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Advanced complementary methods for characterization of the CO_2-induced corrosion scale formation on steels: Synchrotron X-ray diffraction and X-ray computed tomography

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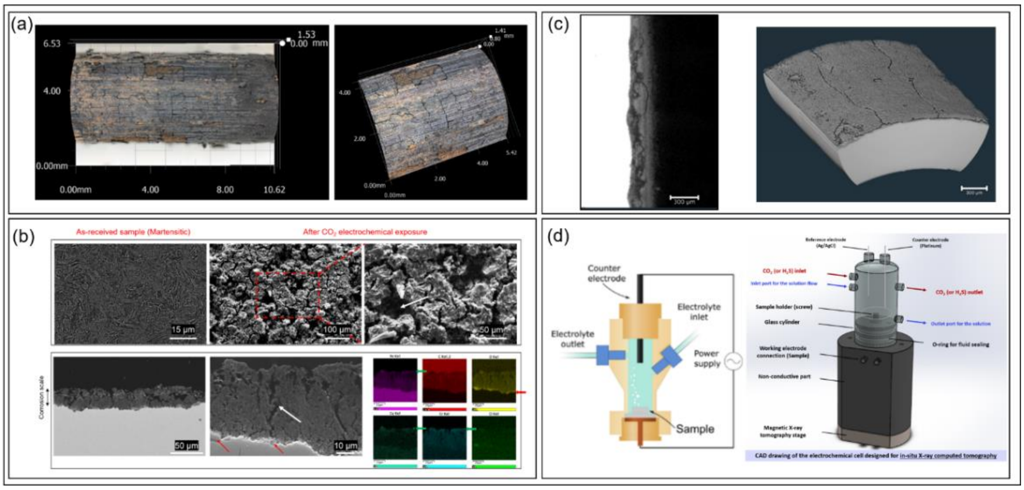
CO_2 corrosion of steels has been a serious issue in the oil and gas industry resulting in high operational costs, safety issues, and loss of material. Moreover, CO_2 corrosion in subsurface non-producing oil wells used for carbon capturing and sequestration might cause serious tubular's failure. This is presently becoming a growing concern since the release of the injected CO_2 and the other contaminations could directly influence the climate change. Therefore, corrosion mitigation is of crucial importance to establish environmentally friendly oil and gas production as well as enhancing the integrity and sustainability of the oil-depleted reservoirs exploited for CO_2 injection and storage.

The complex chemical environment in this industry causes the development of several corrosion products/scales in the surface region of the low-carbon steels as a consequence of electrochemical reactions. Here, it is noted that the dissolution of CO_2 in seawater leads to the formation of carbonic acid, which promotes the kinetics of electrochemical reactions between steel substrates and the aqueous phase resulting in the uniform iron dissolution and ultimately the precipitation of various (crystalline) corrosion products at the surface. Hence, it is both scientifically and technologically important to comprehensively investigate the formation, precipitation, and (potentially) transformation of the corrosion products/scales developed on the surface region of the steel when exposed to CO_2 corrosion using advanced *ex-situ* (post-mortem) and *in-situ* (direct monitoring) characterization methods.

In this work, the results of characterization of the corrosion scale obtained by employing ex-situ high-resolution electron microscopy, depth-resolved grazing incidence synchrotron X-ray diffraction, and X-ray (micro-) tomography applied on the so-called "end-product" are presented. In addition to the ex-situ studies, we aim at developing *in-situ* techniques for an in-depth understanding of the mechanisms responsible for CO_2 corrosion using X-ray computed tomography and synchrotron X-ray diffraction. The current research work also addresses the progress made on in-situ X-ray computed tomography and synchrotron X-ray diffraction combined with electrochemical measurements.



(a) Ex-situ 3D light optical micrograph of the CO_2-electrochemically corroded martensitic low-carbon steel. (b) Electron microscopical characterization of the initial microstructure and the corroded specimen. (c) A volumetric X-ray tomogram of the corroded specimen and one of the cross-sectional orthoslice. (d) The configuration of the flow cell designed for in-situ synchrotron X-ray diffraction and X-ray computed tomography combined with electrochemical measurements.

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