SUBSECTION 2b

Microscopic and Macroscopic Characterisation of an Aerospace Aluminium Alloy (AA2024)

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Abstract

An Al 2024 (AA2024-T351) aerospace alloy having a low amount of Mg (1.2% wt) has been characterised in terms of its microstructure and localised corrosion properties in order to provide both qualitative and quantitative input data for microscale and macroscale corrosion numerical models and simulations. Microstructural characterisation of the studied Al 2024 indicate a significant presence of nanoscale dispersoid and nanoscale and microscale AlCuFeMnSi (second phase) intermetallic particles, but a smaller population of microscale θ phase (Al₂Cu) and microscale S phase (Al₂CuMg) precipitate particles. The more common Al 2024 alloy which has a higher amount of Mg (1.5% wt) shows a much greater presence of S phase precipitates and little or no θ phase precipitates. The results from localised corrosion studies of the Al 2024 alloy having low Mg show that pitting potential (PP) values measured for second phase, S phase, or matrix have a large variation, but that the differences between the PP and open-circuit potential (OCP) values [Δ(PP–OCP)] have a more consistent trend which correlates with the microstructural phase. The corrosion behaviour of the Al 2024 alloy with low Mg is significantly different from that already reported for an Al 2024 (AA2024-T3) alloy with more common composition having a greater amount of Mg.

1 Introduction

For decades, the aerospace industry has used an AA2024-T3 or -T351 alloy for construction of aircraft. In view of aircraft maintenance and long-term use, it
is important to characterise the corrosion initiation mechanisms of the Al 2024 alloy, especially in terms of its microstructure and microscale (localised) corrosion properties.

The results of earlier studies essentially show that the microstructure of Al 2024 is dominated by nanoscale dispersoid (Al_{20}Mn_{3}Cu_{2}) particles and microscale S phase (Al_{2}CuMg) particles, along with a significant amount of other microscale intermetallic particles containing Al, Cu, Fe, Mn, and occasionally Si, distributed throughout the alloy matrix, but with little or no θ phase (Al_{2}Cu) particles [1–8]. However, the Al 2024 alloy can have a varying composition. In Table 2b.1 are shown the composition specification defined for the Al 2024 alloy, the more common composition for Al 2024, and the composition of the material analysed for the study reported here [8,9]. The Al 2024 analysed for this report has only 1.2% (wt) Mg (the lower end of the range specified for Mg) and the same amount of Cu as the more common composition. It is also known that Al 2024 alloys with low Mg have both θ phase and S phase particles distributed throughout the matrix which are about equal in population [8] and a significantly different microstructure from that of Al 2024 with the more common composition.

The disadvantage of having less Mg in the Al 2024 is that the alloy will have a slightly smaller hardness (lower yield strength) [8], but with fewer S phase precipitates formed in the alloy, which are typically the main points of pitting corrosion initiation [1,6,10–12], the corrosion resistance properties of the alloy would be expected to improve. Al 2024 is protected by anodisation, inhibitors, and multiple layers of paint, so only when defects exist in these protective layers, such as scratches, will corrosion of the Al 2024 be able to occur. Having much fewer S phase particles, the usual corrosion initiation sites, means that the chances of a scratch, which penetrates through the protective coating to the Al 2024, encountering an S phase is significantly lower.

Characterisation of the microstructure and its relation to the localised corrosion properties of the AA2024-T351 alloy under investigation has been done in order to provide both qualitative and quantitative input data (microstructural geometry and microscale electrochemical measurement data) for development of microscale and macroscale numerical models and simulations of corrosion [13].

### Table 2b.1: The chemical composition specification (spec.) for Al 2024, the more common Al 2024 composition (common), and the measured composition of the investigated Al 2024 sample in units of percentage by weight (% wt).

