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Optimization of anti-corrosion performance of novel magnetic polyaniline-Chitosan nanocomposite decorated with silver nanoparticles on Al in simulated acidizing environment using RSM

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ABSTRACT

The suitability of newly synthesized magnetic polyaniline-Chitosan nanocomposite decorated with silver nanoparticles (Ag@PANI-CS-Fe_3O_4) as a robust corrosion inhibitor for Aluminum (Al) in a 5 M HCl environment has been investigated via Weight Loss (WL), Alternating Current (AC)-Impedance Spectroscopy (IS), Potentiodynamic polarization (Tafel plots), and Scanning Electron Microscopy (SEM) techniques. The protection efficiency (PE) was mathematically modeled using the Response Surface Methodology (RSM) to fit an empirical relation in terms of temperature, nanocomposite concentration, and time using the face-centered central composite design. The model was accurate with a coefficient of determination (R^2 = 99.27%). The negative Gibb's free energy of adsorption (ΔG_{ads}) values confirmed the spontaneity of Freundlich adsorption isotherm process on Al in 5 M HCl solution. The optimization simulation yielded maximum protection efficiency (of 97.88%) at 5 mg/L nanocomposite concentration, 1 h time, and an intermediate temperature of 304.8 K. Furthermore, the sensitivity of PE was evaluated to find that the low temperature 303 K is favorable for PE, whereas higher temperature will act adversely on PE. The results obtained by the RSM model are in agreement with the experimental observations.

1. Introduction

Corrosion of Aluminum (Al), Mild Steel (MS), Copper (Cu), Stainless Steel (SS), and Brass is responsible for a variety of losses, especially in industrial sections. These metals are having an immense value in defense, household, and industrial sectors at the universal level. Aluminum metal is universally used in many industrial sections such as chemical batteries, machinery, valves, and reaction vessels due to its corrosion resistance nature (oxide layer on Al surface) [1]. But, Al undergoes corrosion in an acidic pickling environment. Al corrosion is a constant progression and cannot be completely reduced. However, some robust corrosion control techniques can mitigate the Al disintegration rate and prevent losses [2–5]. Among the many corrosion control techniques, corrosion inhibitors are preferred because, it is easy to use, low cost, and no special apparatus is needed. Inhibitors are the substances that, when introduced into the corrosive liquids retards the Al corrosion rate by forming a barrier layer on the Al surface. The electronic characteristics and molecular structures of inhibitor molecules are the key parameters that enhance the capability of corrosion inhibitors to get adsorbed on the surface of Al. Organic species are recognized as competent corrosion inhibitors for Al in the acidic pickling system as they possess N, S, P, and O atoms along with pi electrons which participate in physical or chemical adsorption process owing to which corrosion inhibitor molecules effectively binds on Al surface and generates invisible protective layer [2]. Different types of corrosion inhibitors are toxic to the aquatic lives and environment. Therefore, this justification greatly frustrates the use of imported inhibitors in process chemical industries. The species such as ionic liquids, natural polymers, bio extracts, and amino acids are less harmful to the environment and humans have been employed for the mitigation of Al corrosion [6–10]. The green approach received good attention due to its low cost, availability, and zero or little negative environmental effect has been acknowledged [11–13].

The nanoscience scientist focused on an exploration of the synthesis of new nanocomposites and related phenomena for the mitigation of Al

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