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Opinion

Effect of IMPs on the Corrosion Behavior of AA6061 Alloy. Short Review

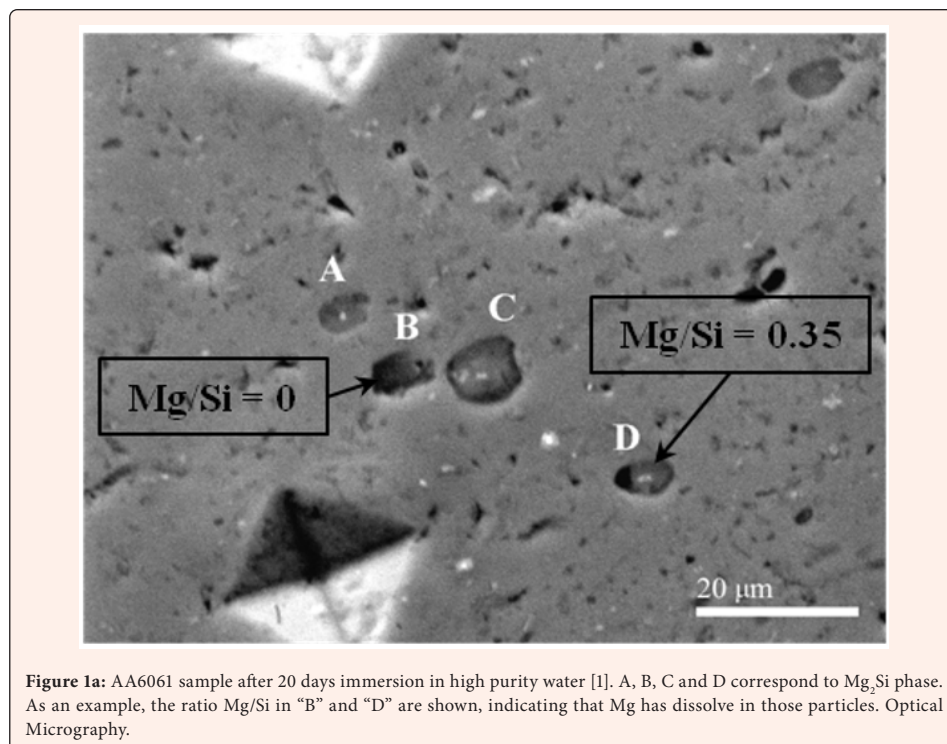
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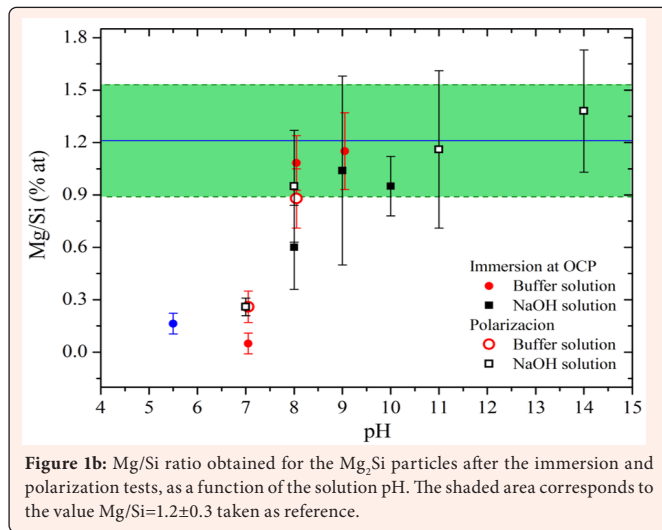
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Opinion

