Investigation on microstructure, mechanical properties and corrosion behavior of Sc-contained Al-7075 alloys after solution-aging treatment

Jinzhao Deng, Jun Shen, Hao Li, Hui Chen and Fuxing Xie

1 State Key Laboratory of Mechanical Transmission, College of Material Science and Engineering, Chongqing University, Chongqing, 400044, People’s Republic of China
2 Confederation of Guangxi’s Enterprises and Employers, Nanning, 530022, People’s Republic of China

E-mail: shenjun@cqu.edu.cn

Keywords: 7075 aluminum alloys, Sc-microalloying, solution and aging treatment, mechanical properties, corrosion resistance

Abstract

This work mainly studies on Sc microalloying in Al-7075 alloys. The microstructure characteristics and mechanical properties of the Sc-contained Al-7075 alloys were investigated after homogenization at 460°C for 10 h. The corrosion behavior of the 7075 alloys after aging was examined using a three-electrode system. The results showed that significant reduction in grain sizes from 129.92 μm without Sc alloy to 32.17 μm with 0.6% Sc. The microhardness increased with the increase of Sc content in the alloy from 71.7 ± 1.3 HV without Sc alloy to 89.2 ± 4.7 HV. The tensile strength also increased from 151.82 ± 1.07 MPa to 212.85 ± 7.35 MPa. The results also revealed that the addition of Sc element in 7075 aluminum alloys not only reduced the corrosion current density of the alloy, but also increased the corrosion resistance of the alloy in the corrosive environment.

1. Introduction

Currently, global energy issues have gradually become the focus of extensive attention from all walks of life, which has made various transportation vehicles continue to face the requirements of weight reduction and fuel consumption. This is also the key to improving the competitiveness of manufacturers such as automobiles, aviation, and ships. Among the few commercial light alloy materials, aluminum alloys are the most widely used, especially in the automotive and aerospace fields [1–3]. In the research of many new types of aluminum alloy materials, the research on the addition of rare earth elements to aluminum alloys and their effects has been receiving much attention, among which Sc and Zr are widely utilized. From the analysis of Al-Sc alloy phase diagram, it can be seen that Sc element and Al element form a finite solid solution, and a small amount of Sc element is added in the Al matrix. It undergoes eutectic reaction with aluminum matrix to form Li2-type Al3Sc phase. After proper heat treatment process, the metal properties of aluminum alloy be significantly improved.

Sc is one of the rare earth elements that have been found to have the best strengthening effect on aluminum and aluminum alloys. Its main functions are to refine grains, inhibit recrystallization, and precipitate small Al3Sc particles to solid solution strengthen the aluminum alloy structure [4]. Al3Sc is a Li2-type face-centered cubic structure with a lattice constant of 0.4103 nm, which is very close to the α matrix (0.4048 nm), with a difference of only 1.5%. Therefore, the Al3Sc phase particles be effectively used as nucleation particles of the α matrix grains, and during the deformation and hot working of the alloy. It can effectively pin the grain boundaries, so that the alloy always maintains fine structure grains [5]. At the same time, the thermal stability of Al3Sc precipitated phase of Al-Sc alloy is higher than that of Al-Mn, Al-Cr and Al-Zr due to the eutectic reaction precipitation phase. During the aging process, it will not decompose, the degree of dispersion is high, and the aging hardening effect is strong, so the strengthening effect of Al-Sc alloy is high. The refinement of grains of Sc
and the effect of hindering recrystallization also strengthen the alloy. Data show [6] that trace Sc elements have a very considerable effect on the recrystallization temperature of aluminum and its alloys. Because the precipitation of Al3Sc has a stronger pinning hindering effect on the nucleation and growth of the recrystallized grains of the alloy, the deformed substructure of the alloy can be maintained at a higher temperature. In addition to the effect on the mechanical properties of the alloy, the addition of rare earth Sc also has an important effect on the corrosion performance of the alloy. Studies have pointed out [7–9] that the larger the angle of the grain boundary, the more prone to stress corrosion of the alloy. The addition of Sc keeps the small-angle grain boundary obtained by deformation in the aluminum alloy, reducing the fracture along the grain and the stress corrosion of the alloy. Sensitivity also narrow the non-precipitation area of the aluminum alloy grain boundaries, which leads to a reduction in the electrochemical difference between the grain boundaries and the crystals, and a part of the anodic corrosion reaction is suppressed, thereby improving the corrosion resistance of the aluminum alloy.