<table>
<thead>
<tr>
<th>Element</th>
<th>Si</th>
<th>Fe</th>
<th>Cu</th>
<th>Mn</th>
<th>Mg</th>
<th>Cr</th>
<th>Zn</th>
<th>Al</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spec. (% wt)</td>
<td>&lt;0.5</td>
<td>&lt;0.5</td>
<td>3.8–4.9</td>
<td>0.3–0.9</td>
<td>1.2–1.8</td>
<td>&lt;0.1</td>
<td>&lt;0.25</td>
<td>Bal</td>
</tr>
<tr>
<td>Common (% wt)</td>
<td>&lt;0.5</td>
<td>&lt;0.5</td>
<td>4.4</td>
<td>0.6</td>
<td>1.5</td>
<td>&lt;0.1</td>
<td>&lt;0.25</td>
<td>Bal</td>
</tr>
<tr>
<td>Sample (% wt)</td>
<td>0.1</td>
<td>0.2</td>
<td>4.4</td>
<td>0.6</td>
<td>1.2</td>
<td>&lt;0.1</td>
<td>0.1</td>
<td>Bal</td>
</tr>
</tbody>
</table>
2 Experimental methods

2.1 Al 2024 alloy composition

Microelectrochemical investigations were carried out on an AA2024-T351 (Al 2024) sheet alloy of 1.6 mm thickness (Airbus, Bremen, Germany) and pure Al (99.999–99.9999%; Goodfellow, Cambridge, UK). The overall composition of the Al 2024 alloy supplied by Airbus was determined using an Oxford Instruments PMI Master Plus glow discharge optical emission spectrometer (GDOES) as well as a Bruker S4 Explorer X-ray fluorescence spectrometer (WD XRF) (refer to Table 2b.1).

2.2 Sample preparation

Prior to all electrochemical experiments, the samples were mechanically ground with successively finer grades (1000 and 2500) of SiC paper which was lubricated with water. Afterwards, they were polished with 6 μm, 3 μm, 1 μm, and 0.25 μm diamond pastes on cloth polishing pads using alcohol as the lubricant.

2.3 Electrochemical measurements

Electrochemical tests were performed on polished samples. The electrolyte solution used was 0.5 M to 1 M NaCl, aerated and non-buffered with a pH of 6–7 or 10 (adjusted with NaOH). A more in-depth description of the technique used to obtain microelectrochemical polarisation curves can be found elsewhere [14]. The technique basically consists of a pulled glass microcapillary, which acts as a microelectrochemical cell, filled with the electrolyte solution and mounted in place of an objective lens in a carousel of an optical microscope. The tip diameter of the microcapillary was 20 to 40 μm. The Al 2024 alloy was used as the working electrode, a 0.5 mm diameter Pt wire was used as the counter electrode, and a saturated calomel electrode (SCE) [Hg/HgCl] was used as the reference electrode. A high-resolution potentiostat (Jaissle 83PCT-BC) with a current detection limit of 20 fA was also employed. Potentiodynamic micropolarisation curves were taken with a scan rate of 1 mV/s and polarised in the anodic direction. The open-circuit potential (OCP; also called rest potential) was measured for 2–5 min and then the micropolarisation curve was started at normally 100 mV to 150 mV below the measured rest potential. The micropolarisation curves were usually stopped shortly after the onset of pitting, normally within 10 s.

Micropolarisation curve measurements of AlCuFeMnSi particles of variable stoichiometry (referred to in this report as second phase), S phase (Al2CuMg), and θ (Al2Cu) phase particles surrounded by matrix, and isolated matrix points in Al 2024 were made. The second, S, and θ phase particles analysed were generally >1 μm in dimension. The matrix points generally contained particles <1 μm in size (nanoscale dispersoids and second phase particles). Random microelectrochemical measurements were also made on pure Al.
2.4 Microstructural analysis

Systematic microstructural characterisation of the Al2024 was done using a Hitachi SU70 and/or S5500 ultra-high-resolution field emission scanning electron microscope (FE-SEM). The S5500 FE-SEM can operate with secondary electron (SE) detection, backscattered electron (BSE) detection in conjunction with a YAG crystal detector, and scanning transmission electron microscopy (STEM) mode detection. In addition, energy dispersive X-ray spectrometry (EDX/EDS) can be done with a ThermoNoran EDX/EDS system. The Hitachi SEMs were operated at 5 kV for SEM imaging, 30 kV for STEM imaging, and 10 kV for EDX/EDS. In addition, a less detailed sample characterisation was done using a LEO 1455 thermionic emission SEM, which was typically operated in the 5 kV to 20 kV range and in conjunction with an Oxford Instruments Inca 7353 EDX/EDS. Due to S and θ phase particles often being less than 3 µm in size, the EDX/EDS analysis of the particles in the alloy was done with an electron beam voltage of 10 kV or less to eliminate the problem of the “mass effect” [1] where the electron beam-specimen interaction volume is larger than the particle and a significant contribution of the signal comes from the surrounding matrix. For EDX/EDS analysis with the LEO SEM, a large difference in the amount of Mg was the main criteria to distinguish S from θ phase, and detection of Fe, Mn, and possibly Si indicated a second phase particle. Geometry and compositional data were obtained from the analysis of several hundred particles of the Al2024.

