Investigation into the Kinetics and Composition of the Protective layer Formed During 'Pseudo Passivation' of Carbon Steel: An In Situ and Ex situ Approach

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The growth of iron carbonate ($FeCO_3$) on the internal walls of carbon steel pipelines used for oil and gas transportation can reduce internal corrosion by blocking active sites on the steel surface and creating a diffusion barrier. Two of the key aspects to consider when predicting pipeline corrosion rates in CO_2 environments are the kinetics of film formation and level of protection afforded by the film under different operating conditions. Solution pH can be considered to be one of the most influential factors with regards to the kinetics, morphology and protection of the $FeCO_3$ film.

In addition to $FeCO_3$, field and laboratory based experiments in recent years have indicated that chukanovite ($Fe_2(OH)_2CO_3$) or magnetite (Fe_3O_4) are corrosion products that can form on steel in CO2-saturated/carbonate rich solutions. Questions on the presence of $Fe_2(OH)_2CO_3$ and Fe_3O_4 still remained unanswered, a pertinent one being what role, if any, these corrosion products play in determining the overall protectiveness of the scales formed.

This paper presents results from a recently developed *in situ* synchrotron radiation-grazing incidence X-ray diffraction (SR-GIXRD) flow cell integrated with electrochemistry for corrosion measurements. The cell was used to follow the nucleation and growth kinetics of corrosion products on X65 carbon steel surfaces in a CO_2-saturated 3.5 wt.% NaCl brine at 80°C over a range of solution pH values (6.3, 6.8 and 7) and flow rates of 0.1, 0.5 and 1 m/s under anodic polarisation through potentiostatic and galvanostatic control methods to accelerate the corrosion kinetics to monitor the composition and growth of corrosion products during pseudo-passivation.

Questions about the mechanism of the formation of the corrosion product layer leading to pseudo-passivation, as well as its morphology and chemical composition, are addressed in this paper. The results show that the composition of the ultra-protective film that formed at the carbon steel interface was believed to be purely $FeCO_3$ and was the dominant phase during every test conducted.