As a type of aluminum alloy with the highest strength and hardness, Al–Zn–Mg–Cu series (7000 series) super-hard aluminum alloys have a wide range of applications. The research on the micro-alloying of 7000 series aluminum alloys is helpful to promote the development of the super-hard aluminum alloy industry and play a positive role in the application of super-hard aluminum alloys in various fields. In this study, 7075 aluminum alloys were used as the research material, and thorium smelting was performed to prepare alloys with different thorium content. The as-cast, homogenized and annealed and solid solution-aging states of rhenium-containing aluminum alloys were studied respectively to reveal the microstructure and property change rules, and the mechanism of rhenium microalloying in 7075 aluminum alloys.

2. Experimental procedures

7075 Al alloys casting with different Sc content were produced by diluting the master alloy method. The nominal content of Sc in the experiment was 0 wt%, 0.1 wt%, 0.2 wt%, 0.3 wt%, 0.4 wt%, 0.5 wt%, 0.6 wt%, respectively. This work used Φ 90 mm stainless steel abrasive casting aluminum alloy ingot to get Φ 90 mm × 30 mm ingot. The chemical composition was verified for each Al-alloy casting by X-rays Fluorescence (XRF), which is illustrated in table 1.

Before homogenizing, the temperature of homogenization was determined by DSC analysis of aluminum alloy samples. Homogenization in air was conducted after casting at 460 °C for 10 h before being cooled inside the furnace to room temperature for the purpose of eliminating the non-equilibrium eutectic phase. The alloys were then hot rolled at 400 °C to 2.5 mm, with 50% reduction in thickness. After hot rolling, the aluminum sheets were solution treated at 470 °C for 1 h, ended up with water-quenching to room temperature. Aging process was performed at 120 °C for 24 h.

The samples of the Sc-contain alloys of different stages of processing were fabricated for metallographic analysis by standard metallographic procedures. The specimens were etched using Keller’s reagent (HF 1%, HCl 1.5%, HNO3 2.5% and 95% distilled water) after mechanical grinding and polishing. Optical microscopy (OM) was applied to reveal the micrographs, and a scanning electron microscope (SEM) was used to observe the microstructure and second phases. Samples were examined by energy-dispersive spectroscopy (EDS) and X-rays diffraction (XRD) in order to detect the phases. Microhardness was measured by a Vickers hardness tester (HX-100 TM) under a load of 50 g. In addition, tensile test specimens were fabricated from homogenized sheets and aged sheets, using an electronic tensile test machine (SANS XYA150C) at room temperature with a tensile rate of 1 mm min$^{-1}$

The electrochemical corrosion measurements of Sc-contained alloys were performed by a RST5000 electrochemistry workstation using a three-electrode system to investigate the corrosion property of the 7075

