Various Properties of Tin-Copper Alloy Film Produced By Heat Treatment

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Abstract
Nickel plating has been used for anti-corrosion purposes. However, the uses may be regulated due to the environmental friendliness. Tin-copper alloy is one of the candidates as substitute. However, the conventional process has some problems, for example, the environmental friendliness of the chemicals, poisonous effluents etc. Therefore, we tried the new process using heat treatment of stacked single layers to produce tin-copper alloy film and investigated the change of properties such as hardness, surface tone and corrosion resistance. As a result, we confirmed that the alloying process decreased surface brightness and brilliancy. However, it increased the Hardness and Corrosion Resistance.

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1. INTRODUCTION

Conventionally, chromium, cadmium and nickel etc. have been used for anti-corrosion plating. However, the use of those metals may have been restricted to some extent or to full scale and the tendency will be more remarkable in the future. As the substitute, alloy plating has been investigated and utilized. However, the process sometimes requires environment-harmful chemicals which enable co-electrodeposition of plural elements on the material surfaces. Therefore, the authors have proposed HSSL (Heating Stacked Single Layers) process to produce alloy films on the material surfaces[(1)-(4)]. In this process, the single layers stacked on the material surface are heat treated and the mutual diffusion among the components makes it possible to produce alloy films. In this paper, some properties for tin-copper alloy films produced by HSSL process were investigated and discussed.

2. EXPERIMENTAL

Carbon steel (JIS SS400) was used as substrate. On these substrates, copper and tin were produced in this order electrochemically. And the plates were cut into small sections (12mm x 15mm).

They were heat treated at some temperatures between 200 degrees Celsius and 350 degrees Celsius in an electric furnace. The atmosphere in the furnace was not regulated specially. And as the cooling process, air cooling (AC) and furnace cooling (FC) were used to investigate how the cooling process affected the characteristics of specimens.

The color tones for specimens were measured, using a color meter (Konica-Minolta, CR-13). The results for the specimens before and after the heat treatments were shown in the coordinate axes of L*a*b*. The glossiness of the specimens were measured by a glossimeter (Konica-Minolta, GM-60) for the specimens before and after the heat treatments.

Vickers hardness for specimens before and after heat treatments were measured by Micro-Vickers hardness testing machine (Akashi, MVK-E). The loads applied to the specimens were 10gf, 25gf and 50gf, and the loading time was 20 sec.

Specimens before and after heat treatments were immersed into 3%NaCl solution and the weight changes with time were measured as the extent of corrosion. The immersion time was two weeks and the temperature of the bath was kept constant at 20 degrees Celsius in an incubator (Sanyo Electric MIR-262). And the surface conditions were observed by a digitizing camera intermittently.

The structures of surface layers were identified by X-ray Diffraction (XRD), using RINT 2100 (Rigaku). The target was copper. X-ray voltage and current were 40kV and 20mA, respectively. The diffraction angles measured in these experiments ranged from 20 to 100 degrees at the scan rate of 2 degrees per minute.

3. RESULTS AND DISCUSSION

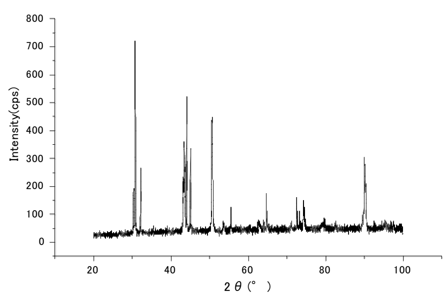

Fig.1 XRD result for the specimen without heat treatments.

XRD results for various specimens were shown in Fig.1, 2 and 3. Fig.1 corresponds to the result for the specimen of stacked copper and tin layers before heat treatment. Although the peaks for copper were recognized, tin peaks could be observed remarkably. The result reflects that the tin layer was formed on the copper one.

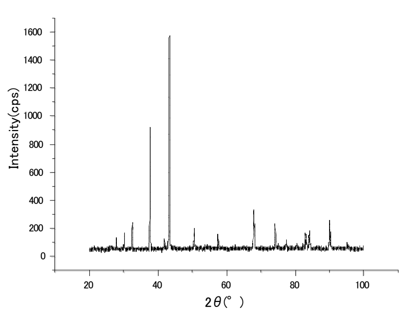

Fig.2 XRD result for the specimen heat treated at 250 degrees Celsius (air cooling).

Fig.2 shows the XRD result for the specimen heat treated at 250 degrees Celsius (Air cooling), while Fig.3 corresponds to that cooled in the furnace. Fig.2 indicates that an intermetallic compound (Cu_3Sn) was formed by the diffusion reaction between tin and copper layers. Tin peaks became very small in this case. It suggests that most of the original tin layer were consumed for the formation of the intermetallic compound. The tendency for the FC specimen was almost the same with AC one. However, the peak intensities for copper in Fig.3 were larger than those in Fig.2. It suggests that the diffusion reaction for the formation of the intermetallic compound proceeded more in the case of FC specimen. For both cases, the peak for tin oxide (SnO_2) was observed and it indicates that the oxide layer was formed on the top of the surface of specimens.

