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STUDY ON THE PROPERTIES OF SILVER PLATING ON A6061 ALUMINUM ALLOY

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ABSTRACT

This article presents the properties of the silver plating on A6061 aluminum alloy. The structure, chemical composition, phase composition, thickness and corrosion durability of the plating are determined by scanning electron microscopy-energy dispersive X-ray spectroscopy (SEM-EDS), X-ray diffraction, corrosion current measurement, frost acceleration and hygrothermal test. The results show that the silver plating has good corrosion resistance, is not blistered, remains white, light, no appearance of rust and other abnormalities. These parameters meet the technical requirements laid out for resonator of ultra - high frequency filter.

Keywords: A6061 aluminum alloy, silver plating, structure, chemical and phase composition.

1. INTRODUCTION

A6061 aluminum alloy (A6061) is a multi-purpose alloy with high-strength, anti-corrosion and has good weldability. In defense industry, this alloy is used in very large quantities. In order to further enhance the properties and functions of the product, aluminum alloy surfaces are often treated by anodizing or electroplating method [1 - 3]. In which aluminization is a method with constant interest. When aluminizing, aluminum alloy can improve electric conductivity, corrosion resistance, enhance hardness, antifriction [4 - 7]. Aluminization and aluminum alloys are relatively complex, so to enhance the quality of the plating, adherence with aluminum base requires intermediate treatment prior to plating [8 - 10]. The traditional silver plating technology uses the bath containing silver plating salt and free prussiate. Because cyanide compounds are toxic, environmental pollution, silver plating liquids containing cyanide are banned or restricted to use in some industrialized countries [11]. The replacement or limited use of cyanide compounds in silver plating solutions has attracted the attention of electrochemists [12 - 16]. Recent studies have shown that silver plating with free-cyanide solutions has physico-mechanical properties, anti-corrosion protective value equivalent to silver plating in traditional cyanide solutions, especially for point contact, electrical conduction or decorative details [12 - 16]. In this direction, we have successfully obtained the composition, zincatization mode and silver plating mode composition on A6061 base. This article presents some study results on silver plating properties which does not contain cyanide on A6061 base.

2. EXPERIMENTAL AND METHODS

2.1. Material preparation

Chemicals include: NaOH; NaOH; Na_2CO_3; Na_3PO_4; Na_2SiO_3; HNO_3; ZnO; $KNaC_4H_4O_6.4H_2O$; $FeCl_3$; $AgNO_3$, KCN, K_2HPO_4, KH_2PO_4, KOH, H_3PO_4 pure (PA), A6061 (India).

In this study, A6061 pattern with size of 10 × 10 × 5 mm, was smoothed with paper P600; P1000 and P2000 (Japan), was deoiling in mixture of NaOH solution (30 g/L) + Na_2CO_3 (50 g/L) + Na_3PO_4 (50 g/L) + Na_2SiO_3 (20 g/L) for 15 minutes and bleach in HNO_3 solution (d = 1.4): 500 ml/L for 30 seconds, then activated in a zincate solution containing ingredients: ZnO (60 g/L); $KNaC_4H_4O_8.4H_2O$ (4 g/L); $FeCl_3$ (0,3 g/L) and proceed to plating under the following conditions: Current density of 0.4 A/dm^2, solution composition of 15 g/L Ag^+; 30 g/L KH_2PO_4; 140 g/L K_2HPO_4, temperature: 60 ^oC [3].

2.2. Investigate the properties of the silver plating

The silver plating is investigated on surface structure, thickness and surface chemical composition by scanning electron microscopy-energy dispersive X-ray spectroscopy (SEM-EDS), JSM 6610 LA-Jeol, Japan. The phase composition of the Rhoen analyzed plating (RXD) was measured on the X'Pert Pro. The corrosion durability, frost and hygrothermal of the plating were investigated by Autolab 30 versatile electrochemical measuring device (Netherlands) and Erichsen frost test unit (Germany). Parameters of the resonance cavity filter are checked by the S21 frequency range characteristic measuring unit (Japan).