### Table 1. XRF results of 7075 Al alloy casting with different Sc content.

| Nominal content of Sc (wt%) | Zn  | Mg  | Cu  | Sc  | Si  | Cr  | Fe  | Al  |
|----------------------------|-----|-----|-----|-----|-----|-----|-----|-----|
| 0  | 5.049 | 2.042 | 1.255 | 0   | 0.765 | 0.209 | 0.266 | 90.316 |
| 0.1 | 5.208 | 1.527 | 1.323 | 0.113 | 0.183 | 0.221 | 0.286 | 91.025 |
| 0.2 | 4.777 | 1.444 | 1.276 | 0.217 | 0.135 | 0.209 | 0.127 | 91.759 |
| 0.3 | 4.395 | 1.963 | 1.102 | 0.333 | 0.683 | 0.198 | 0.229 | 91.027 |
| 0.4 | 4.546 | 1.396 | 1.265 | 0.415 | 0.111 | 0.214 | 0.129 | 91.923 |
| 0.5 | 3.967 | 2.070 | 0.963 | 0.557 | 0.552 | 0.197 | 0.195 | 91.430 |
| 0.6 | 3.901 | 1.805 | 0.929 | 0.622 | 0.121 | 0.188 | 0.123 | 92.297 |
alloys affected by different Sc content. All the specimens acted as the working electrode, while a platinum foil and a saturated calomel electrode (SCE) serve as the counter and reference electrodes, respectively. The corrosive medium was 3.5 wt% NaCl solution. The polarization curves were measured in the applied potential, ranging from $-0.8$ VSCE to $0.8$ VSCE with the scan rate of $1$ mV s$^{-1}$ after the specimens had been immersed in the electrolyte for 60 min, and the measurement was started after the open circuit potential (OCP) was stabilized. Electrochemical impedance spectroscopy (EIS) measurements were conducted at open-circuit potential (OCP) in the frequency range from $10^5$ Hz to $10^{-2}$ Hz with a voltage amplitude of $10$ mV. Each group of samples was measured three times to verify the repeatability of the experiment, and the appropriate circuits and calculation data were obtained by fitting software.

3. Results and discussion

3.1. Evolution of microstructure and mechanical properties of ingots after homogeneous treatment

3.1.1. Microstructure characteristics of as-cast alloys

Figure 1 shows optical microstructure of 7075 Al alloy casting with different Sc content. As shown in figure 1, the as-cast structure of aluminum alloys containing scandium was single-phase solid solution, the morphology of the grains was very smooth, and almost no second phase precipitation. Making additions Sc can refine the grains of 7075 Al alloy ingots, while many non-equilibrium precipitates at grain boundary, coarse dendrites and serious segregation existed in without Sc and 0.10 wt% Sc in figures 1(a) and (b). The alloy grains are gradually changed from coarse dendrites to fine equiaxed crystals and less segregation of increasing amount of Sc. Figure 1(h) shows the grain size changes of as-cast aluminum alloy containing Sc. Sc content from 0 wt% to 0.6 wt%, the grain size of alloy was $129.92 \mu m$, $137.81 \mu m$, $101.53 \mu m$, $101.07 \mu m$, $73.81 \mu m$, $52.68 \mu m$, $32.17 \mu m$, respectively. As the amount of Sc containing in the aluminum alloy increasing, the degree of grain refinement is higher. Figure 2 shows microhardness of 7075 Al alloy castings with different Sc content. The microhardness was between 105 HV and 130 HV. It increased slightly with the increase of Sc content and the most significant increase when adding 0.6 wt% Sc. The effect of grain refinement is also the main reason of increasing

![Figure 1. Optical microstructure of 7075 Al alloy casting with different Sc content. (a) 0 Sc; (b) 0.1% Sc; (c) 0.2% Sc; (d) 0.3% Sc; (e) 0.4% Sc; (f) 0.5% Sc; (g) 0.6% Sc and (h) Grain sizes of the castings.](image-url)
microhardness. According to Hall–Petch equation, the smaller the average grain size, the higher the microhardness of an alloy [10].

Grain refinement due to the precipitation of low melting eutectic Al3Sc phase in liquid aluminum cooling process, which acts as potential nucleation sites for aluminum grains. Moreover, the grain refinement effect becomes more obvious when Sc content is close to eutectic composition (0.55 wt%) in figures 1(f) and (g). The previous reports [11, 12] showed a similar conclusion. The serious segregation exists at grain boundary of alloy because the ingot is in chilled state and at higher cooling rate in the nucleation process, meanwhile forming supersaturated solid solution. The residual stress in the lattice of the supersaturated solid solution is relatively large, and there are many coarse non-equilibrium phases which are preferentially precipitated at the grain boundary. Therefore, the as-cast structure is a non-uniform structure and the microhardness is also high.