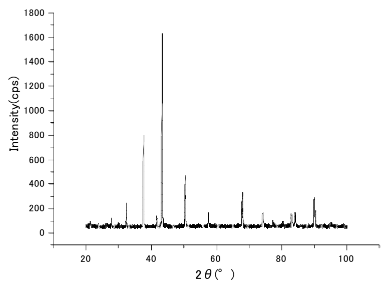

Fig.3 XRD result for the specimen heat treated at 250 degrees Celsius (furnace cooling)

The result for the measurement for color tones of specimens were shown in Fig.4. L values correspond to the brightness of the specimens' surfaces. When the a value is shifted in the positive direction, the surface color tone becomes more reddish. On the other hand, it becomes more yellowish when the b value is shifted in the positive direction. Fig.4 shows the following tendencies. For the non-heated specimen and the specimen heat treated at 200 degrees Celsius, the L values were relatively high, a values were located in the negative area, while b values in the positive one. The L and b values decreased when the specimens were heat treated. When the color tone for FC specimens are compared with those for AC specimens, one can confirm that the a value was lower for the former than that for the latter.

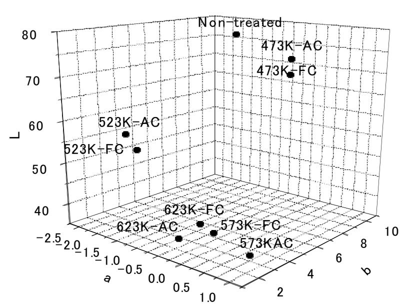

Fig.4 Color tones of specimens

Fig.5 shows the result for the measurement of glossiness. For non-heat treated specimen, the glossiness was about 35. However, it decreased with heat treatment. The glossiness for AC specimens were generally higher than those for FC specimens.

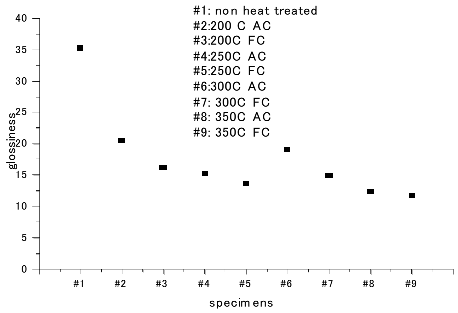

Fig. 5 Glossiness for various specimens.

Fig.6 shows the result for Micro-Vickers Hardness measurement. When the loads were relatively high (25gf and 50gf), the differences were not so remarkable, since the results reflected the substrate characteristics. However, when the load was 10gf, the hardness profile became changeful. Concretely speaking, the hardness increased with the heat treatment temperature. It suggests that the hard intermetallic compound formed with the heat treatment. When the FC specimens' results were compared with those for AC specimens, it is clear that the hardness for FC specimens were higher than those for AC specimens generally. It also suggests that the diffusion reaction proceeded much more for furnace cooling.

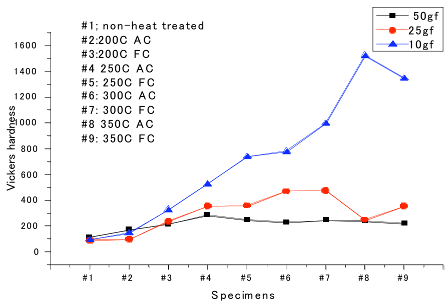

Fig.6 Vickers hardness of surface layers for various specimens

When 14 days passed after the start of the immersion, all specimens were oxidized to some extent. The weight changes during the immersion test were shown in Fig.7. The weight change for the carbon steel (JIS SS400) was the highest. For all specimens including non-heat treated one, the weight changes were lower than those for the substrate steel. The non-heat treated specimen had zinc layer on the top of it. Since the corrosion resistance of zinc is relatively high, the non-heat treated specimen had the high corrosion resistance. However, the heat treated specimens' corrosion resistance was also higher than that of the substrate. And the corrosion resistance of heat treated specimen tended to be lower than that of non-heat treated specimen generally, even though there were some exceptions. When the specimens' heat treatment temperature became higher, the corrosion resistance tended to increase. All of these results indicate that the produced alloy films had the higher anti-corrosion resistance.

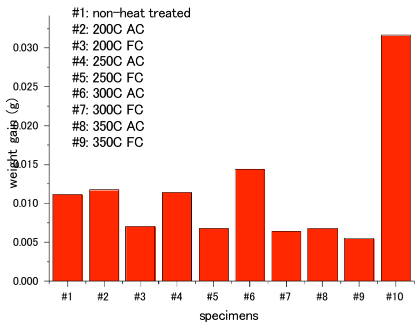

Fig.7 Weight changes after the immersion into NaCl solution.

4. CONCLUSION

Cu-Sn alloy film produced by HSSL process has the high anti-bacterial properties against some bacterial. The authors have already confirmed it in previous studies(5), (6). However, the films should have another good properties for practical applications as plating. Therefore, hardness, glossiness, color tones and corrosion resistance for tin-copper alloy films produced by HSSL process were investigated in this paper. The color tone of alloy film was turned into matte color and the glossiness decreased with the heat treatment. However, the surface hardness and the corrosion resistance increased with the process. Therefore, tin-copper alloy film by HSSL process can be used as anti-corrosive and hard film, even though the glossiness is not so high.

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