Accepted Manuscript

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PII: S1002-0721(18)30348-X

DOI: 10.1016/j.jre.2018.05.003

Reference: JRE 196

To appear in: *Journal of Rare Earths*

Received Date: 16 November 2017

Revised Date: 5 May 2018

Accepted Date: 7 May 2018

Please cite this article as: Mahidashti Z, Ramezanzadeh B, Influence of lanthanum as additive and post-treatment on the corrosion protection properties and surface morphology of mild steelchemically treated by a cerium conversion coating, *Journal of Rare Earths* (2018), doi: 10.1016/j.jre.2018.05.003.

Influence of lanthanum as additive and post-treatment on the corrosion protection properties and surface morphology of mild steelchemically treated by a cerium conversion coating

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Abstract: The influence of cerium conversion coating (CeCC) modified by lanthanum in two forms of additive and post-treatment solution on the corrosion resistance, surface morphology and surface chemistry of the mild steel was studied. Corrosion resistance was evaluated by electrochemical impedance spectroscopy, while the scanning electron microscopy, X-ray photoelectron spectroscopy and contact angle test were employed to investigate the surface characteristics. Results reveal that the CeCC post-treated by lanthanum containing solution gives rise to the deposition of a crack free and uniform conversion coating with enhanced corrosion resistance on the steel surface. Also, the surface free energy is increased after post-treatment.

Keywords: Surface treatment; Corrosion resistance; XPS; AFM; SEM/EDS; Surface free energy

1. Introduction

Chromate based conversion coating (CrCC) has been introduced as a leading pre-treatment approach for many years due to its good adhesion to the organic coatings and self-healing properties. However, the use of this coating has been strongly banned due to its toxic nature and environmental regulations [1]. Nowadays, several researches have focused on synthesizing acceptable conversion films with lower toxicity such as phosphate, molybdate, zirconium and rare earth metal salts [2-7]. In this regard, the CeCC has been considered as a green and promising alternative for CrCCs[8-11]. However, generation of some micro-cracks during the CeCC film formation deteriorates its corrosion performance to some extent due to the access of corrosive ions to the metal surface through the diffusion paths created [12]. Various methods have been used to examine with the aim of modifying the microstructure and corrosion resistance of the conversion coatings, including heat treatment [13, 14], addition of organic and/or inorganic additives [2, 15-18], pre-treatment of the metal substrate [19-21], applying the post-treatment bath [22, 23], among others [24, 25]. Accordingly, Brunelli et al. [24] examined the effect of HCl-pre-treatment of magnesium alloys on the morphology and corrosion resistance of the CeCC. They found that distribution of the conversion coating was more homogeneous in the case of acidic pre-treatment and higher amount of cerium was observed on the surface. This treatment further improved the corrosion resistance of the CeCC. In our previous work [13], we demonstrated the beneficial effect of heat treatment on the as-deposited CeCC, which was attributed to the conversion of cerium hydroxides to the cerium oxides and thus healing of the coating's micro-cracks. Wang et al. [12]studied the effect of sodium dodecyl benzene sulfonate on the Ce film formation andfound that this additive significantly improved the density of the conversion coating and shortened the time of coating formation, leading to the enhancement of the corrosion resistance. Tsai et al. [26] investigated the effect of Mg^{2+}cationson the phosphate bath on the structural evolution of the conversion coating. Results derived from this study showed that the increase in the amount of Mg^{2+}led to the increase of population density and refinement of the phosphate grains and reduction of the surface porosity. Therefore, the corrosion resistance of the modified coating was improved. In alignment with these results, another rare-earth metal salt i.e. lanthanum (La) has also shown a remarkable corrosion performance either used as an additive in the conversion bath or as a conversion coating. The charge transfer resistance of the lanthanum conversion coating modified with citric acid after 20 min immersion in 1 mol/L NaCl solution is determined to be about 15 kΩ cm^2, according to Kong et al.[27], showing the excellent corrosion inhibition behavior of this metal salt. In another study, Yang et al. [28] showed that addition of La^{3+} to the molybdate bath resulted in the acceleration of the conversion coating deposition and improvement of the corrosion performance. In our recent

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