3. RESULTS AND DISCUSSION

3.1. Investigation on the structure and chemical composition of A6061 pattern, zincatized A6061 pattern and silver plating A6061 pattern

Surface morphology and composition of zincatized A6061, A6061 pattern and silver plating A6061 pattern were determined by the SEM-EDX method as shown in Figure 1.

The results show that the surface of silver plating A6061 pattern has a homogeneous, smooth, glossy structure. The results of the EDX analysis show that the plating contains 100% of silver, indicating that the plating contains very pure silver metal.

3.2. Thickness and phase composition of the plating

After investigating the structure and surface chemical composition, the phase composition and surface thickness of the sample was analyzed (Figure 2).

The results showed that plating containing only one single phase of metallic silver. Result of sectional photograph determining the thickness of the plating shows that the plating has a uniform thickness of about 9.7 μm. This plating thickness meets the technical requirements of the ultra-high frequency filter resonator used on observation radiobeacons.

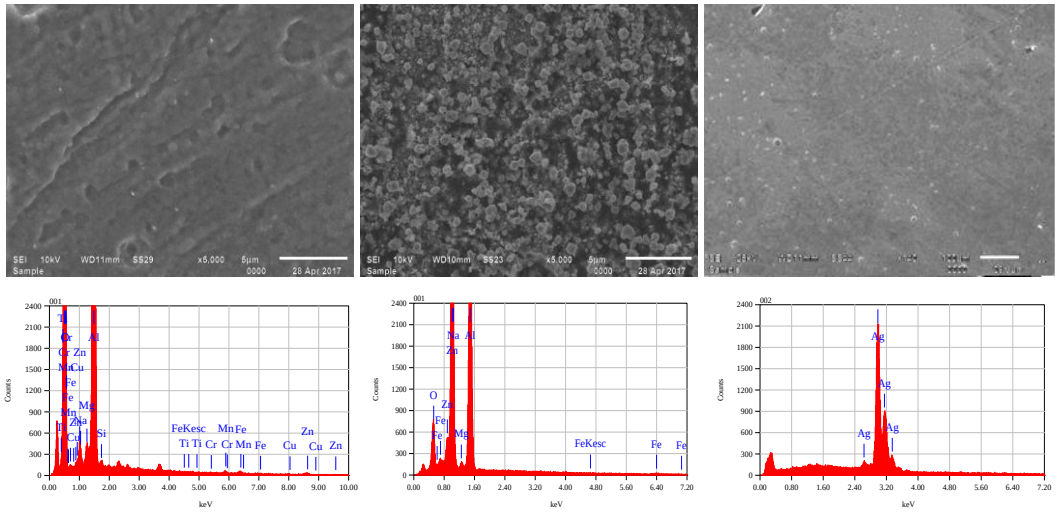


Figure 1. Photo of SEM and EDX spectrum on surface of A6061 pattern (a); zincatized A6061 pattern (b); silver plating A6061 pattern.

