4-2 Microscopic Corrosion Behavior in High-Temperature, High-Pressure Environments

— In-Situ Measurement of Electrical Conductivity of Solution in Stainless Steel Crevices —

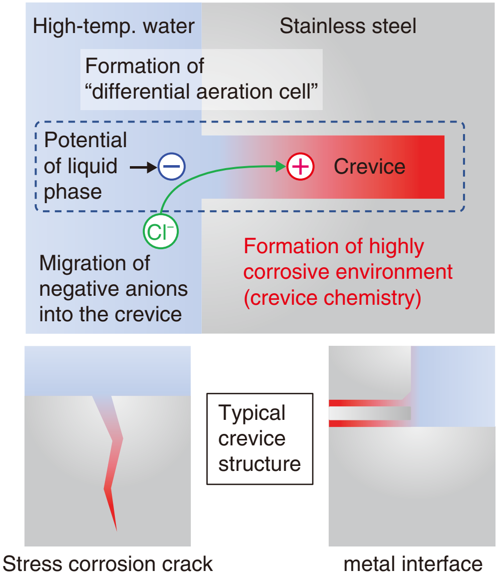

Fig.4-4 Schematic representation of chemical condition within a crevice
A differential aeration cell was formed between the crevice-free surface and the crevice with a limited oxygen supply. This cell acted as driving force to concentrate impurities into the crevice, thus forming a corrosive chemical condition within the crevice (crevice chemistry). Crevice chemistry can be found at the interface of metal (e.g. bolts, nuts, and washers) and inside the stress corrosion crack.

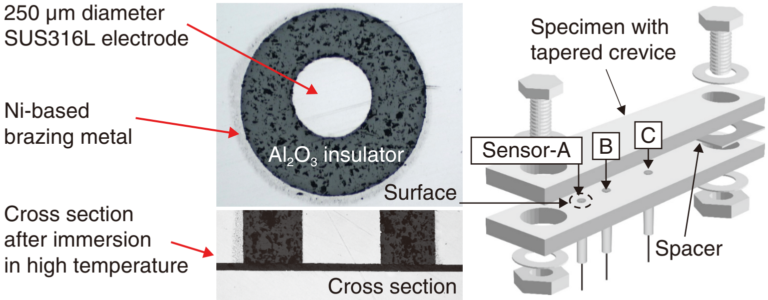

Fig.4-5 Developed sensor systems to measure the crevice chemistry
Small sensors were installed in the crevice to measure the electrical conductivity of the crevice solution. The crevice was tapered to simulate a crack tip of SCC.

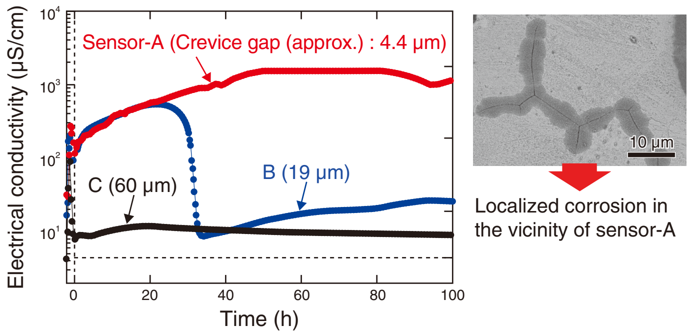

Fig.4-6 Electrical conductivity of the solution within the crevice in 288 °C pure water with dissolved oxygen concentration of 32 ppm
The sensor at the smallest crevice gap detected high electrical conductivity of the crevice solution. Localized corrosion occurred in the vicinity of this position.

Stainless steels are susceptible to stress corrosion cracking (SCC) in high-temperature and high-pressure water represented by boiling water reactor (BWR). SCC of stainless steels have been recognized as a major corrosion related problems of ensuring safety of nuclear power plants. The chemical conditions within a crevice including stress corrosion crack may become more corrosive than those of the bulk coolant (Fig.4-4), and this plays an important role with regard to crack propagation. The chemical conditions within a crevice often referred to as crevice chemistry have been widely studied, however, analysis of the crevice chemistry is still challenging because crevice with micro-meter gap under high temperature and high pressure is experimentally difficult to access.

A sensor system was thus developed to conduct measurement of the crevice chemistry (Fig.4-5). The system is characterized by high durability in the harsh environment, uses small electrodes to allow for measurement in very tight crevices, and in-situ analysis of the chemistry by electrochemical method. The sensors were installed at different positions within a tapering crevice of Type-316L stainless steel and measurement of the local electrical conductivity of the crevice solution beneath the sensor was carried out.

Fig.4-6 shows the time variation of electrical conductivity of the crevice solution at different position in 288 °C and 8 MPa high purity water. The results indicated that smaller crevices led to higher conductivity; sensor-A, with a gap of 4.4 μm had conductivity values over 100 times greater than those at sensor-C, with a gap of 59.3 μm, and sensor-B with an intermediate gap detected high conductivity comparable to sensor-A up to 20 h, but thereafter, it dropped rapidly. Localized corrosion occurred in the vicinity of the sensor-A. Thermodynamic consideration indicated that the high conductivity values corresponds to the acidification of the solution. Thus, corrosive environments were formed in crevice with small gaps and caused the localized corrosion.

Reference
Soma, Y. et al., In-Situ Measurement of Electrical Conductivity of Solution within Crevice of Stainless Steel in High Temperature and High Purity Water, Zairyo-to-Kankyo, vol.67, no.9, 2018, p.381–385 (in Japanese).