Figure 3 illustrates SEM analysis of as-cast structure of 7075 aluminum alloys without Sc and with 0.5% Sc, which corresponding energy spectrum analysis is shown in table 2. The second-phase morphology at the grain boundary of the as-cast aluminum alloy structure is clearly observed at larger magnifications. The gray-white phase (figure 3(b) B, C, figure 3(d) F) is the Zn, Mg, Cu-rich aluminide, and the lamellar phase (figure 3(b) A,
Figure 3(d) D, E) is the impurity phase containing Fe. For 0.5% Sc aluminum alloy, a small amount of Sc elements was also detected in impurity phase containing Fe, which proved that adding Sc could react to the impurity phase containing Fe and change its formation process and mechanism, which was similar to the findings in previous studies [6].

3.1.2. Effect of homogenization on microstructure and mechanical properties

Differential scanning calorimetry (DSC) test was performed on the as-cast alloys without Sc and 0.5 wt% Sc, and the test result curve was shown in figure 4. As be seen in figure 4, these two as-cast alloys are observed an obvious endothermic peak sited at 473 °C and the second endothermic peak sited at 634 °C. The temperature of 473 °C is far lower than the melting point of the alloy, which is the melting peak of non-equilibrium phase in the ingot [3]. It illustrates that the as-cast structure of the Al alloy has the phase separation at the temperature. In order to avoid overburning caused by homogenization, the treatment temperature should not exceed 473 °C. Therefore, the homogenization temperature designed in this study is 460 °C.

The SEM images in figure 5 show microstructures of homogenized 7075 Al alloys with different Sc content. Figure 6 gives optical microstructures under this condition. Chemical composition of the second phase (figure 3) using EDS analysis is shown in table 3. Compared with the as-cast microstructure, the segregation of the alloy after the homogenization treatment is significantly reduced, and many fine and uniformly distributed precipitated phase particles can be observed inside the crystal grains. However, chemical composition cannot be accurately analyzed by EDS since the particles are very fine. In addition, the non-equilibrium phase at the grain boundary was largely re-dissolved, leaving only some Fe, Mn and Si enriched impurity phases diffusing and merging, forming some intercrystalline pores, as showed in figures 6(a)～(d). The grain structure of the alloy change from the as-cast dendrites to equiaxed crystals after homogenization, and the size is slightly larger.

XRD analysis results before and after homogenization treatment of 7075 aluminum alloy ingots without Sc and with 0.5% Sc are shown in figure 7. From figure 7, it is concluded that the two as-cast alloys contain a small amount of MgZn2 and T [Mg32(Al, Zn)49] phases in addition to the α (Al) matrix. After comparison with figure 3, it is determined that the grey and white phase is the T phase. After homogenization treatment at 460 °C, MgZn2 phase has a tendency to grow. Although the microstructure and composition of homogenized ingots tended to be homogeneous, phase analysis could still detect MgZn2 and T phases because the temperature did
Figure 5. SEM pictures of 7075 Al alloys after homogenization: (a), (b) without Sc; (c), (d) with 0.5% Sc.

Figure 6. Optical microstructures of Sc-contained 7075 Al alloys after homogenization treatment. (a) 0 Sc; (b) 0.1% Sc; (c) 0.2% Sc; (d) 0.3% Sc; (e) 0.4% Sc; (f) 0.5% Sc and (g) 0.6% Sc.
not exceed the melting temperature of non-equilibrium phase. Moreover, the addition of Sc did not affect the phase types of microstructure and the phase re-dissolution or precipitation during homogenization.

Figure 8 illustrates microhardness and tensile strength of homogenizing Al alloys contained different Sc content. As can be seen from the figure, the microhardness of the homogenized alloy decreased significantly compared with the as-cast alloy, and increased slightly with the increase of Sc content in the alloy, from 71.7 ± 1.3 HV without Sc alloy to 89.2 ± 4.7 HV, and the tensile strength of the alloy with different Sc content also increased from 151.82 ± 1.07 MPa to 212.85 ± 7.35 MPa. It is proved that different Sc content has certain influence on homogenization alloy ingots.

