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Influence of Surface Treatment on the Strength of Solid-State Diffusion-Bonded Interface of Tin[†]

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Abstract

An investigation has been made of the bond strength of diffusion-bonded interfaces of tin specimens whose faying surfaces were finished through four different treatments: grinding on emery of 800 grade, electrolytic polishing, halogenation by HCl, and halogenation by HF. Bonding temperatures necessary for obtaining bond strength comparable with the base metal were highest when the surfaces were finished by grinding on the emery paper, and decreased in the following order: grinding on the emery paper, electrolytic polishing, halogenation by HCl, and halogenation by HF. When the faying surfaces were subjected to the halogenization treatments, dimples were observed over almost whole areas of the fractured surface of the joint after the tensile test at bonding temperatures of 463-483 K, and granular inclusions rich in Cl and F were observed with a SEM at the bottom of the dimples. In the case of the other surface treatments, however no dimples or inclusions could be detected at the same bonding temperatures. These results suggest that tin halides displaced the superficial oxide film of tin during the halogenation treatments, and were broken up to form granular inclusions at lower temperatures during the diffusion bonding.

KEY WORDS:(tin)(solid-state diffusion bonding)(microstructure)(bond strength)(surface treatment)

1. Introduction

It has been generally accepted that soldering phenomena are strongly dependent on factors relating to the surface of the solder alloy. The superficial oxide film has been taken as the most detrimental factor that interferes with the formation of metallic bonds across the interface in the solid-state bonding for many metals and alloys, but only little information has been reported about the behavior of the oxide film of solder alloy during soldering and solid-state bonding^{1), 2)}. This investigation, therefore, has been undertaken to obtain a better insight into the behavior of the oxide film at the bond interface of tin-base solder alloy by investigating the effect of surface treatment on the bond strength.

2. Experimental Procedure

The specimen to be bonded was a block 15×15×5 mm³ cut from 99.99% tin. The faying surface(15×15 mm face) was finished by 4 different treatments: grinding on emery paper of 800 grade, electrolytic polishing in a solution containing 5% perchloric acid in 10% ethylene glycol monobutyl and 85% ethyl alcohol,

exposing to vapor of chloric acid after grinding on 800 grade emery paper (halogenation by HCl) and halogenation by HF. The diffusion bonding has been carried out in a vacuum of $\sim 10^{-4}$ Pa.

3. Results and Discussion

The relationships between bonding temperature and joint efficiency are shown in Fig. 1. The joint efficiency increased with bonding temperature for all the surface treatments. Bonding temperatures necessary for obtaining

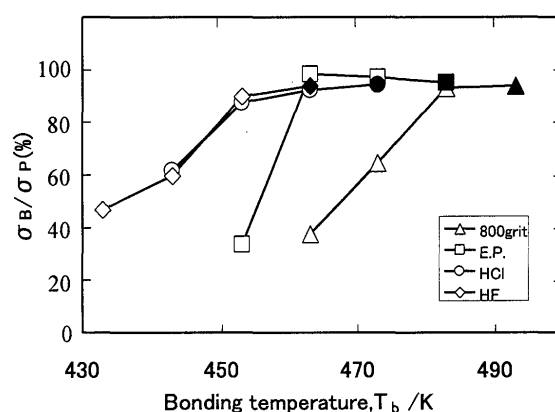


Fig. 1 Effect of surface treatment on joint efficiency, where σ_B is the tensile strength of joint and σ_P the tensile strength of joint fracture at the base metal.

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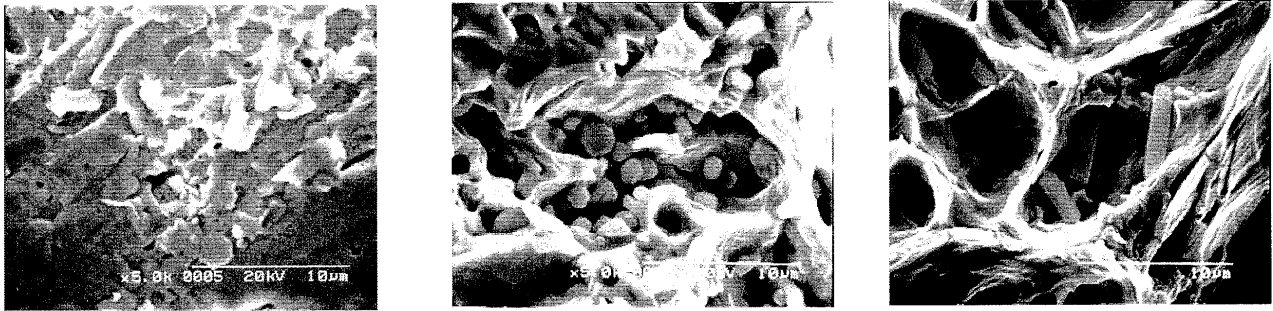


Fig. 2 SEM micrograph of fractured surface. (a) grinding on emery paper ($T_b=463$ K) (b) halogenation by HCl ($T_b=443$ K), and (c) halogenation by HF ($T_b=443$ K).

