Effect of 3D Crystallographic Orientation and Microstructure on the Evolution of Corrosion in Aluminum Alloys

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Keywords: x-ray tomography, laboratory diffraction contrast tomography, aluminium alloys, corrosion

Summary: Recent developments in laboratory-based diffraction contrast tomography (LabDCT) have shown its capability to non-destructively map the 3D morphology and crystallographic orientation in the bulk of a polycrystalline sample. Here we present experimental results acquired on a widely used aerospace structural aluminium alloy and demonstrate how the technique can be utilized to non- destructively investigate corrosion behaviour of these alloys in three-dimensions.

1. INTRODUCTION

Aluminum alloys are frequently exposed to harsh environments in service. For instance, the skins of aircraft on carriers are exposed to corrosive saltwater spray combined with the fatigue stresses of flight operations. The combined service conditions can be difficult to understand, leading to inaccurate models for service life prediction and economic loss. It is known that several factors including the underlying microstructure, presence of defects and crystallographic orientation of the grains play a dominant role in corrosion related fracture of these alloys. Grain mapping techniques like EBSD are restricted to 2D surface imaging and can only be extended in three dimensions by destructive and laborious serial sectioning of the sample. Laboratory-based diffraction contrast tomography is now possible on a commercially available X-ray microscope [1] enabling a time dependent '4D' study of corrosion in aluminium alloys wherein samples can be imaged in 3D at high resolutions to understand the complex mechanisms of corrosion. The inclusions, precipitates and voids in the bulk aluminium alloy matrix span across length scales of few tens of nanometers to the hundreds of micrometers, directly controlling the mechanical and corrosion resistance properties.[2] In addition to LabDCT, 3D correlative tomography utilizes 3D X-ray microscopy (XRM), a non-destructive sub-micrometer tomographic imaging approach, to guide focused ion beam and scanning electron microscopy (FIB-SEM) to reveal specific targeted sub-surface regions of interest at high resolution also in 3D. This coordinated approach, enabled by the emergence of an integrated, modern workflow environment points to the future of correlation in 3D across modalities and length scales. Here we also discuss the scientific challenges and need for such multi-scale studies and the experimental tools required in making such studies a reality.

2. EXPERIMENTAL METHOD

To investigate the effects of corrosion on peak-aged 7475 aluminum alloy, we imaged a sample before and after corrosion using laboratory based non-destructive X-ray microscopy. In combination with the conventional absorption contrast tomography we collected an additional dataset using Diffraction Contrast Tomography which enabled reconstruction of the three dimensional crystallographic information of the grains. The samples were mechanically polished, then soaked in covered 3.5 wt.% NaCl to initiate pitting corrosion. The combined diffraction contrast tomography and absorption tomography provides comprehensive information of the grains containing orientation, grain volume and morphology, and location of impurity inclusions within the samples

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before and after corrosion, enabling a detailed analysis of damage initiation and propagation. For the 3D correlative imaging we imaged a bulk specimen using X-ray microscopy wherein key region of interest was identified. Data from XRM guided us to choose the region where subsequent high resolution FIB-SEM tomography was performed. The sample navigation, data collection and visualization across multiple length scales was facilitated by a specialized designed software platform that allows seamless communication and data integration.

3. RESULTS

We present a selection of results of LabDCT applied on a peak aged 7475 alloy which revel the internal 3D microstructure. Absorption tomography data clearly shows the distribution of inclusions and voids throughout the sample volume along with LabDCT results showing corresponding grain information. We will also present the results of combining the two datasets which enable determining the influence of grain orientation and the local microstructure on formation of initial corrosion pits. Results from correlative tomography, wherein the distributions of much smaller inclusions, present within grains and on grain boundaries, were imaged and will be presented. Data obtained from the quantitative analysis of the correlative tomography data from will also be shown and discussed.

References

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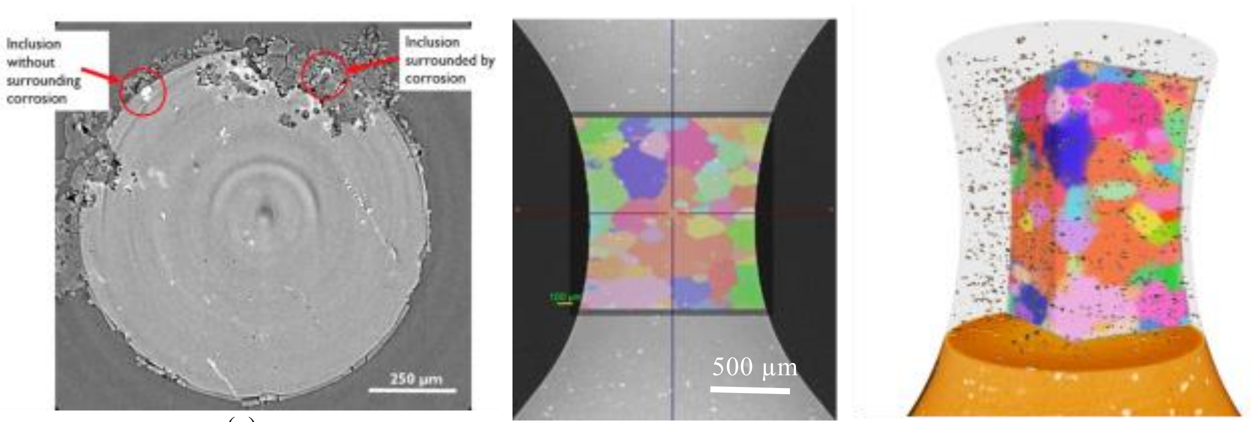

(a) (b)

Figure 1: (a) Reconstructed slice from synchrotron x-ray tomography shows formation of corrosion pits at inclusion sites. (b) 2D reconstructed slices of registered absorption x-ray tomography data (grayscale) and LabDCT grain information (colors) and corresponding 3D visualization showing grains and inclusions in 3D.