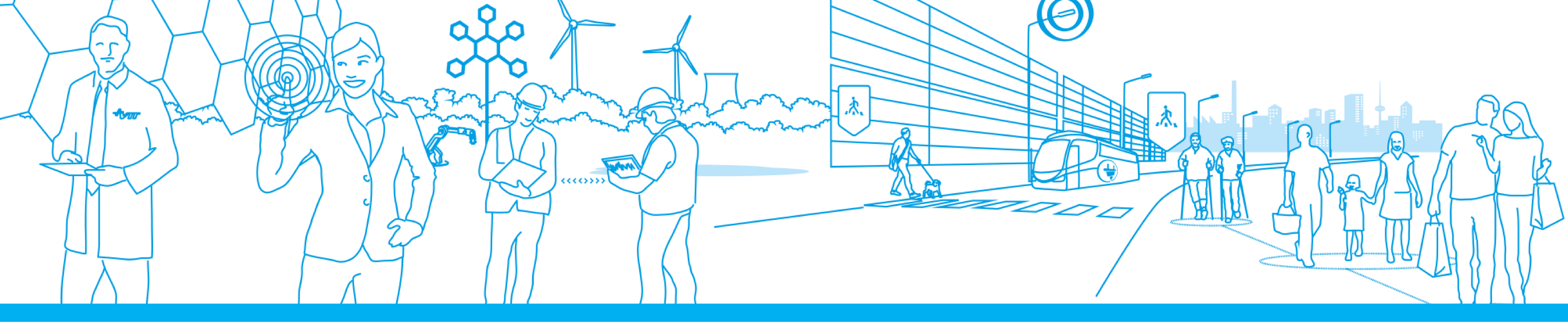

TECHNOLOGY FOR BUSINESS

Water chemistry and plant operating reliability (WAPA)

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Introduction

Corrosion products released from components of nuclear power plant and deposited on other surfaces can cause several corrosion phenomena and increase activity build-up levels if they deposit onto fuel rods, become activated and then are released again.

In order to minimize the amount of released corrosion products for primary side of new plants, the first passivation treatment during the Hot Functional Test (HFT) period is crucial. The quality of passivation is affected by the chemistry used, e.g. LiOH / KOH, H_2, boric acid and zinc. At the moment, there is no consensus on the optimal chemistry to be used.

Corrosion products (e.g. magnetite formed in corrosion of the feed water line components) cause problems also in the secondary side of a nuclear power plant. Magnetite deposition on steam generator surfaces is known to cause corrosion and heat transfer problems. Surface charge (zeta potential) of the magnetite particles possibly controls the deposition process (Fig. 2). Advanced water chemistry, e.g. the use of different combinations of amines, can affect the surface charge of magnetite particles and thereby also the deposition rate.

Optimization of water chemistry for Alloy 690 passivation

The purpose of these experiments was to determine the optimal concentration of lithium and the possible beneficial effect of boric acid to be used in passivation of PWR primary circuit before loading in the first fuel. In these experiments, Alloy 690 tubes were exposed for 100 hours to several different water chemistries (0.5-2.0 wppm Li as LiOH, 0-1200 wppm B as H_3BO_3, 1.3 mmol/l dissolved H_2) and changes in the oxide layer on the surface was measured using electrochemical impedance spectroscopy (EIS). Mixed Conduction Model was used to quantitatively interpret the data.

Based on both experimental and calculation results, it is clear that increasing LiOH concentration in the simulated HFT water leads higher dissolution rates, higher metal oxidation and higher transport rates through the oxide. H_3BO_3 was found to have a beneficial effect that counter-acts the corrosion accelerating influence of Li. Best corrosion resistance was shown to be achieved with low to intermediate Li contents (0.5-1.0 ppm) and with boron addition.

