Corrosion mechanism of spheroidal graphite cast iron GGG40 in saturated Wyoming bentonite

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The overpack of the Pollux® 10 container, taken as a reference for the storage of fuel elements in different types of host rocks, is manufactured from spheroidal graphite carbon steel (GGG 40 / 0.7040) [1]. The near field environment after emplacement is constituted by bentonite, which turns moisty, warm, and anaerobic after some decades because of the decay of the heat generation and the consumption of oxygen by reaction with the container wall, microbes, and minerals [2]. Thus, the corrosion mechanism of metal containers in these conditions is an essential issue for the design of repository concepts of radioactive waste.

In this work, we followed two experimental approaches. In one of them, samples of GGG40 steel were left in contact with light compacted Wyoming bentonite in equilibrium with artificial pore water at 30°C and 50°C. The corrosion was monitored by polarizations and impedance spectroscopy for a period of 3 months. The surface chemistry and morphological changes were investigated by local XPS, SEM-EDX and TEM. This experiment was complemented with corrosion studies performed in pore water under different temperatures, hydrostatic pressures, pH and, with and without dissolved oxygen.

In these systems, the rate of iron dissolution is controlled by its coupling with the reduction of water. The presence of dissolved oxygen seems to play a secondary role in the dissolution mechanism. The oxidation of the silicon contained in the alloy, however, plays a more fundamental role in the activation of cathodic elements localized in the graphite spheres. The morphology of the surface after the corrosion in near neutral pore water shows the formation of series of precipitated iron silicates containing Al, Mg and Cr (figure 1). The significance of the formation of silicates is evident in the surface analysis of samples after long-term experiments in contact with saturated bentonite. TEM pictures of a cross sectional lamella including part of graphite sphere shows the formation of a silicate film covering the corroding surface with an irregular adherence (figure 2). The accumulation of silicates at the surface creates an additional barrier for the metal dissolution, which may favor a crevice type of corrosion.

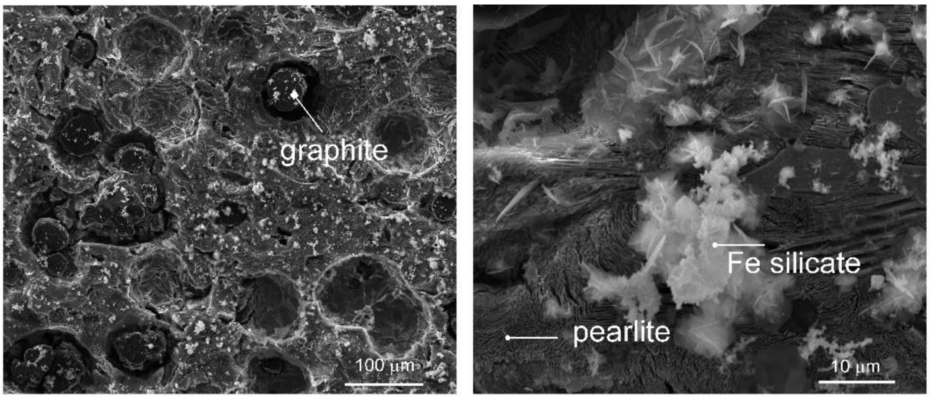

Figure 1: SEM pictures of the surface of GGG40 after corrosion during 48 h in anoxic pore water at 30°C and p: 5 atm.

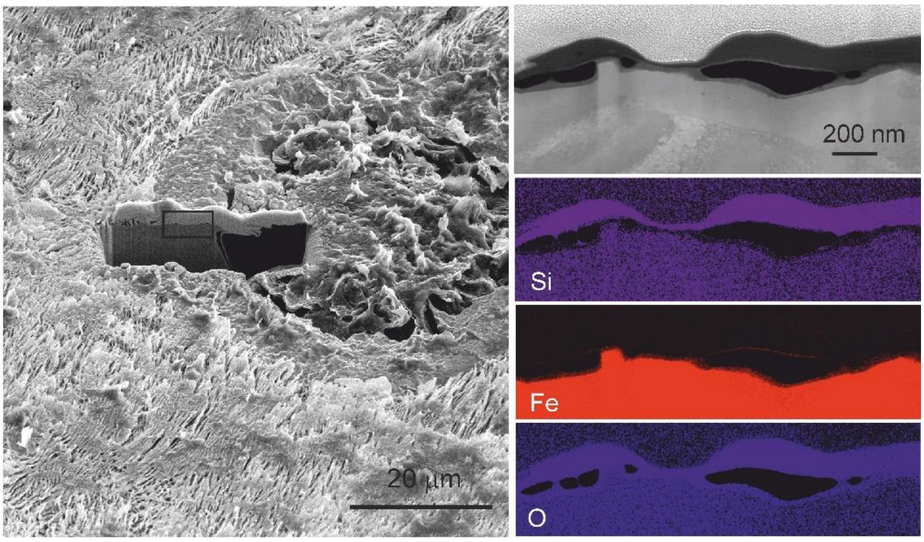

Figure 2: Left: SEM picture showing the surface of GGG40 after 3 months corrosion in contact with saturated Wyoming bentonite at 30°C. Right: STEM-HAADF of a cross section lamella obtained as indicated in the left figure and the corresponding EDX analysis.

[1] T. Hassel, A. Köhler, Ö.S. Kurt, Das ENCON-Behälterkonzept – Generische Behältermodelle zur Einlagerung radioaktiver Reststoffe für den interdisziplinären Optionsvergleich, ENTRIA-Arbeitsbericht-16, Institut für Werkstoffe, Leibniz-Universität Hannover (2019), Hannover, Germany.

[2] F. King, C. Padovani, Corros. Eng. Sci. Technol. 46 (2011), 82-90.