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ARTICLE

Bonding Process and Application Properties of an Al-Ni Layer Composite Sheet for Lithium-ion Battery Packaging

Yu Kun[1,2], Xiong Hanqing[1,2], Dai Yilong[2], Teng Fei[2], Fan Sufeng[2], Qiao Xueyan[2], Wen Li[2]

[1] Central South University, Changsha 410083, China; [2] Yantai Nanshan University, Yantai 265713, China

Abstract: The cold roll bonding process of an Al-Ni layer composite sheet applied as a brazing solder for the welding of nickel and aluminum structures in the lithium-ion battery packaging was investigated. The effects of roll bonding and annealing treatment on the application properties and the interface compounds of Al-Ni composite sheet were also studied. The results show that the appropriate rolling reduction to bond and produce Al-Ni layer composite sheet is between 50% and 60% deformation degree. During the annealing process, the first formed Al_3Ni phase in the interface of Al and Ni is beneficial to the bonding of such two metals, but the sequently formed Al_3Ni_2 phase results in cracks and separation of the Al-Ni layers. The roll-bonded Al-Ni layer composite sheet acquires good bending endurance, stable weldability and suitable electrical resistivity upon annealing at 698 K to 748 K for 1 h.

Key words: Al-Ni layer composite; roll bonding; interface

Layer metal composites can provide customizable materials for specific applications requiring particular properties of different metals[1]. For example, the Al-Ni bi-layer composite sheet can be used as a brazing solder for the ultrasonic welding of nickel and aluminum structures for lithium-ion battery packaging. The main application properties, such as appropriate mechanical properties, stable weldability and low electrical resistivity, require the Al-Ni bi-layer composite to provide a reliable bonding between the individual aluminum layer and nickel layer. Roll bonding is a usual method available to fabricate Al-Ni bi-layer composite sheet because its thickness is only 0.1~0.2 mm[2,3]. The rolling process parameters are important to the bonding reliability. Meanwhile, it is well known that the intermetallic phases formed between aluminum layer and nickel layer by solid state reaction during the roll bonding and sequent heat treatment have great effects on the application properties of Al-Ni layer composite sheet[4]. Some previous investigations were done to study the intermetallic phase formation between nickel and aluminum alloys[5,6]. The solid state reactions in Al/Ni alternate sheets were studied in Ref.[7] and the growth kinetics of the new compounds were obtained by the study of sputtering Al/Ni multi-layer samples or some mechanical ball milling of Al and Ni powders [8-10]. These studies focused on the nucleation and the growth of new compounds between Al and Ni but seldom provided the relationship between the new intermetallic phases and the application properties of Al-Ni layer composite sheet. So, in the present investigation, the parameters of roll boding and the heat treatment of manufacturing the Al-Ni layer composite sheet were studied. In particular, the effects of microstructures on the application properties of the Al-Ni layer composite sheet were discussed.

1 Experiment

The Al-Ni layer composite sheets were obtained by superimposing rolling the sheets of 0.22 mm pure Ni and 0.10 mm pure Al. The pure Ni and pure Al sheets were cleaned by scratch brushing and acetone before folding them together. Then the bi-layer metals were rolled to bond at the ambient temperature by a *Φ*90 mm/*Φ*300 mm×350 mm rolling mill to

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Corresponding author: Yu Kun, Ph. D., Professor, School of Materials Science and Engineering, Central South University, Changsha 410083, P. R. China, Tel: 0086-731-88879341, E-mail: yukunarticle@163.com

obtain the bonded composite sheets with thickness of 0.20, 0.15 and 0.10 mm, respectively. So the calculated rolling reductions were about 38%, 53% and 69% correspondingly. The rolled Al-Ni sheets were annealed at different temperatures from 598 K to 823 K for 1 h to evaluate the bonding effect and to analyze the phase formation between Al and Ni.