### 3.2. Solution and aging treatment

7075 Al alloys casting with different Sc content had a significant decrease in hardness after undergoing homogenization annealing, and the hot workability was improved. Since the 7000 series aluminum alloy has to work hardening characteristics and improve the mechanical properties of the alloy by heat treatment, in order to

| Phase | Al  | Zn  | Mg  | Cu  | Fe  | Si  | Mn  |
|-------|-----|-----|-----|-----|-----|-----|-----|
| A     | 71.3 | 0.9 | 0.4 | 19.8 | 7.7 | 0   | 0   |
| B     | 73.1 | 0.9 | 0.6 | 7.7  | 13.5| 3.3 | 0.6 |
| C     | 85.0 | 1.3 | 1.4 | 3.9  | 7.1 | 1.5 | 0   |

Table 3. Chemical composition of the second phases in figure 3 (at%).

Figure 7. XRD result of 7075 Al alloys in casting state and homogenization.

Figure 8. Microhardness and tensile strength of homogenizing Al alloys contained different Sc content.
obtain good mechanical properties, the Sc-containing 7075 aluminum alloy was subjected to hot rolling, solid solution and aging treatment. Figure 9 shows Al alloy samples before and after rolling. Even if the deformation of hot rolling process design was only 50%, the edge of the rolled plate was still cracked, as illustrated in figure 9. This is due to the high content of alloying elements of the 7075 aluminum alloy and the high stress at the edge of the deformation process leading to cracking. The edge portion needs to be cut off when preparing the finished sheet.

3.2.1. Microstructure and mechanical properties of aluminum alloys containing Sc after solution and aging treatment

Figure 10 represents optical microstructure of three kinds of 7075 aluminum alloys with no Sc, 0.3% Sc and 0.6% Sc after solid solution-aging. The aluminum alloy without Sc appeared a large amount of recrystallized structure after solution-aging treatment, and many of the flat-length grains caused by hot rolling were converted into recrystallized equiaxial grains in figures 10(a) and (b). However, in the aluminum alloy containing 0.3% and 0.6% of Sc, more deformed crystal grains were retained, and many sub grains were formed in the alloy, meanwhile recrystallized grains were few (figures 10(c)~(f)). Studies have shown that the initial temperature of recrystallization of Sc-containing microalloyed aluminum alloys can be increased from 350 °C to 550 °C, and annealing at 470 °C only occurs revert \[13\]. The main reason for this phenomenon is that Al3Sc particles can pin dislocation during alloy deformation and stabilize the alloy substructure, so that higher energy in the as-rolled grains is retained. Therefore, higher energy is needed to provide the driving force for recrystallization of the tissue \[14, 15\].

Figure 11 shows the XRD result of 7075 Al alloys contained three different Sc content after solution treatment and aging. Comparing figure 7, it can be seen that the coarse T phase and the \(\eta\) (MgZn2) phase have not been detected after the solution-aging treatment of 7075 aluminum alloys. During the aging treatment, a large number of finely dispersed aging phases are precipitated in the crystal and at the grain boundaries. These aging phases are very small, and scanning electron microscopy and XRD phase analysis cannot be detected. Research showed that the average particle size of the Al-Sc phase precipitated in the crystal containing Sc aluminum alloy was only 20 nm, and the precipitation phase of the grain boundary was distributed along the grain boundary, and its width was only 8~10 nm. These small aging effects played an important role in strengthening the mechanical properties of aluminum alloys \[16\].

Figure 12 shows microhardness and tensile strength of Sc-contained 7075 Al alloys via hot-rolling, solution treatment and aging. Compared with the homogenization state, the microhardness and tensile strength of the alloy are obviously improved, and the addition of Sc has a certain improvement effect on its value. Due to the inhibition recrystallization effect of Sc, the aluminum alloy after adding a small amount of Sc has a relatively stable substructure, which is mainly reflected by the strengthening of the Hall-Petch strengthening mechanism. The Hall-Petch strengthening in the aluminum alloy containing Sc is reflected in equation (1) \[17, 18\]:

\[
\Delta \sigma_{HP} = k(d_{Sc}^{-0.5} - d_{N}^{-0.5})
\]

(1)
where $k$ is the relevant parameter describing grain boundary strength appreciation, and $d$ is the average grain size. ($d_N$ represents the average grain size of without Sc).

