Real-time Observations of AE44 (Mg-4Al-4Ce) Solidification Including Nucleation and Growth of Primary and Eutectic Phases

K. Nogita[a], H. Yasuda[b], S. D. McDonald[a], T. Nagira[c], K. Uesugi[d]

[a]School of Mechanical and Mining Engineering, The University of Queensland,
[b]Department of Materials Science and Engineering, Kyoto University,
[c]Department of Adaptive Machine Systems, Osaka University,
[d]Japan Synchrotron Radiation Research Institute

In-situ solidification observations with synchrotron radiography were carried out at the SPring-8 facilities on industrially relevant Mg-based AE44 alloys (Mg-4 wt%Al-4 wt%Ce). The results clearly showed that the effect of solute segregation in halting grain growth was apparent in many instances where the growth of adjacent dendrite arms appeared to slow before impingement on their immediate neighbours.

The future work will focus on high magnification, high resolution imaging of the advancing eutectic interface.

Keywords: In-situ X-ray imaging, Magnesium alloys, solidification

Background and aim:

Lightweighting to reduce emissions in transport systems is increasingly important, and Mg alloys are of great interest being the lowest density structural alloys. Development of creep resistant Mg-Al alloys has focused on elemental additions that either improve the stability of the grain boundary intermetallics or remove Al from solid solution. Greater improvements have been obtained through the addition of alkali-earth elements such as Ca (X) and Sr in AXJ530 and AJ62 alloys and REs (Rare Earths) in AE42 and AE44 alloys (Mg- 4Al% with 2% and 4% RE respectively). AJ62 is used in production of BMW engines and AE44 for Corvette engine cradles and Porsche valve covers and oil housings. AE44 is noteworthy for its resistance to hot tearing that limits the use of many of the other high temperature alloys. Recent research shows that Mg-Al-Rare Earth alloys have particular advantages such as being highly castable and suitable for high temperature automotive applications having particularly good strength-ductility combinations.

This has created an opportunity for a new generation of improved high strength structural alloys and potentially new light weight pistons.

The eutectic and near hypereutectic regions of the Mg-Al-RE systems have not been thoroughly investigated and potential exists to tailor the primary and eutectic Al-RE phase morphologies by adjusting the RE mix and content and through the introduction of modifying elements. This experiment focuses on identifying the fundamental mechanisms of eutectic solidification in Mg-Al-RE alloys containing Ce and La including the effect of Ce and La on the morphology of the eutectic phases and on the distribution of eutectic nucleation sites throughout the alloy.

Experimental:

Synchrotron radiography experiments were carried out at the SPring-8 facilities on AE44 alloys (Mg-4wt%Al-4wt%Ce). The experiments were carried out on the BL20B2 beam line. This beam line has a larger field of view (5 mmx5 mm) and hence a slightly lower spatial resolution [1], compared with BL20XU [2]. The castings of the alloy samples were in the form of 20 mm diameter cylinders. A 1cm disc was sectioned from these cylinders, which were further cut, ground and polished to 100 μm thickness. The thin sample was sandwiched between MgO films and inserted into the furnace. The sample was placed within the furnace aligned with the furnace window. The furnace window was set up in line with the X-ray beam in the BL20B2 line. The samples were melted and then cooled at 10 K/min. The cooling resulted in solidification of the sample. The entire sequence of remelting and solidification was carried out with the X-ray beam exposure.

Results and discussion:

The X-ray images of solidification as captured during the experiments are shown in Figure 1 (a) – (d).

The labeled times in Figure 1 are measured from the time at which nucleation (a solid grain) was first observed (tN=0). Although times could be recorded accurately, due to the small sample size it was not practical to embed a thermocouple in the samples and exact temperatures cannot be reported. Very rapidly after grain nucleation (within a few seconds), the total number of grains for each sample is fixed and no further nucleation (no new solid grains) was observed. Around ten seconds after nucleation, the grains had formed a coherent network and no further grain movement was noted. The effect of solute segregation in halting grain growth was apparent in many instances where the growth of adjacent dendrite arms appeared to slow before impingement on their immediate neighbours. It should be emphasized that the absorption images normalized by the melt before solidification allow the evolution of the dendritic structure to be observed.