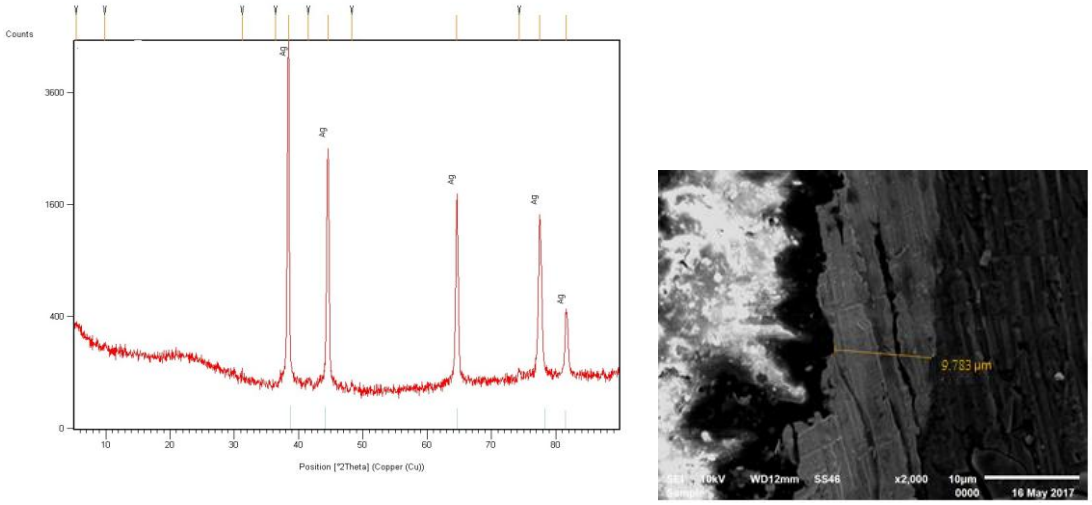


Figure 2. XRD pattern and SEM image of the sample.

3.3. Corrosion durability of silver plating

The color variation of silver does not only affect the appearance, but also affect the weldability, thermal conductibility, electrical conduction of the plating. In order to enhance the durability of the silver plating, avoid the discoloration of the plating during the transport, conduct the passivation for the silver plating after plating in solution as in Table 1.

After the passivation, silver plating still retains the characteristic white color, but its protection is increased. In order to assess the possibility of working in environments with corrosive factors, plating patterns were measured in corrosion currents in NaCl 3.5 %. The

results of the corrosive currents (Figure 3), corrosion position and corrosion rating grade are presented in Table 2.

Table 1. Composition and passivation mode of silver plating.

No.	Composition	Content, g/L	Temperature, ^oC	Embedded time, minutes
1	Kali bicromat $K_2Cr_2O_7$ Boric acid H_3BO_3	100 40	70-80	15-20

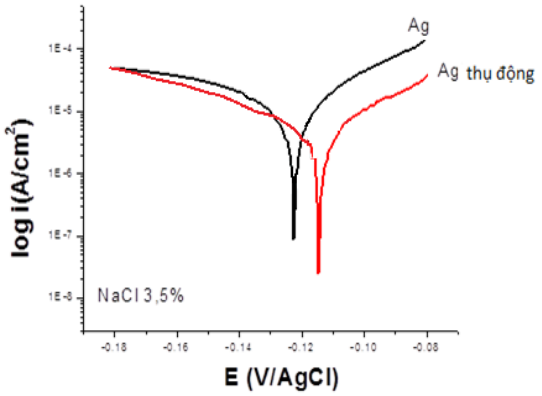


Figure 3. Tafel chart measuring corrosion currents.

Table 2. Measurement results of corrosion position, corrosion currents.

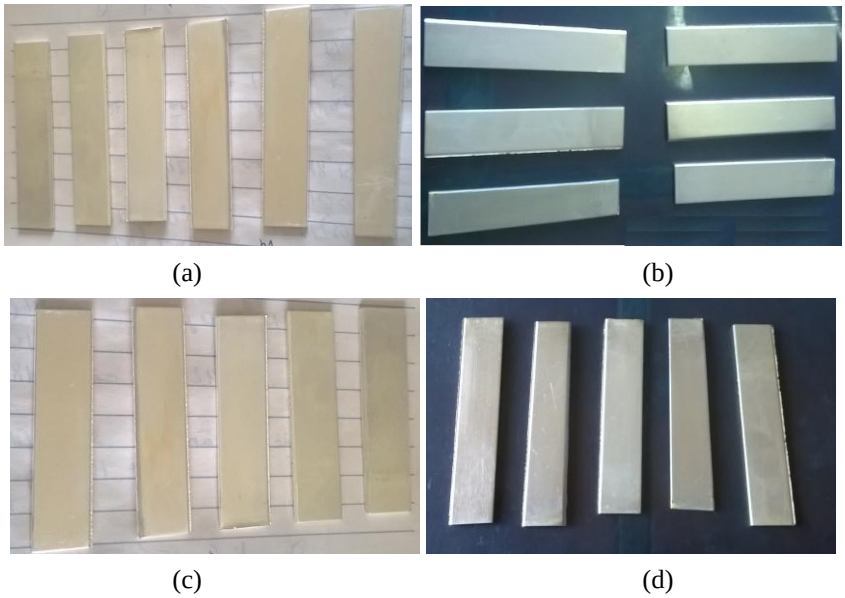
No.	**Plating pattern**	**Corrosion position (mV)**	**Corrosion currents (mA/cm^2)**	**Corrosion rating (mm/year)**
1	Silver plating	-138	$1,829.10^{-5}$	$6,402.10^{-1}$
2	Silver plating after the passivation	-116	$6,659.10^{-6}$	$7,514.10^{-2}$