In addition to grain boundary strengthening, the precipitation strengthening caused by $\text{Al}_3\text{Sc}$ particles in the grain is an important mechanism for the strength increase of the Sc-containing aluminum alloy. According to the study [19], when the average diameter of the precipitated particles exceeded the critical diameter of $4$–$6$ nm, the alloy enhancement was mainly controlled by the Orowan mechanism, so the increase in intensity caused by Orowan enhancement in this study is expressed by equation (2) [20].

$$
\Delta \sigma_{\text{Orowan}} = \frac{0.84 \text{ MGb}}{\pi d_p} \left( \frac{2\pi (1 - \nu)}{3f_V} \right)^{0.5} \ln \left( \frac{d_p}{2b} \right)
$$

where $M$ is the Taylor factor; $\nu$ is the Poisson's ratio; $G$ is the shear modulus; $b$ is the Burgers vector of the aluminum matrix; $d_p$ is the average diameter of the particles; and $f_V$ is the volume percent of the particles.

Figure 10. Microstructures of Sc–contained 7075 Al alloys via hot-rolling, solution treatment and aging. (a), (b) without Sc; (c), (d) contain 0.3 wt% Sc and (e), (f) contain 0.6 wt% Sc.
Figure 11. XRD result of 7075 Al alloys contained three different Sc content after solution treatment and aging.

Figure 12. Microhardness and tensile strength of Sc-contained 7075 Al alloys via hot-rolling, solution treatment and aging.

Figure 13. Polarization curve of 7075 Al alloy contained different Sc content after aging.
3.2.2. Analysis of corrosion performance of aluminum alloy containing scandium 7075 after solution and aging treatment

Figure 13 illustrates the polarization curve of 7075 Al alloys contained different Sc content after aging. It can be seen from the figure that the change of the cathode branch of the polarization curve is more dramatic than that of the anode branch, indicating that the corrosion reaction of the cathode branch is more important, and the corrosion process is controlled by the cathode end [21]. From the polarization curve, the corrosion potential (Ecorr), cathode end slope (bC), and cathode end corrosion current density (IC) is measured, as shown in Table 4. Generally speaking, the more positive the electrochemical corrosion potential and the smaller the corrosion current density, the better the material’s corrosion resistance. The addition of different amounts of Sc in this study did not significantly change the corrosion potential of the 7075 Al alloys. That is, there is no obvious difference in their corrosion tendency. However, with the increase of the Sc content in the alloy, the corrosion current density of the alloy tends to decrease, which proves that the corrosion resistance of the alloy has been improved by the action of trace Sc elements, and some reports also show similar results [22, 23]. It can be seen from the corrosion current density that the corrosion rate of aluminum alloys with a Sc content of 0.3%, 0.4%, 0.5%, and 0.6% after corrosion is lower than that of the aluminum alloy without Sc. Because the single factor analysis error is relatively large, and the electrode reaction is also affected by other variables such as diffusion, surface film or surface adsorption ions coverage. Thus, it is necessary to combine the AC impedance analysis (EIS) to further study the corrosion behavior of Sc-containing aluminum alloys [24].

Figure 14 represents EIS results of 7075 Al alloys with different Sc content after aging: (a) Nyquist plot and (b) Bode plot.

| Sc (wt%) | 0    | 0.1  | 0.2  | 0.3  | 0.4  | 0.5  | 0.6  |
|---------|------|------|------|------|------|------|------|
| Ecorr (V) | −0.723 | −0.734 | −0.744 | −0.788 | −0.718 | −0.757 | −0.770 |
| bC (V/dec) | 0.089 | 0.150 | 0.084 | 0.078 | 0.108 | 0.080 | 0.079 |
| IC (μA cm⁻²) | 1.44 | 3.17 | 2.03 | 0.89 | 0.82 | 0.78 | 0.58 |

Table 4. Corrosion parameters evaluated from the polarization curves.
where \( Z_0 \) is constant, \(-1 \leq n \leq 1\), \( Z_{\text{CPE}} \) is an ideal capacitor when \( n = 1\). CPE is commonly used in AC impedance fitting circuits to simulate capacitive reactance in non-ideal environments. The fitting curve is shown in solid line in figure 14, and the parameters of each component of the equivalent circuit corresponding to the fitting curve are shown in table 5.

