

Anticorrosion Performance of Smart Release Bionanocomposite Coatings on Aluminium Alloy 6061

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ABSTRACT

Protection and maintenance processes are very important in the various sectors utilizing metallic materials. Protection routes can either be passive or active depending on the components of the coating material. Active corrosion protection for metallic substrates is being widely explored with the use of smart release coatings delivering corrosion inhibitors to defective sites upon damage of protective coatings. The incorporation of modified additives into polymers such as epoxy resins offers robust solutions and aims at maximizing the materials' compatibility for the fabrication of protective surfaces. The present investigation describes the contribution of neem phytochemicals as corrosion inhibitors loaded in biocompatible silica nanocontainers providing a protective primer to the corrosion process. The hybrid particles inside the organic matrix were pH-sensitive and the triggered release of encapsulated inhibitors was meant to provide a barrier in the coating defect from the aggressive corrosion-promoting environment. Crystallinity and morphology of the nanoparticles were characterized using XRD and TEM. Further

characterizations were carried out using ATR-FTIR and TGA. The mesoporous silica nanoparticles prepared possessed a surface area of 867.3 m²/g, narrow pore size distribution ($d \sim 3$ nm) and pore volume (~ 0.5 cm³/g) as revealed by the N₂ sorption measurements. These properties supported the loading and storage of the bio-based inhibitor. Two different solvents were explored in the inhibitor loading step. Active anticorrosive performance from an artificially scratched area of the investigated coatings was evaluated via electrochemical impedance spectroscopy (EIS). 2 wt.% of the inhibitor loaded nanocontainers was incorporated in the passive epoxy matrix resulting in a moderate distribution of the nanocontainers in the epoxy matrix. The presence of the bio-based corrosion inhibitor leveraged the anticorrosion performance of the modified epoxy coatings protecting Aluminium alloy 6061 in comparison to the unmodified epoxy coating. The antibacterial efficiency of the studied coatings was explored on the biofilm-forming bacteria *Pseudomonas nitroreducens*, a potential biofoulant.

Keywords: Phytochemical-based inhibitor, Neem-silica primer, corrosion prevention, hybrid coatings, antibacterial.

INTRODUCTION

Coatings for metal protection is a very broad area of research and no single formulation technique is used. Generally, coatings contain micropores, areas of low cross-link density or high pigment volume concentration that provides a diffusion path for corrosive species such as water, oxygen and chloride ions to the coating/metal interface. Therefore, incorporating corrosion inhibitors into a coating system is a basic step required for corrosion protection [1]. Direct addition of corrosion inhibitors has almost always resulted in undesirable leaching of inhibiting molecules and subsequent reactions with the coating matrix. This reduces the effect and duration required to protect the substrate in the aggressive environment. The encapsulation of corrosion inhibitors into a host material as using nanocontainers is an effective delivery system of the corrosion inhibitor in active corrosion protection application [2]. The controlled release of corrosion inhibitors from the cavities of the nanocontainers is expected to provide sustained delivery of the corrosion inhibitor and healing of a damaged coating portion [2-3].

RESEARCH SIGNIFICANCE

This work is focused on the preparation and characterization of the corrosion inhibitor-based nanocomposites using porous silica nanoparticles as the host containers. The guest-host storage of neem leaves extracts (NLE) in porous silica nanocontainers at room temperature and magnetic stirring (energy) is expected to trap the inhibitors (guest) within the nanoporous container (host), controlling premature leaching of the inhibitor molecules while providing inhibition effect to the underlying metallic substrate.

MATERIALS AND METHODS

The Aluminium alloy 6061 substrates with previously established composition [4] was used in this study. Emery papers up to 1000 grit size was used to polish the substrate which were degreased in acetone, alkaline and acid etched to be free of contaminants.

The porous silica nanoparticles (MS) were prepared as described in one of our previous works [5]. The neem extract was loaded using ethanol and hexane as the solvents in a 2:1 ratio of nanoparticle to corrosion inhibitor to give nanocomposites MS-NLE-E and MS-NLE-H.

The coating was prepared using diglycidylether of bisphenol A (DGEGBA) as the resin, triethylene tetraamine (TETA) as hardener, and butanol was used as the diluting agent for both resin and hardener. Resin to hardener ratio was 2:1. The alloy substrate was dip coated at a controlled speed, initially cured at room temperature and post-cured at 50 °C. The prepared coatings were analyzed using electrochemical impedance spectroscopy (EIS) by exposing 1 cm² dimension of the working electrode. Saturated calomel

electrode (SCE) was the reference electrode, and a platinum grid was the counter electrode using CH instrument electrochemical work station. A frequency of 10^5 Hz to 10^{-2} Hz and an amplitude of 5 mV were applied, while 3.5 wt.% NaCl was used as the aggressive sea water environment.

The formulated epoxy-based coatings were tested for antibacterial activity with the inhibition zone method against the test bacterium; *Pseudomonas nitroreducens*. Culture media protocol and evaluation for *Pseudomonas nitroreducens* [5] and the halo formation observed as the zone of inhibition (ZOI) was measured. Bare sterilized Al6061 (uncoated) served as the control and the experiments were carried out in duplicates.

RESULTS

Crystallinity and morphology of the nanoparticles were characterized using XRD and TEM. Functional groups were determined using ATR-FTIR, thermal stability using TGA, surface area, pore volume, and pore size from N_2 sorption measurements and coating performance using electrochemical impedance spectroscopy. Antibacterial activity of the coatings was evaluated.

XRD analysis

In Figure 1, the amorphous halo characteristic of silica nanoparticles was observed in MS at 23 2-theta degree. The amorphous halo is also a feature in biomass extract for compounds not completely crystalline and was observed at 17 2-theta degree in NLE. MS-NLE-H retained some of the crystalline peaks of NLE in the nanocomposite while MS-NLE-E remained amorphous after the loading step.

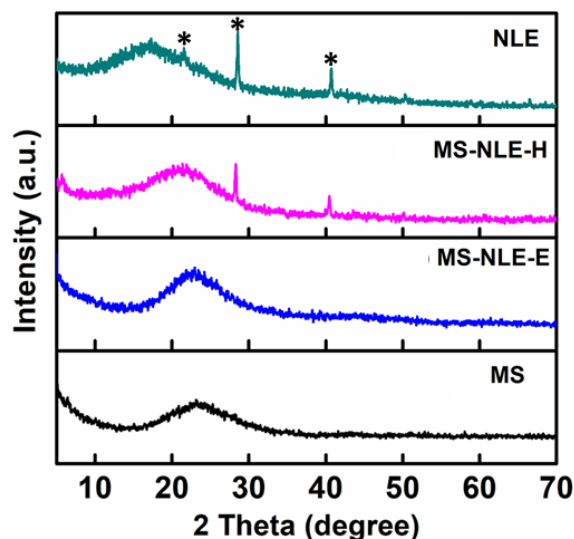


Figure 1: XRD patterns of MS, MS-NLE-E, MS-NLE-H and NLE.

TEM analysis

The TEM micrographs in Figure 2 shows the morphology of (a) MS-NLE-E and MS-NLE-H filled pores. The mesoporous nature of MS allowed for loading of the corrosion inhibitor within and onto its pores. Both nanocomposites are polydispersed and mostly spherical and MS-NLE-H appears roughened on the surface.