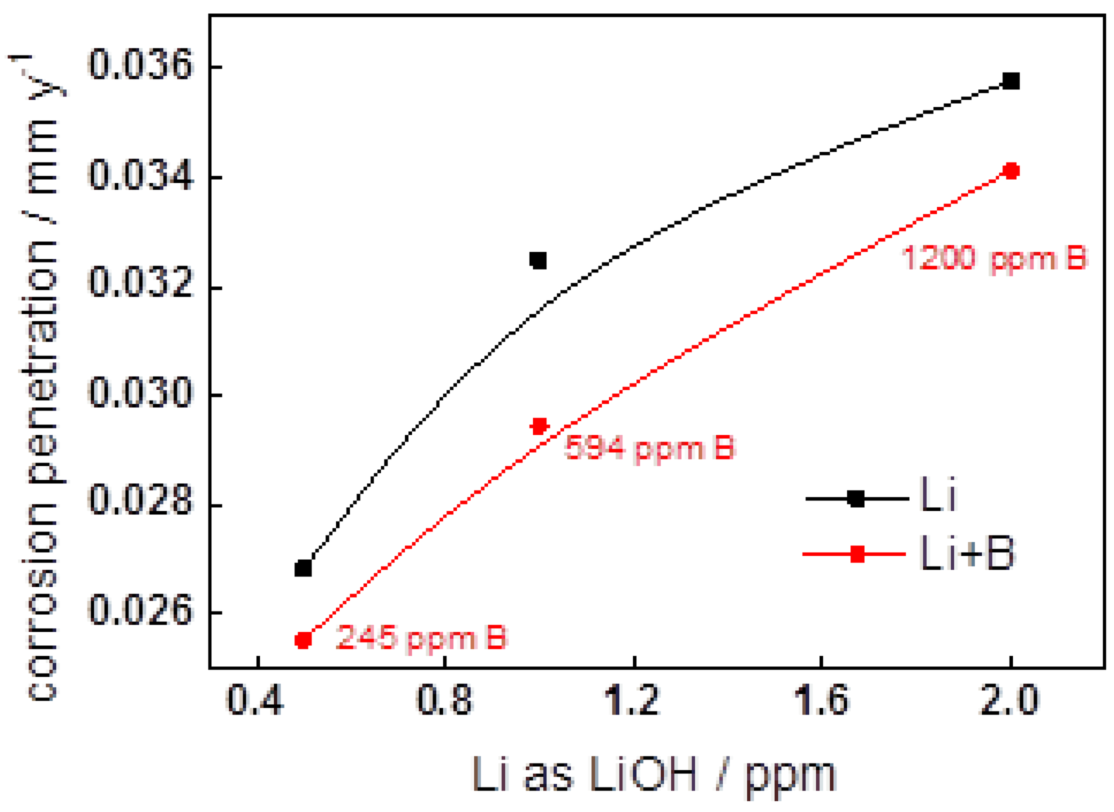

Figure 1. Corrosion penetration estimated from the oxidation rate constant k1 as depending on the water chemistry conditions during HFT. Alloy 690, T = 292°C, exposure time 100 hrs, 1.3 mmol/l H_2 (= 30 cc/kgH_2O).