Table 2 shows that corrosion position moves toward the more positive side and the corrosion current decreases by 2.7 times, leading to that the corrosion rating grade of the silver plating after the passivation is 8.5 times lower than pure silver plating under the same conditions.

3.4. Durability of frost and hygrothermal of the silver plating

Frost test with harsh level 3 and hygrothermal test of silver plating are shown in Figure 4.

The frost test results show that the plating is not blistered, and the plating remains bright white, no appearance of rust and other abnormalities on the surface of the plating (Figure 4b). Similarly, the hygrothermal test results show that the plating is not blistered, the plating remains bright white, no appearance of rust and other abnormalities on the surface of the plating (Figure 4b).



(a) (b)

(c) (d)

Figure 4. Silver plating A6061 pattern before and after frost test (a; b) and hygrothermal (c, d).

3.5. Parameter test results of ultra - high frequency filter

Performance of silver plating on the resonance cavity of the ultra - high frequency filter manufactured by A6061 was checked with the parameters of the ultra-high frequency filter. The results are shown in Figure 5.

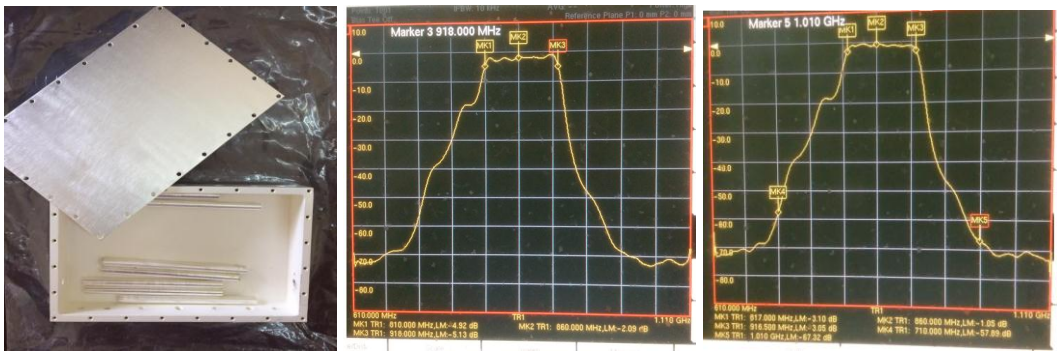


Figure 5. Frequency range characteristic of ultra-high frequency filter (a) 100 MHz bandwidth before (b) and after (c) plating.

From the chart of frequency range characteristic in Figure 5, the results are as shown in Table 3.

The results of Table 3 show that the resonance cavity of the ultra-high frequency filter after plating has an attenuation in strip is -1.05 dB and barrier outside strip is 67.32 dB @ 1010 GHz. These parameters have met the technical requirements laid out for the resonance cavity of ultra-high frequency filter.

Table 3. Parameter test results of ultra - high frequency filter.