The microstructure evolution and the phase formation of the rolled and annealed Al-Ni layer composite sheets were observed by a Polyvar-MET optical microscopy (OM) and a FEI Quonta-200 scanning electron microscopy (SEM) with energy-dispersive X-ray spectroscopy (EDX). The hardness of Ni layer and Al layer was tested by SHIMADZU HSV-1000 micro-hardness tester. A 180° bending test of Al-Ni composite sheet was performed as shown in Fig.1a to evaluate the local exfoliation of Ni or Al layers after bonding. The tensile strength was tested by CSS-41000 electronic stretcher system to measure the junction force of a weld zone after ultrasonic welding of Al-Ni layer composite sheet with a 0.5 mm pure aluminum plate contacted in the aluminum layer side (Fig.1b). The Al-Ni layer composite sheet and the pure aluminum plate were bent at the measurement point to L typeface at the edge of a weld zone, the edge was pulled, and the hauling force making a joint exfoliate was measured and taken as junction force. The electric resistivity of Al-Ni layer composite sheet was tested by Kelvin double bridge methods. All the experimental tests were performed three times per each sample to acquire the average values.

2 Results and Discussion

2.1 Cold roll bonding of Al-Ni layer composite sheet

Roll bonding is a solid state welding process in which bi-layer metals are stacked together and rolled to cause enough deformation to produce solid state welds [11]. Since the bonded surfaces of the Al and Ni sheets are cleaned by the scratch brushing and acetone, the applied sufficient pressure can form the bond of such two metals. It is well established that a threshold deformation degree must be achieved to obtain a relative firm and reliable bonding.

Three different rolling reductions were performed to bond the Al and Ni sheets together as shown in Fig.2 to obtain a suitable roll bonding deformation degree. It is obvious that the Al layer and Ni layer separate after rolling with the reduction of 38% (Fig.2a) but they will join well with the reduction over 50% (Fig.2b). The plastic deformation degree over 50% is required for the Al-Ni composite sheets to provide enough pressure to make Al and Ni meshing each other. But the sheet distorts seriously under a reduction over 60% because of the difference of plastic deformation behavior of Al and Ni. Such warpage or waviness shape (Fig.2c) is unacceptable to fabricate the Al-Ni composite sheets. Therefore, controlling of a suitable rolling reduction about 50%~60% is the most important step to produce the Al-Ni bi-layer composite.

On the other hand, the mechanism of the interfacial bonding of such two metals at this rolling state is only a mechanical meshing, but not a metallurgical bonding. The interface microstructure of the rolled Al-Ni composite sheet is shown in Fig.3. The EDX analysis of the interface of Al and Ni shows that there is no reaction occurrence between Al and Ni during the rolling process. The microstructure of Al and Ni interface forms a jagged, interlocking pattern which is beneficial to bonding of these two metals.

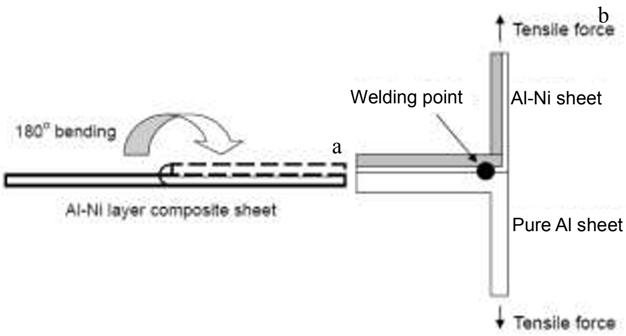

Fig.1 Schematic diagram of testing the Al-Ni composite sheet: (a) bending test of Al-Ni sheets and (b) welding junction force test of Al-Ni with Al sheet

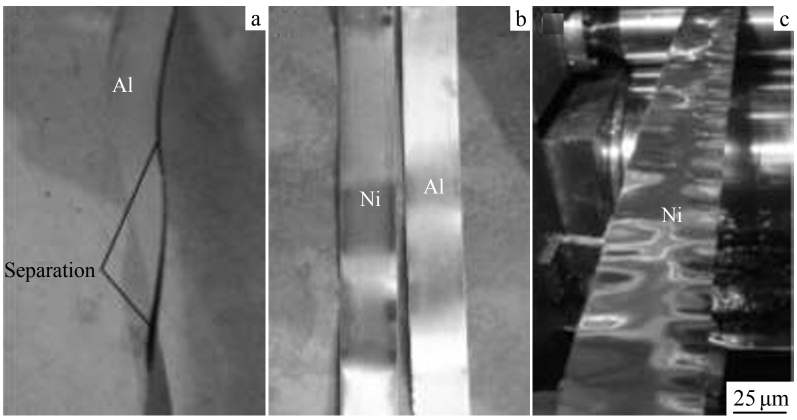

Fig.2 Cold roll bonding of Al-Ni bilayer composite sheet with different reductions: (a) 38%, (b) 53%, and (c) 69%