Corrosion Behaviour of Various Steels for Compression, Transport and Injection

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Keywords: Corrosion, steel, condensation, compression, transport, injection

Corrosion behaviours of potential structural materials to be used within the CCS process chain are investigated in the COORAL joint research project (CO_2 Purity for Sequestration and Storage). Herein evaluation of corrosion mechanisms under near-field conditions including composition of the CO_2 stream, temperature, pressure, flow rate is aimed.
A selection of different alloys was assembled according to commercial and scientific reasons. Three low alloyed carbon steels and soft iron were chosen to represent materials that are typically used for pipelines. Alloyed steels were selected for higher temperatures. For the use in compressor wheels, specific high alloyed steels were selected.

Chemical compositions of alloys ranging from soft iron to steels with high chromium and nickel content were analyzed by spark emission spectroscopy and microstructures were characterized with metallographic methods. Ferritic, martensitic, and austenitic crystalline structures, partly heat treated, and various types of inclusions represent a large number of steel characteristics. Reproducible sample pretreatment allowed direct comparison. Samples were exposed to continuous flows of synthetic gas mixture over a period of 600 hours. Low flux of oxygen (up to 1.8%), sulfur dioxide (70 ppm), nitrogen dioxide (100 ppm) and carbon monoxide (750 ppm) were continuously injected into a constant carbon dioxide stream (1.5 L/min per vessel). Water vapor (dew point -28°C) was added by leading a part of the CO_2 through a wash flask containing distilled water. Temperatures of 5°C, 60 and 170°C were implemented by posing reaction vessels into climate chambers.

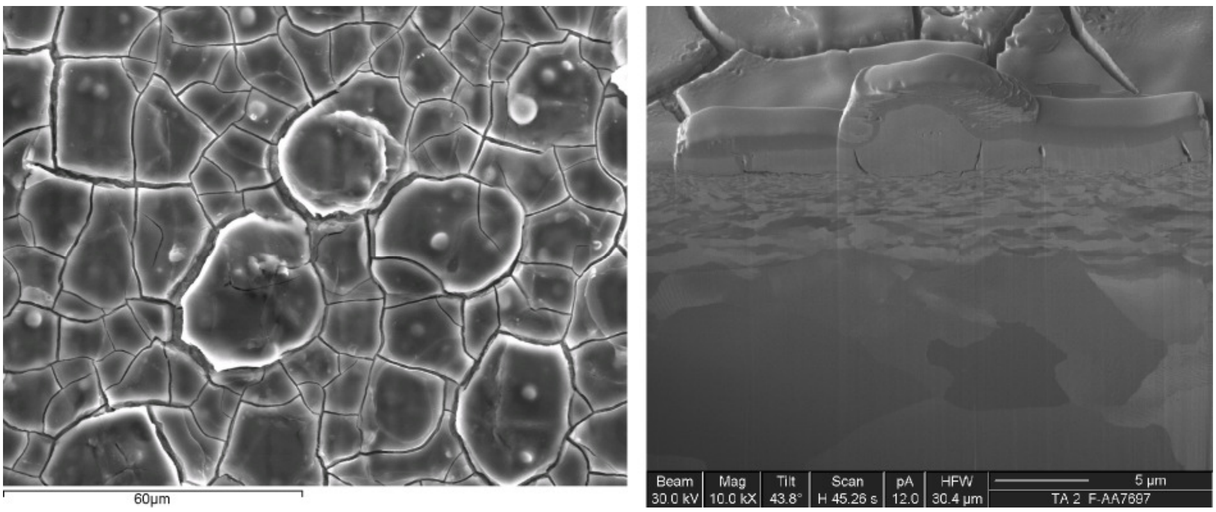

Figure 1: Scanning electron microscopic image (left) of the flawy corrosion layer and cut with focused ion beam through the corrosion layer on a pipeline steel surface after 600 hours exposure at 5°C to a synthetic CCS process gas.

No corrosion was observed on steels exposed to the gas mixture at 60° and 170°C. Annealing colors were found on alloyed chromium steels at 170°C but not on the highest alloyed chromium nickel steel and titanium.

Corrosion products were found on all low alloyed pipeline materials (Figure 1) with minor differences between the steels and purely ferritic soft iron. Measured weight increase was between 12 and 16 mg (approximately 5 g/m^2). Layer thickness was quantified to be approximately 5 to 10 µm.

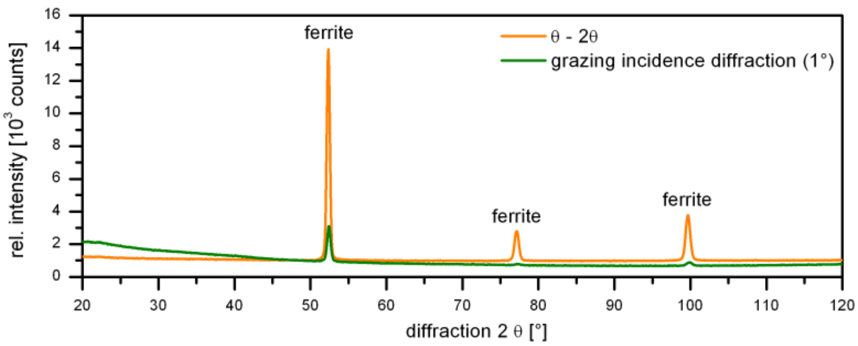

Figure 2: conventional and grazing incidence X-ray diffraction on the corroded sample surface.

X-ray diffraction was applied to analyze the corrosion layer. Crystalline corrosion products were found besides ferrite of the steel sample neither in the conventional (Θ-2Θ) nor in the grazing incidence mode. Both energy dispersive and wavelength dispersive X-ray spectroscopy were conducted to analyse the chemical composition of the X-ray amorphous corrosion layer. Both sulphur and nitrogen originating from sulphur dioxide and nitrogen dioxide were detected in cross section of the layer. Focused ion beam was applied to prepare specimen for transmission electron microscopic (TEM) analyses. Electron diffraction at the corrosion layer confirmed that the layer is amorphous. Therefore it is not possible to conclude about the protectiveness of the layer.

Acknowledgements

This Project is funded by the Federal Ministry of Economics and Technology under contract 0327790C.