Parameters	Filter before plating	Filter after plating
Bandwidth	$\Delta f = 100MHz \pm 5$	$\Delta f = 100MHz \pm 5$
Center frequency	860 MHz	860 MHz
Depreciation in strip	-2.09 dB	-1.05 dB
Barrier outside strip	57.89 dB @ 710 GHz	67,32 dB @ 1010 GHz

4. CONCLUSION

From the properties of the silver plating on the A6061 base, it can be showed that the plating was homogeneous, smooth and shiny structure, with a thickness of about 9.7 μm. The plating has a chemical composition and phase composition of silver metal with very high purity. Measurement results of corrosion current, frost acceleration test and hygrothermal test show that silver plating after the passivation has good corrosion resistance, is not blistered, still remain white, light, no appearance of rust and other abnormalities. These parameters meet the technical requirements laid out for the resonance cavity of ultra - high frequency filters.

REFERENCES

1. Nguyen Duc Hung - Finishing technology of copper plating, nickel plating, gold and silver plating, decoration for the protection of cultural work, Subject of Science and Technology Association, Institute of Chemistry - Materials, 2008-2009.
2. Nguyen Van Loc - Electroplating Technology, Education Publishing House, 2005.
3. Mai Van Phuoc - Silver plating on A6061 aluminum alloy, Project of Chemical and Material Institute, 2016.
4. David G. Foster, Yonathan Shapir, Jacob Jorne - Scaling of roughness in silver electrodeposition, Journal of The Electrochemical Society **150** (6) (2003) C375-C380.
5. Shashikala A. R., Sharma A. K., Bhandari D. R. - Solar selective black nickel–cobalt coatings on aluminum alloys, Solar Energy Materials and Solar Cells **91** (2007) 629-635.
6. ZAbdel Hamid, TAbou Elkhair M. - Development of electroless nickel–phosphorous composite deposits for wear resistance of 6061 aluminum alloy, Materials Letters **57** (2002) pp. 720-726.
7. Sukonnik M., Judge J. S., Evans W. T. - Characterizing the interface of nickel-zincate-aluminum thin films, The Journal of The Minerals, Metals & Materials Society **41** (1989) pp. 37-39.
8. Gintaras Baltrunas, Ausra Valiuniene, Zana Margarian, Gintare Viselgiene, George Popkirov - The electroreduction kinetics of silver sulfite complexes, Electrochimica Acta **53** (2008) pp. 6513-6520.

9. Enam Khan, Oduoza C. F. - Surface characterization of zincated aluminium and selected alloys at the early stage of the autocatalytic electroless nickel immersion process, Journal of Applied Electrochemistry **37** (2007) 1375-1381.
10. Nelson K. J. H., Hughes A. E., Taylor R. J., Hinton B. R. W., Wilson L., and Henderson M. - Characterisation of aluminium alloys after HNO_3/HF–NaOH–HNO_3/HF pretreatment, Materials Science and Technology **17** (2001) pp. 1211-1221.
11. Enthol-OMI, Silver-plating, http://enthone.com/Industries
12. Electrochemical products Inc, Non-Cyanide Alkaline Silver Plating**,** data technical, E-Brite 50/50.
13. Feng-zhang Ren, Li-tao Yin, Shan-shan Wang, A. A. Volinsky, Bao-hong Tian - Cyanide-free silver electroplating process in thiosulfate bath and microstructure analysis of Ag coatings, Trans. Nonferrous Met. Soc. China **23** (2013) 3822-3828.
14. Edward Hradil, Hana Hradil, Non-Cyanide bright silver electroplating bath therefor, silver compounds and method of making silver compounds, United States Patent **4.246.077** (1981).
15. Hazelwood E. - Non-Cyanide Silver as a substitute for cyanide processes, The Illinois Waste Management and Research Center, 2002.
16. Kurt R. Grebe, Non-cyanide silver plating bath", US patent **3.406.107,** 1968.