Synchrotron microtomography studies of atmospheric corrosion of stainless steel and aluminum alloys

Alison Davenport[1], Andrew Du Plessis[1], Na Mi[1], Liya Guo[1], Steven Street[1], Majid Ghahari[1], Haval Mohammed-Ali[1], Trevor Rayment[1,2], Christina Reinhard[2], Marco Stampanoni[3], and Peter Modregger[3]
[1]University of Birmingham, Birmingham, UK
[2]Diamond Light Source, Didcot, Oxfordshire, UK

Atmospheric corrosion of metals is particularly difficult to study owing to the limited extent of the electrolyte and the penetration of corrosion into the metal under corrosion products. Synchrotron X-ray microtomography is a promising method for in situ characterization of the time-dependent corrosion processes (1-4).

In this study, X-ray microtomography has been used to investigate atmospheric corrosion of the aluminum alloy AA2024 and 304L stainless steel. Salt droplets are deposited at the top of metal rods (1 mm for aluminum and 2 mm for stainless steel), and placed in a plastic tube in which the relative humidity (RH) is maintained at a constant value by filter paper soaked in a saturated salt solution.

Fig. 1 shows the evolution of corrosion of AA2024 under a droplet containing a mixture of NaCl and $MgCl_2$. Fig.1(a) shows the droplet on top of the pin after corrosion at 90% RH for 23 hours. The droplet is already full of corrosion products, and hydrogen bubbles are visible above corrosion fissures (viewed parallel to the rolling direction). Fig.1(b) shows the same sample as (a) rotated by 90° so that the length of the fissures can be seen parallel to the rolling direction. Fig.1(c, d) show the same views as (a, b) following 2 hours at ~30% RH. It is evident that the corrosion products have dried out, and the fissures have grown substantially.

Fig.1(e) shows a vertical section through the tomogram of the sample shown in Fig.1(c). Salt crystals, probably predominantly NaCl, have deposited above the major corrosion fissure. The fissure itself is growing parallel to the sheets of intermetallic inclusions (bright particles) in the alloy.

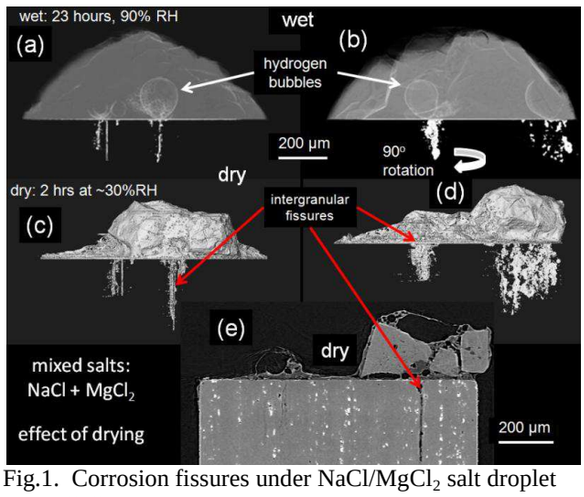

Fig.1. Corrosion fissures under NaCl/$MgCl_2$ salt droplet on AA2024 during drying: (a) end of wet period (b) same view rotated 90°; (c, d) after drying; (e) vertical section. (TOMCAT beamline at the Swiss Light Source)

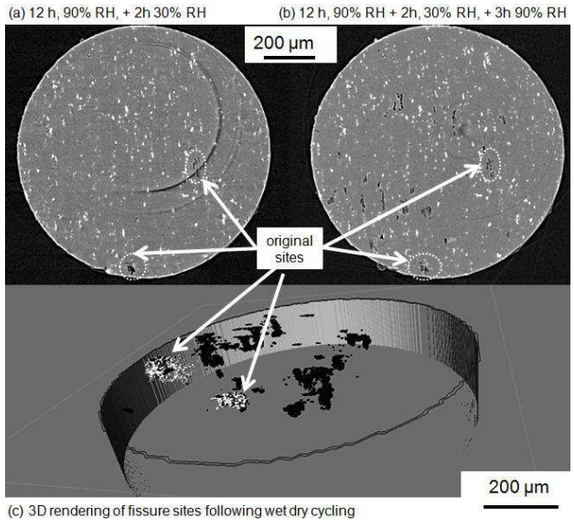

Fig.2. (a) Horizontal section close to the top of a rod of AA2024 after corrosion under a $MgCl_2$ droplet followed by a drying period and (b) after rewetting at 90% RH; (c) segmented view of original corrosion sites (white) and corrosion after rewetting (black). (TOMCAT beamline at the Swiss Light Source)

Fig.2 shows a wet/dry cycling experiment in which two small corrosion sites form under an $MgCl_2$ droplet after 12 h at 90% RH and 2 h at 30% RH (Fig.2(a)), visible as white sites in Fig.2(c). On rewetting to 90% RH for 3 h, multiple new sites have formed (Fig.2(b) and black sites in Fig.2(c)). Comparison of the white and black sites show that the original sites are unchanged and all of the corrosion is taking place in new sites on rewetting.

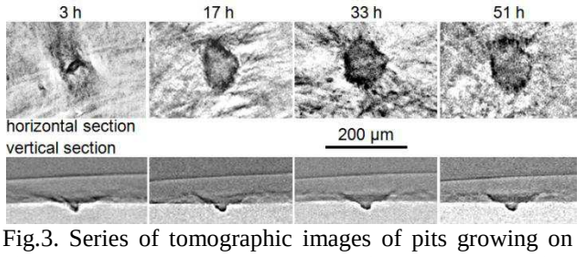

Fig.3. Series of tomographic images of pits growing on 304 stainless steel under a droplet of $MgCl_2$ at 45% RH. (Diamond Light Source Beamline I12).

Fig.3 shows pit growth under a thin layer of $MgCl_2$. It can be seen that the diameter of the pit is gradually increasing whereas there is little increase in pit depth.

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References

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