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Publication date:
2022

Document Version
Peer reviewed version

Epoxy Novolac Coating Interactions at High Pressure High Temperature Conditions

Narayanan Rajagopalan, Claus E. Weinell, Kim Dam-Johansen, Søren Kiil*
CoaST, Chemical Engineering Department, Technical University of Denmark (DTU), Denmark.
*: Corresponding author – email address: sk@kt.dtu.dk

Abstract:
Despite the progress in the usage of renewable resources, the oil and gas industries rely increasingly on wells and reservoirs operating at high pressure and high temperature (HPHT) conditions [1]. Under such conditions, and in the presence of hydrocarbons, seawater, and CO_2, the substrate (steel) corrosion rate increases, along with the risk of mechanical failures. To avoid material degradation at HPHT, process equipment, transportation pipelines, and underground storage tanks are normally coated internally with high performance, epoxy-based coating systems. Owing to the complex and multi-phase situation at HPHT, substrate corrosion and coating degradation cannot, at present, be prevented, and the underlying degradation mechanisms remain more or less unknown.
Using an exclusive three-phase batch reactor that simulate the HPHT conditions [2], this investigation studies the influence of carbon dioxide (CO_2), present in the gas phase at conditions of HPHT, on the degradation and surface interactions of an amine-cured epoxy novolac (EN) coating. In addition, how the hydrocarbon associated surface softening (glass transition temperature depression) allowed the dissolved CO_2 gas to diffuse into the EN network is explained. In what way the synergistic action of CO_2, para-xylene, and seawater resulted in an increased chain motion of the EN network, subsequently allowing CO_2 and seawater ions to diffuse the EN crosslinking to the steel substrate, imposing underfilm corrosion (Figure 1b) is mapped and discussed. Lastly, the rapid gas decompression (RGD), i.e. the depressurization to ambient conditions, and its influence on the deposition of underfilm corrosion products on the coating surface (Figure 1a) is described.
The findings, additionally, have the potential to provide a muchneeded supercritical CO_2-resistant epoxy-based candidate to protect transport pipelines for the next-generation carbon capture and storage (CCS) domains.

Keywords: corrosion, glass transition temperature, crosslinking, seawater, hydrocarbons, oil and gas, pipelines, batch reactor.

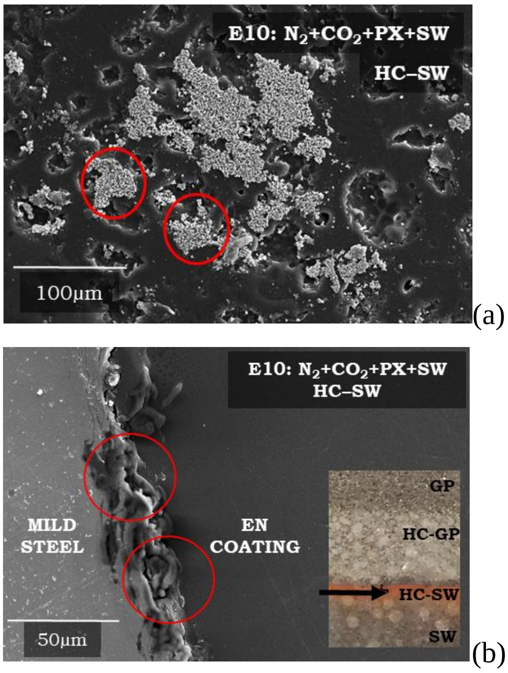

Figure 1: (a) Scanning electron microscopy (SEM) image showing corrosion products (later confirmed as oxides of iron by elemental mapping) deposited on the coating surface (marked with red circles) when exposed to HPHT conditions, and (b) the cross sectional SEM image of the exposed panel displaying corrosion products at the coating-steel interface (marked by red circles). The inset picture shows the area of SEM scan (marked by the black arrow). After [3].

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