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Synchrotron tomography study of atmospheric pitting corrosion of stainless steel during wet-dry cycles

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Atmospheric pitting corrosion of stainless steel (SS) can take place when airborne salt particles deposit on the metal surface and form droplets when the relative humidity (RH) reaches a critical value, the deliquescence relative humidity (DRH) of the salt. Studies of pit growth are generally carried out under constant conditions of temperature and humidity, but under natural exposure conditions, these fluctuate, influencing corrosion behavior. In this study, the effect of wet/dry cycling on pitting corrosion of stainless steel under $MgCl_2$ droplets is investigated with in situ X-ray microtomography and optical microscopy.

It has been reported pitting corrosion for SS304 only progresses when the atmospheric exposure RH is below 65%[1]. In other words, a stable pit may stop growing when the exposure RH is high, e.g. 85%. Meanwhile, when the exposure RH is below the DRH of the salt deposited, drying of the droplet may take place, so that pitting can no longer take place. However, when the RH returns to a level where pitting is possible, it is necessary to determine whether the "old" pit will start growing again, or whether new pits may initiate elsewhere on the surface. This is an important factor in determining whether damage accumulates at a single pit during successive cycles, or whether many small pits form.

Work has been done to investigate pitting corrosion under atmospheric wet-dry cyclic exposure by corrosion current and potential monitoring [2-4]. However this only gives information on the total current passed, but does not show the growth of individual pits during the cyclic exposure.

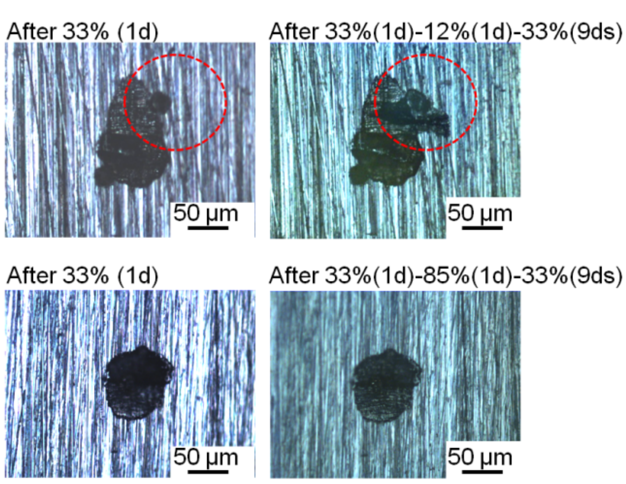

Fig.1. Optical microscope images of the size change of a pit formed on a SS304L plate under a $MgCl_2$ droplet giving a chloride ion deposition density of ~1 mg/cm^2 following fluctuation in the relative humidity as indicated.

Fig.1 shows optical microscopy measurements of pit diameter during an experiment in which a pit is grown under a droplet of $MgCl_2$ solution for one day at 33% RH. The RH is then either decreased to 12% RH (upper images) or increased to 85% RH (lower images), and then returned to 33% RH for 9 days. It is evident that the pit diameter continues to grow for the sample that has had a decreased RH, but the diameter has stopped increasing for the sample that has been exposed to higher humidity.

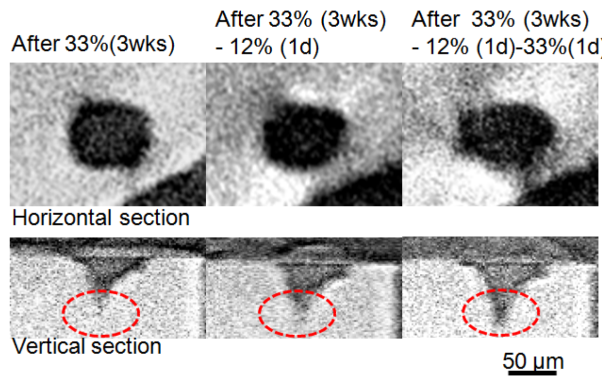

Fig.2. Horizontal section (upper images) and vertical section (lower images) of a pit formed on a 2 mm SS304L pin under a $MgCl_2$ droplet with a chloride ion deposition density of ~1 mg/cm^2 during fluctuation in the relative humidity as indicated. Monitored with in situ X-ray microtomography at Diamond Light Source, Beamline I12.

In-situ X-ray microtomography was carried out to observe the behavior of pits during wet-dry cycling (Fig.2). In the experiment, the RH was first set to 33% for 1 day to grow a stable pit and then changed to 12% for a day followed by a day at 33%. Growth in both the width and depth of the pit was observed during exposure to 33% RH after a day at 12% RH. This indicates that after "drying", corrosion can continue in the same pit once the condition becomes "wet".

Acknowledgements
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