As can be seen from the data in table 5, the values of \( R_s \) and \( R_f \) are negligible compared with \( R_t \). Therefore, in the Nyquist diagram, only a large capacitive arc extending from zero is clearly seen, which corresponds to a larger \( R_t \) value. The \( R_t \) values of aluminum alloys with 0.3% scandium and 0.6% scandium are \( 19219 \, \Omega \, \text{cm}^2 \) and \( 17144 \, \Omega \, \text{cm}^2 \), respectively, which are greater than those without scandium. According to Faraday’s law, the greater the charge transfer resistance, the worse the charge conduction ability, which is manifested as the lower the corrosion rate of the electrode. The main indicator of aluminum alloy corrosion resistance, the larger the \( R_t \) value, the larger the corresponding capacitive arc radius, reflecting the better alloy corrosion resistance. Only by enlarging the high-frequency region can we see the small capacitive arc resistance corresponding to \( R_f \), which proves that the oxide film on the alloy surface is processed ideally and its impedance is ignored.

From the impedance spectrum, it can be observed that the capacitive reactance arc radius of the aluminum alloy with 0.3% and 0.6% Sc is larger than that of aluminum alloy without Sc. At the same time, the impedance mode in the low frequency region is larger, and the height and width of the maximum phase angle are also larger (figure 14(b)). Combined with the results of the polarization curves of each combination of gold, it is proved that the addition of trace Sc in 7075 aluminum alloys effectively improves the corrosion resistance of the alloy. Because the single factor analysis error is relatively large, it can only be proved that the addition of Sc helps to improve the corrosion resistance, but the specific amount of Sc added to achieve the best corrosion resistance needs further analysis. According to literature reports [22], the main reasons for the increase in the corrosion resistance of aluminum alloys by the addition of Sc are the suppression of recrystallization effects and the narrowing of the no-precipitation zone at the grain boundaries, so that some anode reactions are suppressed to improve the corrosion resistance of aluminum alloys.

4. Conclusions

The in-depth study of the microstructure and property evolution of 7075 aluminum alloys with different Sc content was carried out. At the same time, the action mechanism of Sc element in 7075 aluminum alloys was revealed. The conclusions are summarized as following:

1. The addition of Sc significantly reduces the grain size of the aluminum alloy microstructure, from 129.92 \( \mu \text{m} \) without Sc alloy to 32.17 \( \mu \text{m} \) with 0.6% Sc. The decrease of the grain size of the alloy results in the increase of its microhardness and tensile strength in various states.
2. Homogenization treatment eliminates segregation in aluminum alloy ingots and makes the composition of the structure uniform. The secondary phase Al3Sc at the grain boundaries in the as-cast structure was partially dissolved in the homogenization treatment, leaving only a small amount of impurity phases containing Fe, and its microhardness decreased accordingly.

3. After thermal deformation and solution-aging treatment of Sc 7075-containing aluminum alloy, the coarse phases in the structure are completely dissolved, and the secondary phases Al3Sc are precipitated in the grains and grain boundaries, which significantly improves the microhardness and tensile strength.

4. According to the results of polarization analysis and AC impedance analysis, the addition of Sc element in 7075 aluminum alloys would improve the corrosion resistance of aluminum alloys, because the increase in the corrosion resistance of aluminum alloys by the addition of Sc are the suppression of recrystallization effects and the narrowing of the no-precipitation zone at the grain boundaries.

Acknowledgments

This research is supported by a Fundamental Research Funds for the Central Universities of China (Grant No. 2018CDGFCL0003).

ORCID iDs

Jun Shen @ https://orcid.org/0000-0002-5769-1223

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