4–4 Development of a New Corrosion Inhibition Method Using Chelation Technique

— Crevice Corrosion Suppression by EDTA-Based Metal-Ion Introduction —

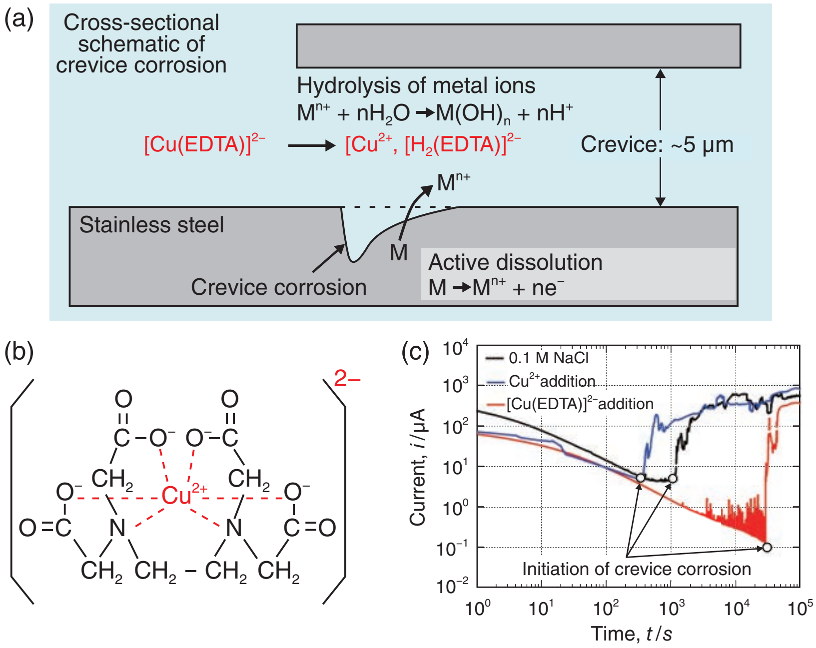

Fig.1 (a) Cross-sectional schematic of crevice corrosion, (b) structural formula of $[Cu(EDTA)]^{2-}$, and (c) inhibition effect of crevice corrosion by $[Cu(EDTA)]^{2-}$
During the incubation and propagation periods of crevice corrosion, the hydrolysis of dissolved metal ions from stainless steel generates H^+, which reduces the pH inside the crevice. The pH reduction causes anion migration into the crevice to maintain electrical neutrality. The addition of corrosion-inhibiting anions outside the crevice is known to be effective in reducing crevice corrosion[*1–2]. Cu^{2+} cation forms a chelate complex with ethylenediaminetetraacetic acid (EDTA) and exists as the $[Cu(EDTA)]^{2-}$ anion in a neutral solution. The addition of $[Cu(EDTA)]^{2-}$ to NaCl solution suppresses crevice corrosion of Type 316L stainless steel. $[Cu(EDTA)]^{2-}$ is an anion that migrates into the crevice and separates into Cu^{2+} and $[H_2(EDTA)]^{2-}$ in the low-pH environment inside the crevice, thereby inhibiting crevice corrosion.

One method to inhibit the corrosion of stainless steel is to add metals that improve corrosion resistance. copper(Cu)-containing stainless steels are attracting attention because of their relatively low cost and high ability to inhibit corrosion growth. However, the addition of Cu is known to increase the risk of corrosion initiation, and a solution to this problem is desirable. In this study, we aimed to demonstrate the corrosion inhibition effect of Cu without increasing the risk of corrosion initiation by adding Cu as a corrosion inhibitor to the solution. As shown in Fig.1(a), migration of ions into the crevice is dominated by the migration of anions to maintain electrical neutrality, and hence, the introduction of cations such as Cu^{2+} is difficult. Therefore, we focused on the chelating technique to introduce Cu^{2+} into the crevice by using $[Cu(EDTA)]^{2-}$ (Fig.1(b)), a chelate complex of Cu^{2+} and EDTA that decomposes in low-pH environments. Thus, we established a new inhibition method for crevice corrosion.

Fig.1(c) shows the results of crevice corrosion tests performed on specimens made of Type 316L stainless steel in 0.1 M (mol L^{-1}) NaCl with 10 mM $[Cu(EDTA)]^{2-}$. Compared with the case of NaCl and with added Cu^{2+}, the rise in current due to crevice corrosion initiation was delayed when using our proposed method, indicating that crevice corrosion was suppressed. This result indicates that the Cu^{2+} added to the solution did not migrate into the crevice, and only $[Cu(EDTA)]^{2-}$ migrated into the crevice, thereby suppressing the initiation of crevice corrosion. In addition, the $[Cu(EDTA)]^{2-}$ that migrates into the crevice reacts with H^+ generated in the crevice when Cu^{2+} separates. This reaction is expected to reduce the pH inside the crevice because of the consumption of H^+ by $[Cu(EDTA)]^{2-}$ and also to suppress crevice corrosion because of the inhibiting effect of the separated Cu^{2+}.

This research has shown that the chelating method can be used to introduce metal ions with corrosion-inhibiting effects into the crevices. In the future, we will explore various combinations of metal ions and chelating agents to develop more effective corrosion inhibitors against crevice corrosion.

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[*1] Aoyama, T. et al., *In Situ* Monitoring of Crevice Corrosion Morphology of Type 316L Stainless Steel and Repassivation Behavior Induced by Sulfate Ions, Corrosion Science, vol.127, 2017, p.131–140.

[*2] Aoyama, T. et al., NH_4^+ Generation: The Role of NO_3^- in the Crevice Corrosion Repassivation of Type 316L Stainless Steel, Journal of the Electrochemical Society, vol.166, no.10, 2019, p.C250–C260.

Reference

Aoyama, T. et al., Introduction of Cu^{2+} to the Inside of the Crevice by Chelation and Its Effect on Crevice Corrosion of Type 316L Stainless Steel, Corrosion Science, vol.210, part 2, 2023, 110850, 10p.