al-Sn-Pb samples and distribution of the elements by different diffusion time and temperature are presented in Table 1. With increasing diffusion time, the inter-diffusion in the three elements goes up. Forms interfaces are gradually thickened. Interfaces widths are uniform distribution just like wave. Because of Sn melting at a temperature close to that of Pb, far from Al, the inter-diffusion occur between Sn and Pb are easier than Al and Sn, thus, firstly, the inter-diffusion between Sn and Pb to come about, and then the inter-diffusion between Al and Sn happens. Finally, a solid solution consisting of Al, Sn, and Pb produces [4]. The new interface layers of Al-Sn-Pb are shown in Table 1 as the distribution of the elements from Al side to Pb side.

Table 1 Interfacial characterization of Al-Sn-Pb samples(250 ℃)

Diffusion time(min.)	Interface width(μm)	Distribution of the elements from Al side to Pb side
15	2.3	Al ǁ Sn-Pb ǁ Pb-Sn ǁ Sn
30	4.4	Al ǁ Sn-Pb-Al ǁ Pb-Sn ǁ Pb
45	7.8	Al ǁ Sn-Pb-Al ǁ Pb-Sn ǁ Pb
60	9.6	Al ǁ Al-Sn ǁ Sn-Pb-Al ǁ Pb-Sn ǁ Pb
75	11.8	Al ǁ Al-Sn ǁ Pb-Sn-Al ǁ Pb-Sn ǁ Pb

Figure 3 shows the relationship between the bending strength and the diffusion times. The analysis of the interface by SEM, EDS indicate that the diffusion tendency of Pb moving in the direction of Al, and the tendency of Sn moving in the direction of Pb, makes a difference to the bending strength of the interfaces. When the diffusion time reaches 30min., the interface width and the inter-diffusion arrive in perfect physical and chemical conditions, the corresponding bending strength is 18MPa, and then the strength decreases for the samples sintered over 30 min. ,which may be attributed to the broadening of the solid solution layer because of its low bonding strength performance.

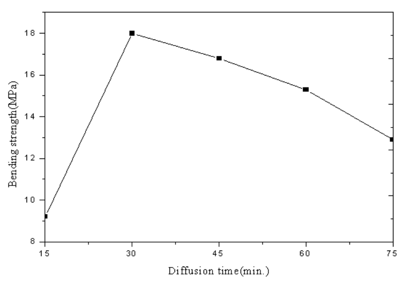

Fig. 3 The bending strength of Al-Sn-Pb layered composite materials at different times

Conclusions

The results reports in this work indicate that：

1. The Al-Sn-Pb layered composite materials were prepared by a special solid-liquid coating method.
2. Inter-diffusion in the Al/Pb interface region occurred with taking Sn as the third element and a metallurgical bonding interface between Pb and Al formed, the inter-diffusion in the three elements went up as temperature increase. Formed interfaces were gradually thickened. Interfaces widths were uniform distribution just like wave.
3. The optimum diffusion time and temperature for the best bending strength activity were determined to be 30min., 250 ℃ , respectively. The corresponding best bending strength was 18.0MPa, and the mechanism was discussed.

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