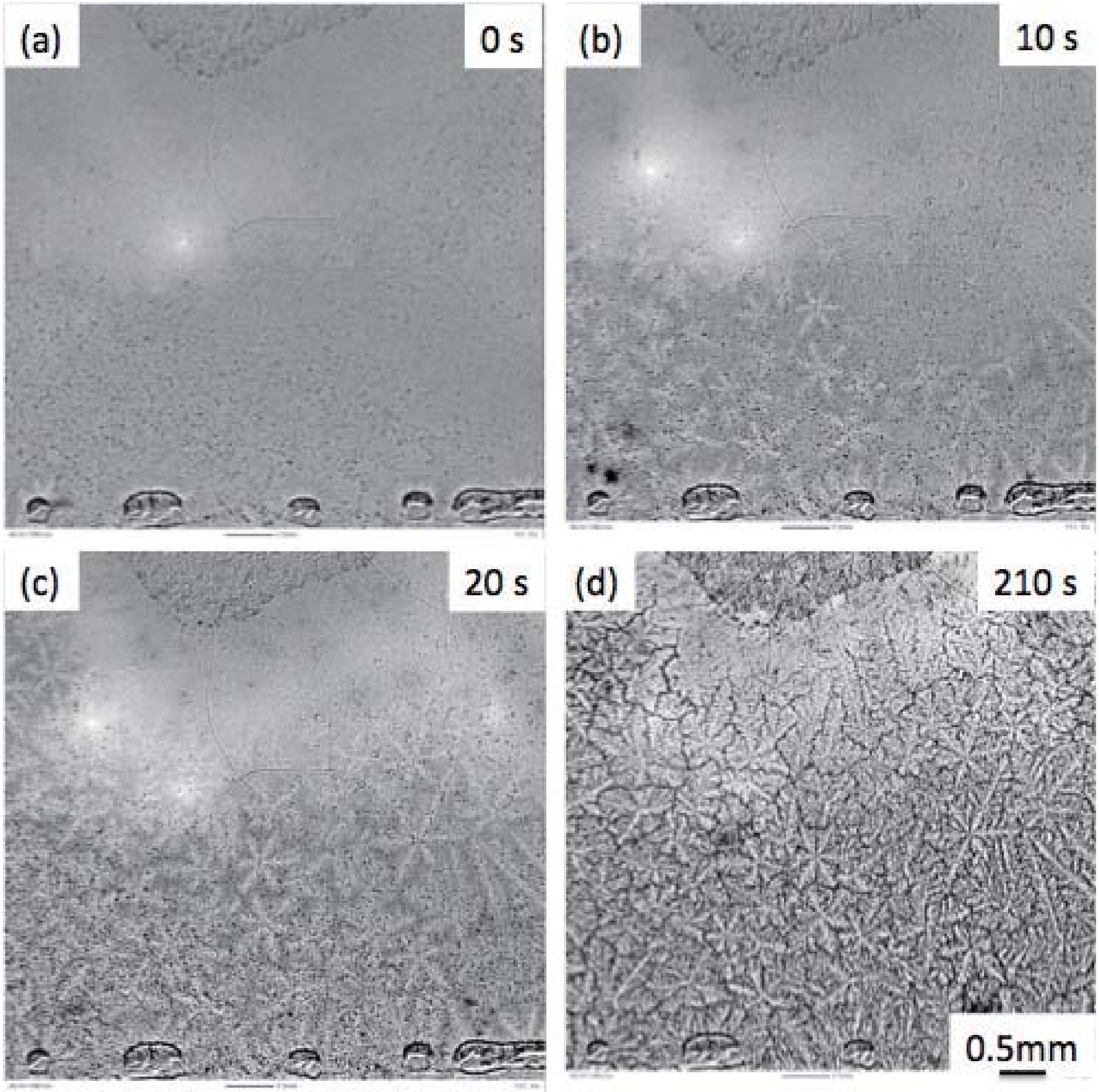

Figure 1. Selected X-ray stills of solidification for the AE44 alloy.

Conclusions and future works:

These experiments have been successfully completed. The in-situ observation of Mg alloys is a significant achievement and the experimental set up has successfully overcome the problems that arise due to the oxidation of liquid Mg and its interaction with the enclosing substrate/interface. Now that successful observations have been made, future work will focus on high magnification, high resolution imaging of the advancing eutectic interface.

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References:

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