Corrosion study of low carbon steel under simulated geological disposal environments for HLW in China

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In the multi-barrier system of HLW repository, overpack is the first barrier to isolate high-level radioactive nuclides from biosphere, and Low carbon steel has been considered to be a promising candidate material for manufacturing the oberpack due to its good mechanical performance and workability and weldability. However, during thousands of years of geological disposal, the corrosion resistance of low carbon steel and its corrosion evolution behavior are the first element that must be fully understood, because it determines the life cycle of the artificial barrier.

Conventional studies had suggested that the corrosion of low carbon steel under the deep geological environment was driven by hydrogen evolution reaction (HER) based on that the dissolved oxygen was completely depleted during the long term disposal. However, the residual oxygen content is a critical factor to determine the corrosion mode of cathodic reduction reaction. Thermodynamics data indicated that the initial ferrous corrosion products formed in the deaerated bicarbonate solution can be chemically oxidized into ferric substance by the trace content of dissolved oxygen, and the accumulated FeOOH as a cathodic depolarizer significantly increased the open circuit potential and enhanced the corrosion rate of the low carbon steel. Moreover, chloride and sulfate in the simulated groundwater can reduce the increase of open circuit potential but it still promotes the corrosion of the low carbon steel. As the environments contained aggressive anions and high concentration of dissolved oxygen, low carbon steel was prone to suffer from the localized corrosion and the corrosion rate was obviously increased. By alloying with some contents of Ni and Cu, the corrosion rate of low alloy steel was decreased by an order of magnitude and it was less prone to suffer from the localized corrosion.

Under the conditions of simulated groundwater with different content of GMZ bentonite—the bentonite colloidal particle layer attached to the surface of low carbon steel showed blocking effect on resisting oxygen diffusion to the steel substrate, which consequently decrease the further oxidation of ferrous to ferric substances and the corrosion rate of low carbon steel. However, the barrier performance of bentonite colloids would be deteriorated due to their coagulation caused by the ferrous ions dissolved from the steel substrate. High content of bentonite was beneficial to maintain and to prolong the stabilization of the barrier system. An equivalent circuit model which correlates with the interfacial structure between electrode substrate and rust and bentonite layer was proposed. The fitting results showed a very good match between the model and experimental data, and the evolution of the results was also in
agreement with real changes.