3 Results and discussion

3.1 Al2024 microstructure: intermetallic particles and matrix

Analysis of the Al2024 alloy investigated shows that there are four types of intermetallic particles (similar to studies of Al2024 in the literature) found embedded in the alloy matrix:

- microscale and nanoscale particles with a composition of AlCuFeMnSi having variable stoichiometry (called second phase),
- microscale S phase (Al2CuMg) precipitates,
- microscale θ phase (Al2Cu) precipitates, and
- nanoscale dispersoids (Al20Cu2Mn3).

More details about each phase of the alloy are described below.

3.1.1 S and θ phase precipitates
The intermetallic precipitate particles S (Al2CuMg) and θ (Al2Cu) phase of Al2024 form during the heat treatment (T3) when the alloy is in the solid state (via diffusion of the elements Cu and Mg within the solid alloy matrix). Also, they are often in clusters, such as that seen in Figure 2b.1. Clusters of precipitate particles (mainly S phase) in Al2024 with a more common composition have also been reported.
in the literature [2,6,15]. It is well known that the usual sites of pitting corrosion initiation in Al 2024 are the S phase precipitates, as they tend to be more susceptible to localised corrosion. On the contrary, the \( \theta \) phase precipitates have been shown to have a much better resistance to localised corrosion than S phase [10,12].

### 3.1.2 AlCuFeMnSi (second phase) particles

Besides the precipitates, other intermetallic particles were observed, which form while the Al 2024 alloy is in the liquid state – thus their shapes are distorted and asymmetrical. During the rolling part of the alloy sheet production, these particles may crack and increase in number.

In the literature, a large number of chemical stoichiometries are reported for these particles, such as AlCuFeMnSi, AlCuFeMn, Al\(_7\)Cu\(_2\)Fe, Al\(_2\)Mn\(_3\)Si, Al\(_2\)(Fe,Mn)\(_3\)Si, Al\(_6\)(Cu,Fe), Al\(_3\)Fe, Al\(_3\)Mn, and (Al,Cu)\(_6\)Mn [1,2,8,15,16]. In the investigated Al 2024 with low Mg, only particles with AlCuFeMn or AlCuFeMnSi were found; therefore, as already mentioned above, these particles are referred as second phase intermetallics.

Clustering of the second phase particles has been observed in previous studies [15,16] and in the examined Al 2024 with low Mg as well. Clustering of the particles may lead to the formation of inhomogeneous second phase particles, which are shown in Figure 2b.2. Each zone of these particles differs in chemical composition, as demonstrated by the EDX/EDS data of Table 2b.2, with all of them containing Al, Fe, Cu, Mn, and sometimes Si.

The second phase particles have been studied in Al 2024 with a more common composition and reported to have a better resistance to localised corrosion than S phase but about the same as \( \theta \) phase [1,6,10–12].

### 3.1.3 Matrix

Matrix points of the Al 2024 with low Mg which exclude microscale particles have been analysed with high-resolution microscopy to determine whether nanoscale intermetallic particles are present. Figure 2b.3 shows an SEM micrograph from an area on the Al 2024 surface and a STEM micrograph which is a zoom-in on the
Figure 2b.2: SEM (BSE) images of inhomogeneous second phase particles; the points marked 1–5 indicate areas analysed by EDX/EDS (refer to Table 2b.2).

Table 2b.2: Elemental composition of the points 1–5 marked in Figure 2b.2.

