Alloys and Intermetallics

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Stress corrosion cracking in AA5083 mold material used for curing rubber compounds

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Aluminum and its alloys can fail by cracking along grain boundaries when simultaneously exposed to specific environments and stresses of sufficient magnitude. AA5083 material is a non-heat treatable wrought aluminium alloy and it is strengthened by elements in solid solution and dislocation structures introduced by mechanical deformation. After service for extended period of time at ambient temperature or elevated temperature, alloying elements may segregate to grain boundaries, leading to several different types of precipitates. If these grain boundary precipitates are anodic to the alloy matrix, they can serve as the path for intergranular stress corrosion cracking. The segregation of magnesium at grain boundaries leads to the formation of anodic intermetallic Al_3Mg_2 which is known as β-phase, and this β-phase has been proven to be the major cause of stress corrosion cracking in AA5083 material [1-10].

In this study, the failure analysis of AA5083 mold material, used for curing rubber compounds, was carried out. The problem revealed itself as the formation of bubbles, 4-6 mm in diameter, on the mold surface during curing process and caused quality problems in the final product (Figure 1a). In the first stage of the analysis, elemental distribution maps were taken by energy dispersive x-ray spectrometer (EDS) from the interior part of a bubble (Figure 1b) and accumulation of both Mg and also Cl was observed (Figure 1c, Table 1). In the second stage, two samples 10-25 mm in width were taken out from the mold material. The first sample was very close to outer part of the mold and had no contact with the rubber compound. The second sample was taken from the inner part of the mold, 5 mm in depth from the surface. The samples were embedded in resin and polished surfaces were examined using scanning electron microscope (SEM) and EDS.

It was concluded that (i) the contamination by Cl ions was due to the cutting oil used to open vent holes during mold cleaning, (ii) the outer part of mold material had finer α-Al grains whereas the inner part in contact with the compound had coarse grains due to the thermal effect of curing process (Figure 2a and b), (iii) β-phase (Al_3Mg_2) formed at the grain boundaries after a sufficient exposure to temperatures above 50 °C (Figure 2c), (iv) the grain boundaries had Mg-rich phase showing anodic behavior, while the grains had Al-rich phase showing cathodic behavior, (v) the cracks initiated and propagated through the grain boundaries as stress corrosion cracking which resulted in the separation of grains and the accumulation of gases appeared as bubbles due to thermo-mechanical aging and effects of corrosive medium.

1. M. O. Speidel, Metallurgical Transactions A, 6 (1975), pp. 631-651.
2. S. K. DeWeese, S. T. Ningileri, S. K. Das, J. A. S. Green, The Journal of The Minerals, Metals & Materials Society, 60 (2008), pp. 50-57.
3. G. L. Makar, J. Kruger, K. Sieradzki, Corrosion Science, 34 (1993), pp. 1311-1323, 1325-1342.
4. A. Zielinski, Materials Science, 34 (1998), pp. 469-475.
5. M. Bobby-Kannan, V. S. Raja, R. Raman, A. K. Mukhopadhyay, Corrosion, 59 (2003), pp. 881-889.
6. Q. Li, J. Zhao, P. Zhang, Journal of Wuhan University of Technology-Mater. Sci Ed., 27 (2012), pp. 648-651.
7. J. Gao, D.J. Quesnel. Metallurgical and Materials Transactions A, 42 (2011) pp. 356-364.
8. J.L. Searles, P.I. Gouma, R.G. Buchheit, Metallurgical and Materials Transactions A, 32 (2001), pp. 2859-2867.
9. R.H. Jones, J.S. Vetrano, C.F. Windisch, *Corrosion*, 60 (2004), pp. 1144-1154.
10. R.H. Jones, D.R. Baer, M.J. Danielson, J.S. Vetrano, Metallurgical and Materials Transactions A, 32 (2001), pp. 1699-1711.

