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Barrier properties of an epoxy novolac resin system under conditions of high pressure and high temperature: Influence of inorganic fillers and its morphology

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The present study explores the barrier properties of amine-cured epoxy novolac (EN) resin systems under high pressure high temperature (HPHT) conditions, defined by the US code of Federal Regulations [1,2], as a pressure rating greater than 100 bars and/or a temperature greater than 170 ^{o}C. The aim has been to investigate the effects of different inorganic fillers (i.e. concentration, and morphology) on the performance behaviour of EN systems before and after HPHT exposure. Due to high consumptions and fast depleting resources, the increase in demand for energy is pushing the oil and gas industry to explore and produce in geological formations that show abnormally high pressures and high temperatures (HPHT). Corrosion under HPHT is predominant and all applications in the HPHT zones are under severe attack from the extremely corrosive environment. Conditions of high pressures and temperatures in the presence of hydrocarbons, seawater and carbon dioxide gas can increase corrosion rates with unexpected degradation pathways [2].
Owing to the extremes, process equipment, wells, tanks, and pipelines in the HPHT zones are often lined with highly cross-linked epoxy coatings for substrate durability and corrosion protection. The morphology and structure of fillers can impact the barrier properties of such coating systems and here we studied the effects of aluminium-silicates with flake structure, hollow-spheres with spherical structure and meta-silicates with acicular structure. HPHT conditions of the oil and gas industry were simulated encompassing three phases in a chamber namely; a gas phase that includes a mixture of nitrogen (N_2) and carbon dioxide (CO_2), para-xylene (PX) as the hydrocarbon phase and 3.5% NaCl solution as the seawater phase at high pressures and high temperatures. EN systems incorporated with different fillers were analysed before and after HPHT exposure. Characterization techniques viz. Scanning electron microscopy (SEM), Energy Dispersive X-Ray (EDX), Fourier Transform Infrared Radiation (FTIR) and Differential Scanning Calorimetry (DSC) were used to understand the structure relation properties of the fillers with respect to its corrosion resistance. Using SEM, the changes in surface topography and cross-section images were mapped and showed the dispersion state of fillers and its condition after HPHT exposure. EDX showed the elemental composition at all areas and cross sectional line mapping analysed the depth of penetration of HPHT components in to the coating system. FTIR analysed the chemical changes in the resin crosslinking before and after HPHT exposures. Lastly, DSC allowed understanding the change in glass transition temperature, supporting the changes in corrosion resistance and the overall coating system. The results demonstrate the characteristic barrier properties of each of the fillers with respect to degradation pathways under HPHT conditions. It was concluded that each HPHT phase interacts differently with the crosslinked network and owing to the filler morphology, the coating system provides different torturous paths and thermal stability minimizing the interaction of corrosive HPHT components.

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