<table>
<thead>
<tr>
<th>Point</th>
<th>Al (% wt)</th>
<th>Cu (% wt)</th>
<th>Fe (% wt)</th>
<th>Mn (% wt)</th>
<th>Si (% wt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>60.88</td>
<td>24.89</td>
<td>10.95</td>
<td>3.29</td>
<td>–</td>
</tr>
<tr>
<td>2</td>
<td>57.42</td>
<td>14.67</td>
<td>17.85</td>
<td>8.84</td>
<td>1.21</td>
</tr>
<tr>
<td>3</td>
<td>57.54</td>
<td>11.7</td>
<td>17.8</td>
<td>8.83</td>
<td>4.12</td>
</tr>
<tr>
<td>4</td>
<td>45.23</td>
<td>34.72</td>
<td>14.72</td>
<td>5.34</td>
<td>–</td>
</tr>
<tr>
<td>5</td>
<td>49.58</td>
<td>18.71</td>
<td>20.79</td>
<td>9.39</td>
<td>1.53</td>
</tr>
</tbody>
</table>

Figure 2b.3: EM micrographs of microscale and nanoscale particles detected in the investigated Al 2024 (1.2% wt Mg): (a) SEM image of microscale S, θ, and second phase particles and (b) STEM image of nanoscale dispersoid particles found distributed throughout the matrix where indicated by the arrow.

Al 2024 matrix. The STEM image shows many intermetallic particles at the nanoscale. These particles have a composition of Al$_{20}$Mn$_2$Cu$_2$ and have been identified as dispersoids which are commonly found in Al 2024 with a more common composition [17]. Typically, the dispersoid particles have a size between 15 nm and
Figure 2b.4: STEM image showing dispersoid-free areas around an Al 2024 S phase precipitate.

Table 2b.3: Population frequency, area fraction of the total alloy surface, and average size of the microscale Al 2024 particles found in the examined material (1.2% wt Mg).

<table>
<thead>
<tr>
<th>Al 2024 phase</th>
<th>% particles</th>
<th>% area</th>
<th>Average area (µm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S (Al₂CuMg)</td>
<td>13.3</td>
<td>0.4</td>
<td>3.6</td>
</tr>
<tr>
<td>θ (Al₂Cu)</td>
<td>14.5</td>
<td>1</td>
<td>7.8</td>
</tr>
<tr>
<td>Second phase (AlFeCuMnSi)</td>
<td>72.2</td>
<td>1.8</td>
<td>3.0</td>
</tr>
</tbody>
</table>

95 nm. In addition, sub-micrometre second phase particles were found in the size range of 0.3 µm to 1 µm.

High-resolution EM observations reveal, in agreement with the literature, that microscale intermetallic particles (θ, S, and second phase) are often surrounded by areas free of nanoscale particles, mainly dispersoids. An example of an S phase particle in the studied Al 2024 with a dispersoid-free area around it is shown in Figure 2b.4. It has been proposed that the dispersoid-free areas develop around the microscale particles due to Cu depletion in such areas, preventing dispersoid formation [1,2,6].

3.1.4 Statistical analysis of the particles
The results of EDX/EDS analysis for several hundred intermetallic particles in the Al 2024 under study are summarised in Table 2b.3. The data displayed in this table profoundly differ from those previously published for Al 2024 with a more common composition [1–8], as the S phase is definitely a minority particle. The low amount of Mg present in the investigated Al 2024 explains this finding. The precipitates of both S and θ phases are almost equal in number and account for <28% of all
Figure 2b.5: Histograms of the particle size, \( d \), for (a) S phase, (b) \( \theta \) phase, (c) second phase, and (d) dispersoid particles.
observed microscale particles, while the second phases account for >70% of them. In Table 2b.3, the area fraction of the total alloy surface for the particles and their average area per particle are also shown.

In addition, the size distributions of all particle types (nanoscale to microscale) are shown in Figure 2b.5. The average size per particle for S, θ, and second phase is 2 µm, 2.5 µm, and 1.5 µm, respectively. The majority of second phase particles are smaller in size than 3 µm.

It should be mentioned also that if all particles from the nanoscale to the microscale are considered together, the nanoscale dispersoids would represent >99% of them and occupy about 4% of the total alloy surface area (more than all the microscale particles combined), while the matrix would occupy about 92.8% of the surface.

In addition to the size and density of particles, it is important for corrosion modelling to know the inter-particle distances of the alloy. Therefore, the distances between the nearest neighbour particles were determined using the Voronoi transformation [13]. The results of these measurements are shown in Figure 2b.6 and Table 2b.4.

The results show that the second phase particles are most densely packed with an average nearest neighbour inter-particle distance of 6.1 µm. For S and θ phase, the nearest neighbour inter-particle distances are 9.3 µm and 12.7 µm, respectively. The observed differences are related to the variations in the area (and volume) fraction of the respective particles.

