



Response to the Comment on “Corrosion of Copper by Water” [*Electrochem. Solid-State Lett.*, 10, C63, (2007)]

P. Szakálos,^{a,z} G. Hultquist,^b and G. Wikmark^c

^aSzakalos Material Science AB, SE-11240 Stockholm, Sweden

^bRoyal Institute of Technology, SE-10044 Stockholm, Sweden

^cAdvanced Nuclear Technology, SE-751 83, Uppsala, Sweden

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We disagree with the comments by L.-G. Johansson, where he suggests an alternative interpretation of our observations. His interpretation is based on hydrogen evolution due to thickening of a 316L-stainless steel passive film exposed to humidity around 70°C. This interpretation must be ruled out due to the following:

The author of the comments discards the ion pump experiment where a continuously increasing hydrogen evolution from copper corrosion is recorded for 7100 h, see Fig. 2. In this copper exposure there are no stainless steel surfaces present in the experimental set-up.

The author claims that the residual O₂ in the system is much higher than we have considered and suggests that we have not taken into account O₂ dissolved in the water. This is not an accurate claim. The amount of dissolved O₂ in 0.09 dm³ H₂O(l), in equilibrium with 12.5 mbar O₂, is, according to Henry's law, 0.04 mg at 22°C. This value should be compared with 0.8 ± 0.1 mg and is obviously insignificant. We are not sure what L.-G. Johansson means with his estimate: leaving on the order of 40 mbar of air in the chamber. The chamber was evacuated for approximately 3 s which caused an immediate boiling of the water. This resulted in evacuation of virtually all air above the water and the remaining 28 mbar gas consisted only of water vapor. A new equilibrium was then reached between dissolved gases in the water and the gas phase above the water, according to Henry's law as discussed above. One should also bear in mind that a complete conversion of an oxide into a hydroxide can at the most result in a weight increase by 6.2%. Finally, our calculation of weight gain of copper is still conservative since we have omitted a weight loss due to copper in solution.

If another source for hydrogen evolution than corrosion of copper is assumed, for instance thickening of the passive film of stainless steel 316L, a reduction of the solid copper corrosion products is expected from the classical potential-pH diagram. However, such a reduction was not observed. Furthermore, from Figure 3 it is con-

cluded that the activation energy for the hydrogen evolving reaction is very high in the temperature range studied. We hence consider the speculative idea of hydrogen evolution due to a passive film growth on stainless steel in such a low temperature-range lacking support in the observations.

Based on the points above, we find no support for the proposed alternative interpretation by introducing the idea of hydrogen evolution due to a passive film growth on stainless steel 316L. The only reasonable explanation that fits all of our published results is anoxic copper corrosion under hydrogen evolution. And consequently, the potential-pH diagram for anoxic copper corrosion in neutral water should be revised.

In addition, the theoretical calculation related to hydrogen evolution from a passive film growth on the stainless steel equipment in the order of 2–3 nm by the author of the comment, is incomplete. The amount of hydrogen in the gas phase represents only a fraction of the total amount of hydrogen. Although not reported in the original publication, the copper samples contained about 1 wppm hydrogen before the exposure and higher amount after the exposure. At the end of this particular experiment there was about one order of magnitude more hydrogen in the copper metal than in the gas phase. This amount of hydrogen would require a stainless steel passive film growth which would result in discoloring of the stainless steel equipment. This was not observed. Hence, the total amount of hydrogen after exposure corresponds well with the estimated weight gain of the copper samples due to corrosion of copper by water but not with the proposed stainless steel reaction even in the experiments with such materials present.

To conclude, all observations comply with our proposed explanation but not with the proposed alternative idea of hydrogen evolution due to a passive film growth on stainless steel 316L suggested by the author of the comment.