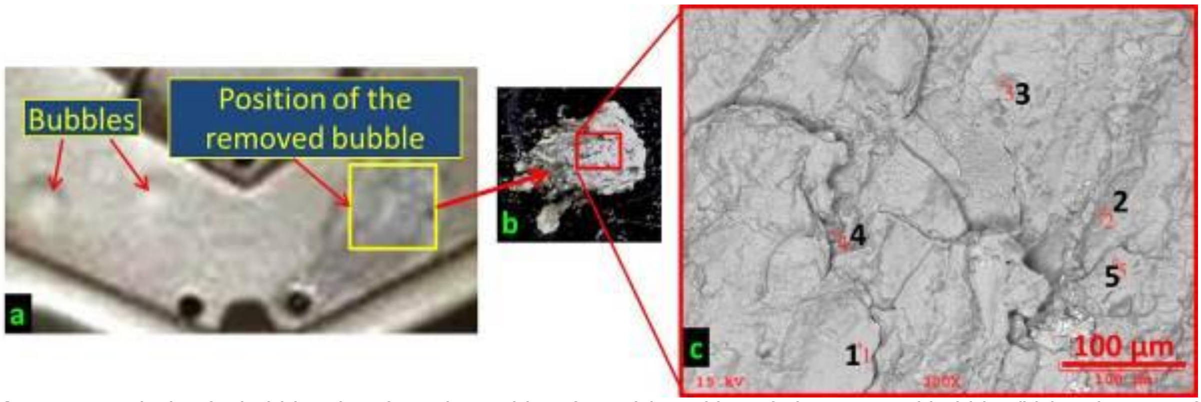
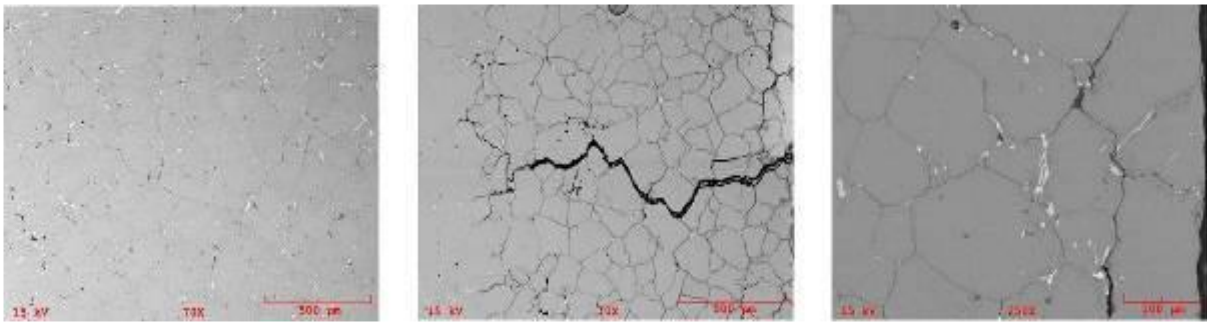


Figure 1. Analysis of a bubble taken from the mold surface; (a) position of the removed bubble, (b) interior part of the removed bubble; c) points where the spot analyses were carried out.

Spot	Element (count-%)										
	C	O	Mg	Al	Si	P	S	Cl	Ti	Mn	Fe
1	0.171	6.882	4.576	86.910	0.101	-	-	0.608	0.266	0.451	0.035
2	0.123	17.685	7.121	72.026	0.040	0.163	0.015	2.120	0.101	0.489	0.117
3	0.0037	25.904	11.761	60.129	0.040	0.255	-	1.362	0.064	0.344	0.104
4	0.028	42.319	26.048	29.842	0.237	-	0.010	1.182	0.053	0.245	0.037
5	0.618	9.557	4.318	84.391	0.028	0.223	0.019	0.493	0.052	0.257	0.042

Table 1. EDS results of the spots shown in Figure 1c.



(a) (b) (c)

Figure 2. The variation of α-Al grain size in the outer (a) and inner part of mold material (b), Mg-rich phases visible in light contrast at the grain boundaries (c).