3.2 Al 2024 corrosion properties

3.2.1 Microscale electrochemical measurements (micropolarisation curves)

Micropolarisation curves were measured to characterise the localised corrosion behaviour of microscale particles surrounded by matrix and isolated matrix points.
Figure 2b.6: Examples of Voronoi transformation and determination of nearest neighbour inter-particle distances.

Table 2b.4: Average nearest neighbour distances between different types of particles found in Al 2024.

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Average distance (µm)</td>
<td>9.33</td>
<td>12.74</td>
<td>6.13</td>
<td>5.71</td>
<td>5.48</td>
<td>6.18</td>
</tr>
<tr>
<td>Standard deviation (σ)</td>
<td>8.11</td>
<td>9.88</td>
<td>2.71</td>
<td>4.34</td>
<td>2.95</td>
<td>3.39</td>
</tr>
</tbody>
</table>

(containing nanoscale dispersoid and second phase intermetallic particles) in the Al 2024 under study. Examples of potentiodynamic polarisation curves measured for S phase and second phase particles surrounded by matrix, as well as isolated matrix points, are shown in Figure 2b.7. The OCP and PP values for each phase were taken from such curves.

It is well known that the preferred sites of pitting corrosion initiation in Al 2024 are the S phase precipitates, while both the θ- and second phase particles have been shown to have a better localised corrosion resistance [1,6,10–12]. Due to the fact that second phase represents >70% of the Al 2024 microscale particles (Table 2b.3) and that preliminary microelectrochemical results showed the θ and second phases to behave noble compared to S phase, in agreement with previously published results [11,12,18], only the second phase particles were thoroughly investigated for this study.

SEM micrographs of a second phase surrounded by matrix and an S phase surrounded by two θ phase particles and matrix are seen in Figure 2b.8. These SEM images demonstrate how the micropolarisation curve method was exploited to study the localised or pitting corrosion behaviour of the Al 2024 alloy. Many
Figure 2b.7: Examples of micropolarisation curves measured for S phase (black/solid line), second phase (green/dashed line), and matrix points (red/dotted line) in Al 2024 (1.2% wt Mg). Semi-log plot of the absolute electrochemical current density (I) (µA/cm²) and the electrochemical potential (E) (mV).

details about the technique have already been reported and can be found in the literature [11,14,19–21]. Figure 2b.8c also shows typical “trenching” around an S phase, which is the preferred site for pitting initiation in Al 2024 as already reported for Al 2024 with a more common composition [1,6,11,12].

Using data of OCP and PP values (extracted from micropolarisation curves, such as those seen in Figure 2b.7), the difference between the PP and OCP [Δ(PP–OCP)] has been calculated. These data, PP and Δ(PP–OCP), are shown in Figure 2b.9. The data show that the PP values measured for second phase, S phase, or matrix points have a large range of variation from 350 mV to 900 mV (average PP values are −323 mV, −405 mV, and −247 mV, respectively). However, the differences between the PP and OCP [Δ(PP–OCP)] demonstrate a more consistent trend which correlates with the microstructural phase. For instance, the Δ(PP–OCP) values for S phase tend to be <100 mV, for second phase between 100 mV and 200 mV, and for matrix points typically >200 mV (average Δ(PP–OCP) values are 38 mV, 195 mV, and 368 mV, respectively). Data on the localised corrosion behaviour of an Al 2024 alloy with a more common composition (Figure 2b.9c) [11] differ significantly from that shown here for Al 2024 with low Mg (1.2% wt Mg). When comparing the distribution of PP values between phases (Figure 2b.9a), the significant overlap of the potential value distributions for the different phases seen is in stark contrast to the more separated distributions obtained for Al 2024 with a more common composition (Figure 2b.9c) [11].
3.2.2 Difference in localised corrosion between the Al 2024 alloys
(low Mg versus the more common composition)