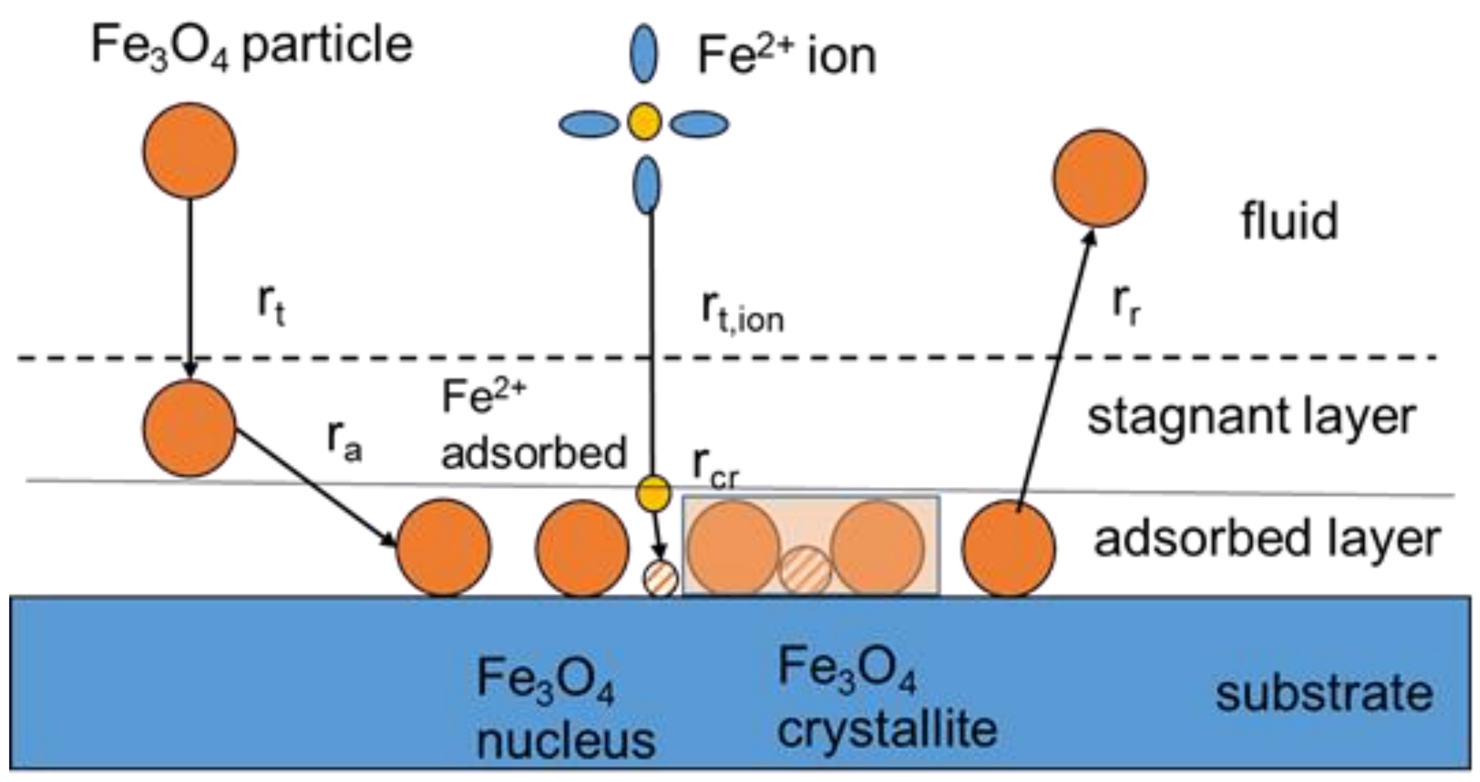

Figure 2. Scheme of the magnetite deposition process according to the proposed model.

Magnetite deposition

In these experiments the effect of alternative water chemistries on deposition of magnetite particles onto steam generator surfaces was studied and also the basis of a deterministic model for magnetite deposition was created. A sensitivity study of the model showed that the two most important parameters affecting the deposition are the Hamaker constant and the zeta potential of magnetite.

Zeta potential of magnetite particles in different secondary side water chemistries at high temperatures was measured using a new experimental arrangement based on streaming potential measurements. The chemistries studied were ammonia, ethanolamine and morpholine solutions. The magnitude of zeta potential decreased as a function of temperature in all cases and approached zero at T=250°C. This could indicate that other forces than surface charge, e.g. thermohydraulic phenomena, dominate the deposition of magnetite particles at high temperatures.

Conclusions

•In situ electrochemical tools, combined with application of the Mixed Conduction Model (MCM) for high temperature oxide films provide a reliable methodology to estimate the effect of chemical variables on the corrosion resistance of major NPP components

•The optimal concentration of Li for prepassivation of PWR primary circuit with Alloy 690 steam generator tubing is 0.5-1.0 ppm. Addition of boric acid is beneficial irrespective of the Li concentration applied.

•The model for magnetite deposition shows promising capability in predicting the effect of different variables affecting deposition.

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