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Characterization and corrosion behavior of electroless Ni–P/nano-SiC coating inside the CO_2 containing media in the presence of acetic acid

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ABSTRACT

In this research, Ni–P and Ni–P/nano-SiC coatings were applied on the X70 steel substrate successfully without any surfactant. Then, CO_2 corrosion in the presence of acetic acid (HAc) was investigated using electrochemical techniques. Scanning electron microscopy (SEM), energy dispersive spectroscopy (EDS) and X-ray diffraction (XRD) techniques were used for surface analyses of the coatings. The electrochemical behavior of corrosion was investigated using polarization test and electrochemical impedance spectroscopy (EIS). XRD pattern of Ni–P/nano-SiC coating was very similar to that of Ni–P coating. EDS results demonstrated the presence of SiC particles in the coating. SEM images confirmed the presence of SiC nano-particles with almost uniform distribution in the coating. The corrosion current density was less in the Ni–P and Ni–P/nano-SiC coated samples than uncoated X70 steel. Ni–P/nano-SiC coated sample had the most corrosion resistance because of less effective metallic area available for corrosive media. The overall protection mechanism of Ni–P and Ni–P/nano-SiC coatings was achieved by formation of a layer of adsorbed hypophosphite anions ($H_2PO_2^-$).

1. Introduction

One of the major problems in oil and gas industry is the CO_2 corrosion of carbon steels [1–4]. In this type of corrosion, CO_2 dissolves in brine and as a result, carbonic acid produces which makes the media corrosive [1,3]. In addition, in most of the oil and gas fields the effect of organic acids especially acetic acid (HAc) as a corrosion promoter has been noted [5–7].

Electroless nickel–phosphorous (Ni–P) coating is widely used in different industries because of its high hardness, excellent corrosion and wear resistances and its uniform thickness [8]. It can be rationally anticipated that the inclusion of nano-sized particles in electroless Ni–P alloy coating would be significant for broadening the scopes of these coatings in industry. Nano-sized particles could endow the coating with special functionality. This has been primarily verified by the studies on electroless Ni–P alloy coating co-deposited with hard particles such as SiC, B_4C, Al_2O_3, etc. [9–11]. Among these coatings, the combination of Ni–P/SiC has proved to be one of the best-performing combinations [10–12].

Recently some attempts have been made to prevent the internal corrosion of pipelines and tubes using Ni–P coating [13,14]; however, it seems that there is a gap in this topic for the Ni–P/nano-SiC coating and also the environments that are found in oil and gas industry like CO_2 containing media that is accompanied with dissolved acetic acid.

In this research, first the incorporation of SiC nano-particles on the structure of electroless Ni–P matrix was studied. Then the effects of Ni–P and Ni–P/nano-SiC coatings on the corrosion behavior of X70 steel, in CO_2 containing media in the presence of acetic acid, were investigated.

2. Experimental procedures

X70 steel samples, with nominal composition shown in Table 1, were coated by Ni–P and Ni–P/nano-SiC coatings. The shapes of steel samples were cylindrical with the exposed surface area of about 5.3 cm^2. They were polished using 60–2000 grit silicon carbide papers then degreased in acetone using an ultrasonic cleaning device and washed with ethanol.

For coating of X70 steel samples, in addition to the above mentioned process, all the specimens were subjected to the following pre-treatment and plating procedure:

1. Alkaline cleaning in a solution containing 20 g/l sodium hydroxide (NaOH), 26 g/l sodium phosphate (Na_3PO_4), 26 g/l sodium carbonate (Na_2CO_3) and 5 g/l sodium silicate (Na_2SiO_3) at 75 ± 2 °C for 7 min.
2. Cleaning in 20 vol.% H_2SO_4 at room temperature (RT) for 30 s.
3. Cleaning in 5 vol.% H_2SO_4 at RT for 30 s.

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