The difference in localised corrosion behaviour between Al 2024 with a more common composition and that studied here (1.2% wt Mg) is clearly attributed to the difference in microstructure. The smaller percentage of S phase and the different distribution of microscale and sub-microscale second phase, which are chemically inhomogeneous, as well as sub-microscale S phase are likely to be the major factors causing the difference in localised corrosion behaviour compared to that of Al 2024 with a more common composition. Inhomogeneous microscale second phase particles (Figure 2b.2 above) are present in the Al 2024 with low Mg and clearly some zones of these second phase particles are richer in Cu than others. Previous studies have shown that inhomogeneous second phase particles with Cu-rich zones can have a very different corrosion behaviour from those which are more uniform [22–24]. The reported study showed that the cooling procedure after heat treatment, especially the time spent in air before water cooling (quench delay time) and
Figure 2b.9: Data extracted from micropolarisation curves for S phase (green squares) and second phase (blue triangles) particles and matrix points (red diamonds) in Al 2024 (1.2% wt Mg): (a) pitting potential (PP) values for each phase and (b) the difference between the PP and open-circuit potential (OCP) values [$\Delta$(PP – OCP)] for each phase. (The full range of values (ΔPP and $\Delta$[(PP – OCP)]) is also indicated.) Data extracted from micropolarisation curves for Al 2024 with a more common composition: (c) PP values for each phase (adapted from reference [11]).
the aging procedure after quenching, has a drastic effect on the Al 2024 corrosion behaviour, mainly due to the formation of particles that significantly differ in size, shape, and composition after precipitation. With long quench delay times, the second phase particles became chemically inhomogeneous and shell-shaped, meaning that the core of the particle becomes Cu poor compared to the surface at the particle/matrix interface [23]. A large potential difference was observed with scanning Kelvin probe between the core and shell of these particles, which was explained, to induce a severe galvanic coupling under open-circuit conditions, weaken the natural Al 2024 oxide, reduce its ability to repair itself when attacked, and thus, result in an increased likelihood of localised pitting corrosion [24].

3.2.3 Variation in potential values measured with micropolarisation curves

The phenomenon of potential value variation seen in the Al 2024 micropolarisation curve data seems to be caused by the nature of the Al oxide on the alloy surface. As Al oxide/hydroxide formed on the surface is a good insulator, there will be high electrochemical impedance at the electrolyte solution/Al 2024 interface. However, if the oxide film is at least partially removed or defects are formed in it, then the impedance at the electrolyte solution/Al 2024 interface will decrease significantly [25]. Considering specifically the matrix, the number of defects per unit area in the Al oxide/hydroxide layer can vary with the scale (micrometre to millimetre); a macroscopic area will have a very large number of defects in the Al oxide/hydroxide, and the amount will change very little from one macroscopic area to another. The large number of defects will lead to a low impedance at the electrolyte/Al 2024 interface and result in reproducible polarisation curves and potential values extracted from them [21,26]. For the Al 2024 alloy studied here, potential values (both OCP and PP) extracted from macroscale polarisation curves (areas 10 mm in diameter) showed a variation of less than 30 mV, and the difference between the PP and OCP were less than 10 mV. This small level of variation in the potential values for Al 2024 macroscale polarisation curves is in agreement with previous results [21]. However, for microscopic areas, the number of defects encountered in the Al oxide is much smaller, and the amount can change significantly from one microscopic area to another causing a large variation of the potential values [21,26].

4 Conclusions

The localised corrosion behaviour of an Al 2024 (AA2024-T351) sheet alloy with a low amount of Mg (1.2% wt) has been studied. The microstructure of this Al 2024 is quite different from that of an Al 2024 (AA2024-T3) alloy with more common composition (1.5% wt Mg) as the vast majority of the microscale particles are second phase, while S and θ phase particles are in the minority. Nanoscale dispersoids are commonly seen in the Al 2024 with low Mg, similar to Al 2024 of a more common composition, but in contrast, nanoscale second phase particles were also present.

Localised corrosion results using micropolarisation curves show that the Al 2024 alloy with low Mg has a corrosion behaviour which is significantly different
from that reported for the Al 2024 sheet alloy with a more common composition. Data taken from micropolarisation curves show that OCP and PP values measured for microscale second phase or S phase particles or matrix points without microscale particles (containing nanoscale dispersoid and second phase particles) show a large variation. However, the differences between the PP and OCP have a more consistent trend which correlates with the microstructural phase. The difference in localised corrosion behaviour between the Al 2024 studied here (Cu/Mg = 3.7) and that with a more common composition (Cu/Mg = 2.9) is related to the difference in microstructure, especially due to the dominant presence of inhomogeneous second phase at the microscale and nanoscale with Cu-rich zones which, along with the S phase particles, can initiate pitting corrosion.

There is some evidence that the variation of the PP and OCP values extracted from Al 2024 micropolarisation curve data is related to the density of defects in the Al oxide/hydroxide layer, but further investigation needs to be done.

Acknowledgements

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References