In recent works our group has studied the influence of IMPs (Intermetallic Particles) in the corrosion behavior of the AA6061 alloy in high purity water and in diluted electrolyte solutions. The IMPs are intentionally developed in aluminum alloys during thermomechanical processing to produce specific mechanical properties. The following IMPs have been identified in AA6061 alloy: Al_3Fe ; α/β (Fe-Si-Al); π -(Fe-Si-Al-Mg); Mg_2Si ; Si and $TiAl_3$ [1]. In the literature it is generally accepted that these particles can be classified into cathodic or anodic according to their relative nobility or activity in relation to the aluminum matrix [2]. Regarding the Mg_2Si phase in 0.1 M KCl solution, Alodan & Smyrl [3] found that the corrosion potential (OCP) of this phase is more active than that of the aluminum matrix and finally concluded that these IMPs dissolve. Rodriguez. et al [1] found that magnesium dissolves preferentially from Mg_2Si particles during immersion in high purity water. On the other hand, it has been demonstrated that iron-rich IMPs as Al_3Fe and α/β -(Fe-Si-Al) act as cathodes for oxygen reduction reaction, increasing the pH in its surroundings [4]. The localized alkalization causes aluminum dissolution creating a trench around the particle. In the literature, this kind of attack and the selective Mg dissolution coming from the Mg_2Si phase are both referred to as "pitting corrosion". However, the correct meaning of pitting corrosion is the localized dissolution that occurs in the presence of an aggressive anionic species and above a certain potential value, named the Pitting Potential (EP) [5]. In order to clarify the influence of both Mg_2Si and iron-rich IMPs in the AA6061 localized corrosion our group has conducted several studies. With the purpose to study the Mg_2Si behavior, some particles of this phase in as-polished AA6061 samples were characterized by SEM (Scanning Electron Microscope) and EDS (Energy Dispersive Analysis), obtaining the Mg and Si composition and then the ratio $Mg/Si=1.2\pm 0.3$, which was established as a reference value. Then, immersion and polarization tests were carried out in de-aerated phosphate buffer and NaOH solutions with pH from 7 to 14. Comparing the Mg/Si in the particles after the immersion and polarization tests with the (Mg/Si)REF, it was determined that the Mg_2Si phase undergoes selective magnesium dissolution from pH 7 to lower values, while it remains stable in solutions with a pH of 8 to 14 (see Figures 1a & 1b). In the pH range 8-14 it was confirmed that the Mg dissolution does not depend on the applied potential, since the composition of Mg_2Si particles remained the same after polarization to 1.5 V above the OCP (Figure 1b), [6].





In order to assess the influence of the localized alkaline dissolution around iron-rich IMPs (Figure 2) on the corrosion behavior of AA6061 alloy, the Pitting Potential (EP) was measured in aerated and de-aerated 10⁻³ M NaCl solution. For the sake of comparison, the E_p for Al5N (Al 99,999%) was measured in the same solutions as well. 10 measurements were made for each material in each solution in the two aeration conditions, with the aim to analyze the EP values with statistical significance. Applying the hypothesis testing procedure, it was concluded that the presence of oxygen in the 10⁻³ M NaCl solution decreases the EP of AA6061 by 100 mV and does not affect the E_p for Al5N (See Table 1). This decrease is related to the alloy dissolution around the iron-rich IMPs and can be explained in terms of the Model of Localized Acidification regarding the difference between pitting and crevice corrosion [5,7]. When AA6061 is immersed in aerated 10⁻³ M NaCl, the alkaline attack that begins at OCP and continues during the polarization produces trenches up to 1 μm in depth, where the critical acidification can be reached. The characteristics of the oxide inside the trench (see Figure 2) that are different from the anodic oxide grown during the polarization could promote this process. Moreover, it was found that the presence of iron-rich particles shift the OCP of AA6061 to more noble values in relation to those of Al5N [8].

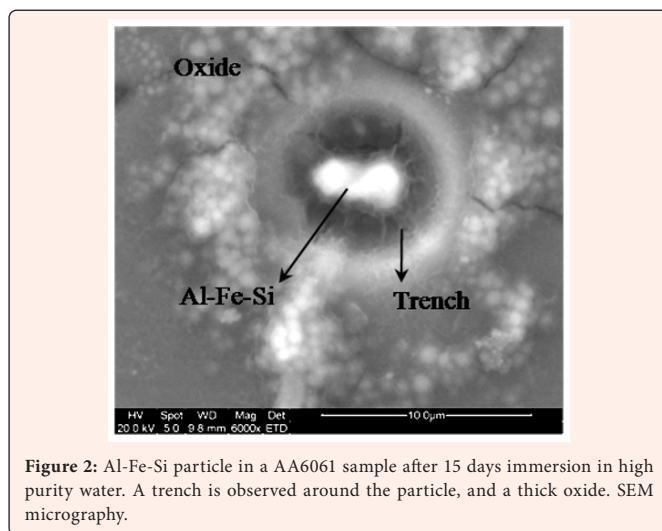


Table 1: E_p values for AA6061 and Al5N in 10⁻³ M NaCl solutions. Values in columns 2 and 3 show the mean and standard deviation of 10 E_p measurements. Column 4 summarizes the conclusions obtained from the hypothesis testing.

Pitting potential in 10 ⁻³ M NaCl			
Alloy	E _p ^{AER} (mVSCE)	E _p ^{DE-AER} (mV _{SCE})	Conclusion
AA6061	-462 ± 19	-366 ± 38	E _p ^{AIR} ≠ E _p ^{DES}
Al5N	-378 ± 59	-342 ± 69	E _p ^{AIR} = E _p ^{DES}

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