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Nanomaterials as Innovative Technology for Corrosion Control in Petroleum Fields

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Editorial

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Editorial

In oil production plants, many cases of extensive corrosion have occurred in production tubing, valves, and in flow lines from the wellhead to the processing equipment. The reason for this is that oil and gas from the well contain varying amounts of water, which can be precipitated as a separate phase in contact with the material surface, and that this water contains gases such as CO_2 and possibly H_2S, as well as salts [1]. Nanocrystalline metals and alloys have revealed much improved performance and, in some cases, unique properties over conventional materials with the same chemical composition. Increased hardness, improved corrosion and wear resistance, lower coefficients of friction and enhanced solid solubility make nanostructured metals and alloys ideal candidates for many industrial applications. The investigation of the corrosion behavior of nanocrystalline materials has attracted considerable attention so as to enable better understanding of their structural and chemical characteristics. The reported results seem to suggest that the effect of nano-crystallization on corrosion performance is neither uniform nor definite, but varies according to the nature of the material and environment. A possible reason for such variation may be that the corrosion properties of nanocrystalline materials depend on the actual structures of the nanocrystalline phases prepared by different techniques [2]. However, nanotechnology has been utilized in endowing the steel bulk materials with excellent corrosion resistance and other enhanced properties, mainly by refining their crystal grains to the nanometer scale. The steel substrate with a nano-phased grain structure tends to have less defects or inhomogenities where corrosion attack traditionally initiates and/or propagates [3]. However, nano-crystallization is reported to often result in improved corrosion resistance [4-6].

Another significant role for nanomaterials in the field of corrosion control is nano-coatings. In recent years, there has been an overwhelming interest in the production and widespread utilization of multifunctional, nanostructured coatings by various industries [7-9]. Specifically, increasing demands for greater power density, more compact design, better reliability, lower fuel and material consumption in numerous advanced tribological systems have increasingly necessitated the use of such coatings to achieve greater performance, longer durability, and high efficiency. For numerous applications, nanostructured coatings can make a huge positive impact [10-12]. Because of their superior mechanical properties (in particular, super hardness and super toughness) and high chemical inertness, these coatings can significantly lower friction a wear losses and at the same time increase resistance to fatigue, erosion, and corrosion, which have increasingly become the life-limiting factors for mechanical components in many industrial applications. Such coatings can also provide greater resistance to contact deformation and damage during heavily loaded rolling or rotating contacts [13]. Their isotropic, nanocrystalline structure may provide higher load-carrying capacity, greater fracture toughness, and hence better resistance crack initiation and growth under both normal and tangential loads [14]. One of most important nanostructured coatings is Nanocomposite Coating.

Generally, Nanocomposite materials are formed by mixing two or more dissimilar materials at the nanoscale in order to control and develop new and improved structures and properties. A nanocomposite coating comprises of at least two phases: a nanocrystalline phase and an amorphous phase, or two nanocrystalline phases [15]. The properties of nanocomposites depend not only upon the individual components used but also upon the morphology and the interfacial characteristics. Nanocomposite coatings and materials are among the most exciting and fastest growing areas of research; with new materials being continually developed which often exhibit novel properties that are absent in the constituent materials. Nanocomposite coatings therefore offer enormous potential for new applications including: aerospace, automotive, electronics, biomedical implants, non-linear optics, mechanically reinforced lightweight materials, sensors, nano-wires, batteries, bioceramics, energy conversion and many others [16]. Recent experimental studies have shown that some of the key advantages of nanocomposite coatings over conventional coatings for tribological applications are superior mechanical hardness, resilience and toughness, high resistance to fatigue, oxidation, and corrosion, lower friction, and eater tendency to produce lubricious tribofilms on dry or marginally lubricated sliding surfaces [17,18]. Significant problem has been facing the corrosion engineers which is; due to routine wear and tear, surface scratches and other defects are generated in the paint film and micro-cracks developed. These micro-cracks eventually lead to macroscopic damage, which results in the coating losing its aesthetic and protective functions. Corrosion protection coatings are especially intolerant to crack formation because cracks will expose the underlying metal to corrosive environments, thereby shortening the service life of the coating. Damage to coatings applied to metal substrates can lead to catastrophic failure of the structure because a very unfavorable anode (small area of exposed metal surface) to cathode (large coated surface area) ratio is established, resulting in rapid corrosion of and eventual perforation of the metal. Hence, nanostructure material's engineering provide engineering smart coatings that can release corrosion inhibitors on demand when the coating is breached, stressed or an electrical or mechanical control signal is applied to the coating. The use of a self-healing coating will increase the operational life of the coating and eliminate the need to frequently repaint or replace damaged coatings. As a result, huge cost savings can be realized with the successful development of a self-healing coating due to: (a) the increased service life of the painted object; (b) the reduction of the raw materials and energy used to produce the coating materials used for repainting; (c) the labor and materials needed to apply the repair paint; and (d) the environmental costs and societal impact of repainting (e.g., waste disposal, volatile organic compounds, etc.). Most of these commercial self-healing coatings are based on capsules imbedded in the polymer matrix [19-21]. Nanotechnology has brought fundamental changes to the methods of mitigating corrosion risk either by enhancement of the inherent corrosion resistance and performance of the metals and alloys ,or by reducing the impact of corrosive environments through the alternation of the metal/electrolyte interface by providing coatings with superior abrasion resistance and good corrosion resistance. However, the research in this domain is ongoing and the interdisciplinary nature of nanotechnology requires experts from a variety of disciplines working together to produce viable and applicable solutions.

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