PEER REVIEWED
ASIA-PACIFIC
SOLAR RESEARCH CONFERENCE

Mechanism of Degradation and Interfaces Formation of Stainless Steel Subjected to High Temperature Cycling with Phase Change Salts

Yanting Yin [ab], Raihan Rumman [ab], David Lewis [ab], Gunther Andersson [ab]

[a] *Flinders Institute for Nanoscale Science and Technology, Flinders Microscopy and Microanalysis, Flinders University, Adelaide SA 5042, Australia*

[b] *Funded by Australian Solar Thermal Research Institute*

A comprehensive investigation of degradation upon stainless steel as containment for phase change materials (PCM) is performed in our research. In our work stainless steel 316/347H alloy tokens were immersed in a variation of carbonate/chloride and mixed carbonates based PCM. The set of samples were thermally cycled up to 500 times (in total 1500 hours) at a high temperature between 550 ˚C to 700˚C under air and Argon ambient, respectively. The PCM changed its phase from solid to liquid and inversed during cooling. Upon the thermal cycle, growth of corrosion on the steel was observed.

Scanning electron microscopy with energy-dispersive X-ray analysis were carried out on finely polished cross-sections of the alloys under air cycling. Elemental distribution and line scanning along cross-section showed that due to the high temperature cycles, Ni and Cr from the alloy migrated towards the surface, where Cr oxidised to CrO_x at the surface because of its high chemical potential in presence of O_2. Presence of such CrO_x layer is thought of as a passivation front against further migration of Ni and Fe in the bulk. However, with continuous cycling in PCM, Cr on the coupon surface depleted and eventually dissolved into the liquid PCM. As a result, oxidant from atmosphere penetrated the surface and oxidised the alloys, forming a brittle corroded layer.

A complementary use of X-ray photoemission spectroscopy and X-ray diffraction revealed that the distribution of Fe layer on the surface was highly oxidised and the oxidation state decreased from the outermost layer into bulk but increased with increasing cycles. Furthermore, Cr has been oxidised to Cr_2O_3 across the element migration layer and depletion of Cr_2O_3 from alloy into PCM was found by analysing the PCM. XRD showed that the presence of heavily oxidised Fe_2O_3 in hematite alpha phase increased with increasing thermal cycles, while the intensity of Cr_2O_3 -R3/c phase decreased.

Study of tokens under Ar ambient reveals a different corrosion mechanism, where the decomposition of carbonates was observed. Such decomposition occurs under the ambient lacking oxidant, which produces corrosive NaO. The presence of NaO is likely to be a main reason causing degradation. NaO penetrates the steel token surface, oxidising along the grain boundary and causes delamination of the surface layers.

The research offered a comprehensive understanding about the corrosion mechanism of stainless steel used for PCM containment in CSP.

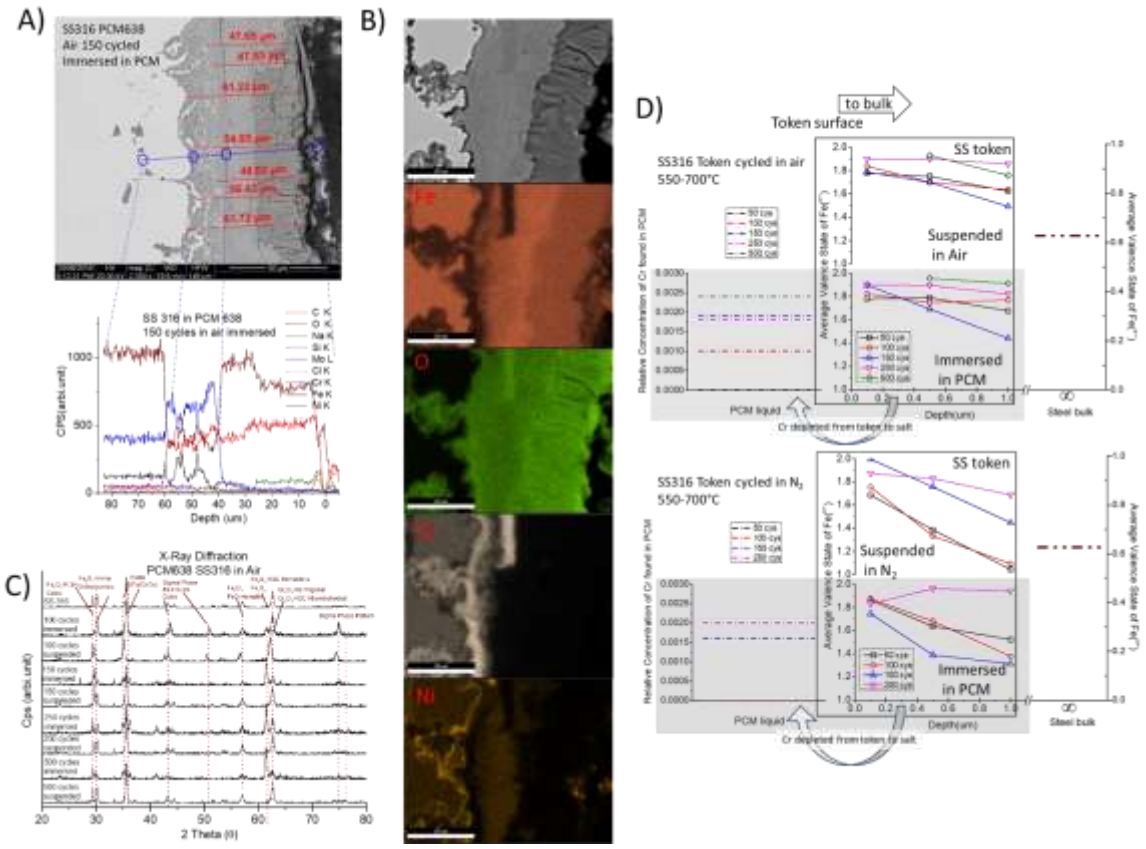

Figure 1. A) Line scan of the interface with SEM; B) Element mapping of the interface with EDAX; C) XRD result revealed the sigma phase brittle structure; D) XPS result shows oxidation of Fe and Cr and the states trend from surface into bulk