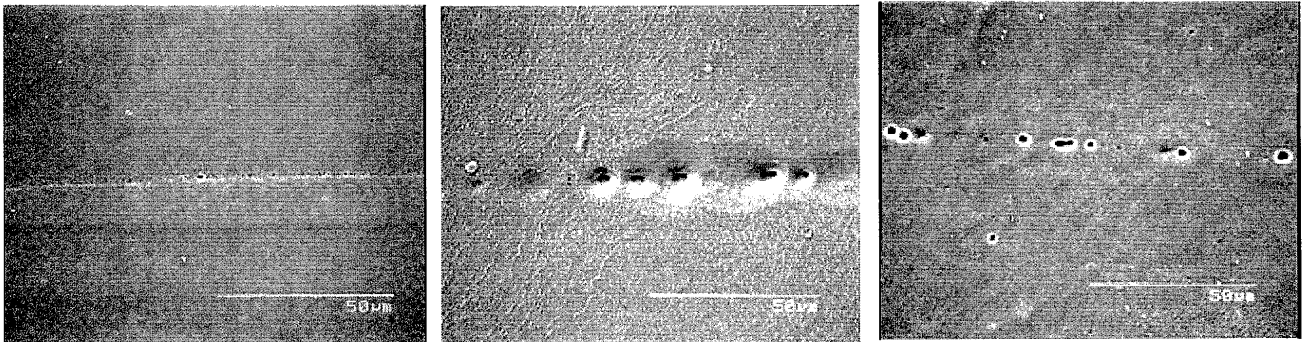


Fig. 3 SEM micrograph of bond interface. (a) grinding on emery paper ($T_b=463$ K) (b) halogenation by HCl ($T_b=443$ K), and (c) halogenation by HF ($T_b=443$ K).

bond strengths comparative with the base metal depended significantly on the surface treatments; the halogenation treatments were very effective in decreasing bonding temperatures at which the bond strength approached the level of the base metal strength.

The fractured surfaces of the joints are shown in Fig. 2. When the faying surface was finished by the halogenation treatments by HCl and HF, spherical and rodlike inclusions were observed at the bottom of dimples as shown in Fig. 2(b) and 2(c), respectively. These inclusions can be regarded as tin chloride and fluoride, since EDX analyses suggested that they were rich in Cl and F. In the case of the surface treatment of grinding on emery paper, on the other hand, no dimples or inclusions could be detected as shown in Fig. 2(a), although the bonding temperature was higher by 20 K. These results suggest that the oxide film on the tin surface finished by grinding on the emery paper was displaced during the halogenation treatments by tin halides, which could be broken up to form dispersed granular inclusions at lower bonding temperatures than the oxide film. Probably, the effect of the halogenation treatments on the bond strength can be explained as resulting of the displacement of the oxide film on the surface with the halides.

SEM micrographs of the joints are shown in Fig. 3. When the faying surface was finished by grinding on emery paper, a continuous bond line was obviously observed at a bonding temperature of 463 K, as shown in Fig. 3(a). In contrast, when the faying surface was finished by the halogenation treatments, the bond line became discontinuous and partly disappeared. The voids observed at the interfaces can be considered to form at the inclusion of

tin halides, since tin halides are soluble in alcohol and will be lost during electrolytic etching. These results support the view that the tin halide produced granular inclusions at lower bonding temperatures than the oxide film, as suggested by the observation of the fractured surface.

4. Conclusions

- (1) The bond strengths of diffusion-bonded joints of tin are influenced remarkably by the surface treatments.
- (2) A bond strength (sufficient for the joint to fracture in the base metal on tensile test) was obtained at lower bonding temperatures when the faying surface was finished by the halogenation treatments than by grinding on the emery paper and electrolytic polishing.
- (3) The effect of the halogenation treatments on the bond strength can be explained as resulting from the displacement of the superficial oxide film with tin halide, which can be broken up to form granular inclusions at lower bonding temperatures.

References

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