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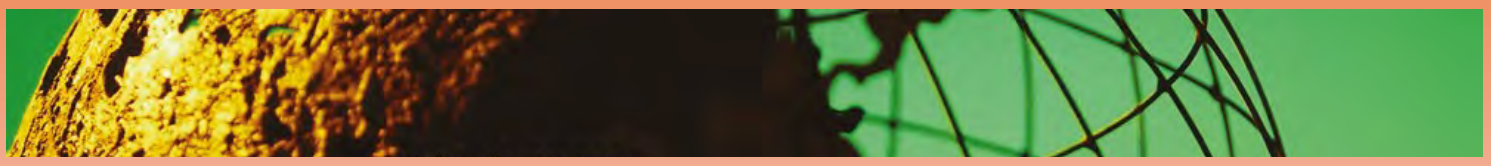
WP4 Nuclear Corrosion



Is copper a safe canister material for long-term storage of nuclear waste?

SIMS- and TEM-based high-resolution studies of internal corrosion of copper exposed to synthetic groundwater

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Thursday, April 25, 2024, 14:00 to 15:30 CEST (UTC+2), online, registration:

https://dechema.zoom.us/webinar/register/WN_aIBSR_12TOyhGxOCgbLn4A

According to the nuclear waste disposal strategy in Sweden and Finland, copper is identified as the candidate material for constructing canisters during the long-term storage of nuclear waste. An essential aspect requiring thorough investigation involves the potential direct interaction of ground water with the copper canister. The groundwater, hosting corrosive species such as Cl^-- and SO_4^{2-}-ions, along with HS^--ions originating from microbiological activity in close proximity to the canister, adds complexity to the scenario.

Several years ago, a study was initiated wherein copper was subjected to simulated groundwater conditions at both room temperature and 60 °C. The penetration of corrosive species, encompassing S, O and Cl was examined using Time-of-flight secondary ion mass spectrometry (ToF-SIMS). The findings unequivocally demonstrated the significant penetration of corrosive species into the microstructure of copper [1]. This penetration primarily occurs locally along specific fast pathways, most likely grain boundaries. Notably, after a four months exposure at 60 °C, S penetrated approximately 500 nm along these pathways.

To provide further evidence of the potential penetration of corrosive species along grain boundaries of copper, ongoing supplementary investigations are being conducted. Copper samples, exposed to synthetic groundwater, have been prepared through FIB-cutting and subjected to Nano-SIMS analysis. This method offers a higher lateral resolution compared to ToF-SIMS, enabling more detailed chemical information. Additionally, Transmission electron microscopy (TEM), is employed to unveil the microstructure of grain boundaries with both Nano-SIMS and TEM providing lateral resolution at the nm scale.

In all, these efforts aim to unravel the mechanisms underlying the penetration of corrosive species containing S, O, Cl and H into copper, which turns out to be much faster at 60 °C than at room temperature. O is observed along the grain boundaries while S and H exists within confined areas of the copper matrix. The study seeks to elucidate potential implications on internal corrosion processes, including S-induced stress corrosion cracking and H-induced embrittlement of the copper canister. The ensuing discussion will delve into ramifications for considering copper as a canister material for the long-term storage of nuclear waste.

[1] X. Yue et al, Corrosion Science, 210 (2023) 110833

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