Investigation of filiform corrosion on coated carbon steel by Scanning Kelvin Probe Force Microscopy

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Filiform corrosion is usually encountered on steel, aluminum, and magnesium underneath organic or metallic coatings in a humid air environment. Corrosion initiates in the presence of soluble ionic species at defects in the coatings and propagates at the metal/coating interface as worm-like filaments. The growth pattern, behavior, physical dimension and velocity of filaments have been reviewed in detail [1-3]. The average width of filaments is only 0.05 mm to 0.3 mm for steel and 0.5 to 3 mm for aluminum but they can reach considerable length and compose intricate patterns [1]. A mechanism based on a differential aeration cell or oxygen concentration cell proposed by Kaesche [4] is the most satisfactory in explaining the reported characteristics of filiform corrosion. In this mechanism oxygen diffuses through the tail and leads to the separation of anodic and cathodic reaction zones. The primary cathodic region is near the back of the head (at the head/tail boundary) where oxygen is supplied and the primary anodic region is at the front edge of the head of the filament.

Although there is experimental support for this mechanism, there are still uncertainties on the exact location or shape of the cathodic and anodic sites. A more descriptive microscopic picture of local reaction sites in the head or near the head has not been presented yet. The mechanistic study of filiform corrosion by conventional electrochemical techniques is difficult because of the relatively small width of the filaments and the presence of the coating. For instance, the high resistance of organic coatings is the principle obstacle to the use of electrochemical impedance spectroscopy (EIS). EIS also fails to identify the corrosion concentration cells.

SKPFM was used to spatially map variations in Volta Potential on the surface of coated plain carbon steel undergoing filiform corrosion. Different segments of filaments about 100 µm wide were investigated under epoxy coatings with a thickness of approximately 300 nm at 93% RH. Potential profiles showed regions of lower potential in the head consistent with anodic dissolution of steel while tails exhibited higher Volta potentials. Volta potential maps of regions less than 100 µm x 100 µm and topographic features will be presented.