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NUMERICAL MULTIPHYSICS SIMULATION FOR LOCALIZED GALVANIC CORROSION PROBLEMS

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The multi-material design of vehicles is recently in progress in order to reduce the weight. However, the multi-material structure consisting of metals, carbon composites, etc. brings localized galvanic corrosion especially around the undercarriage of the vehicle, which shortens its life. The localized galvanic corrosion of vehicles has been evaluated by experiments so far. The way of evaluation, however, costs high because the localized corrosion is a complex multiphysics problem. Accordingly, the development of numerical evaluation of localized corrosion is expected to be an effective approach to this issue.

In the numerical simulation of localized galvanic corrosion, the multiphysics problem including electromigration, mass diffusion, chemical reactions, and moving boundaries should be taken into account [1, 2]. Additionally, the conservation of mass and electroneutrality must be simultaneously satisfied in the analysis. We have developed a numerical method considering all of these elements for time-dependent localized corrosion of uniform materials [3]. In this study, an upgraded numerical method for localized galvanic corrosion problems with multiple materials based on our previous work is proposed.

Our method adopts the voxel-based finite volume method. The electrochemical calculation including electrostatic analysis and mass transport analysis is performed using finite volume method; the chemical reactions are calculated at each voxel independently; and the moving boundaries are represented using the volume of fluid (VOF) of the voxels.

Figure 1 shows the outline of the validation test consisting of an aluminium anode (Al), glassy carbon cathode (GC), and sodium chloride solution. H_2O, H^+, OH^-, Na^+, Cl^-, Al^{3+}, $Al(OH)^{2+}$, $Al(OH)_2^+$, $Al(OH)_3$, $Al(OH)_4^-$, and O_2 are considered as the chemical species. The hydrolyses of aluminium [4] and dissociation of water are also considered as the fast chemical reactions. The distribution of pH and $Al(OH)_3$ after 72 hours of testing are shown in Fig. 2. The numerical results are in good agreement with the experimental results; thus, the effectiveness of the proposed method is validated.

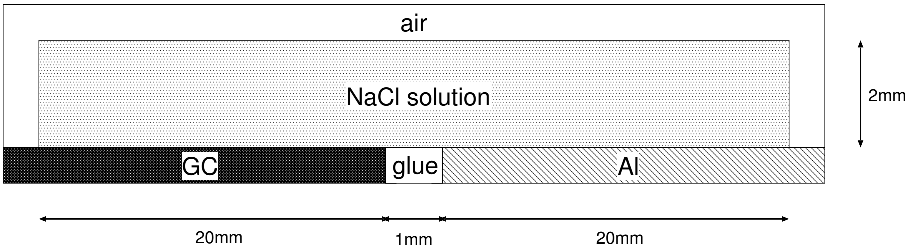
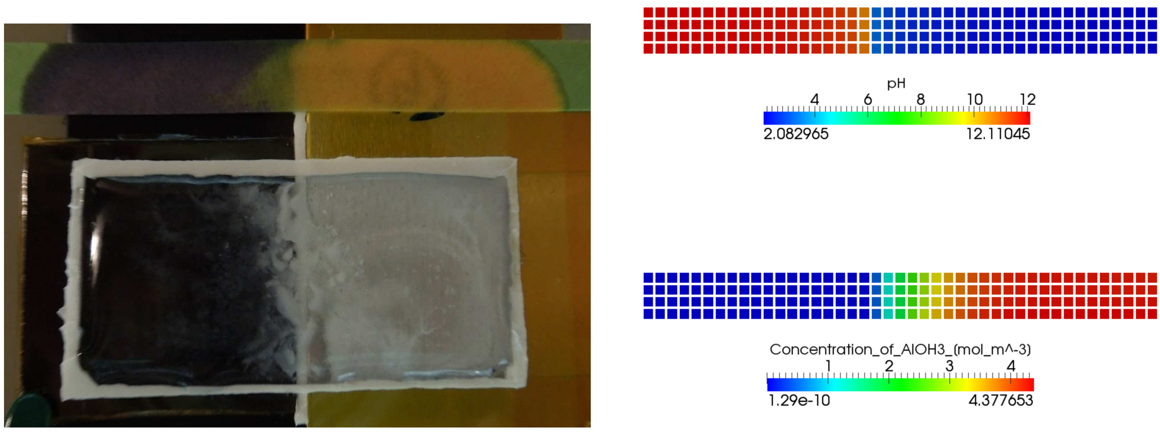


Figure 1: Outline of the validation test. The cathodic reaction occurs on the GC surface, whereas the anodic reaction occurs on the Al surface, which leads to localized galvanic corrosion.



(a) (b)

Figure 2: Comparison of the distribution of pH and $Al(OH)_3$ after 72 hours of testing between experiment(a) and numerical simulation(b). The pH indicator paper shows the step-function-like pH distribution between pH 2 $\sim$ 12 approximately. The white turbidity shows the $Al(OH)_3$ distribution: weak turbidity on GC and strong turbidity on Al.

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