Development of 1-Ethyl-3methylimidazolium Phenylalaninate Ionic Liquid as an Environmentally Friendly Corrosion Inhibitor for Carbon Steel

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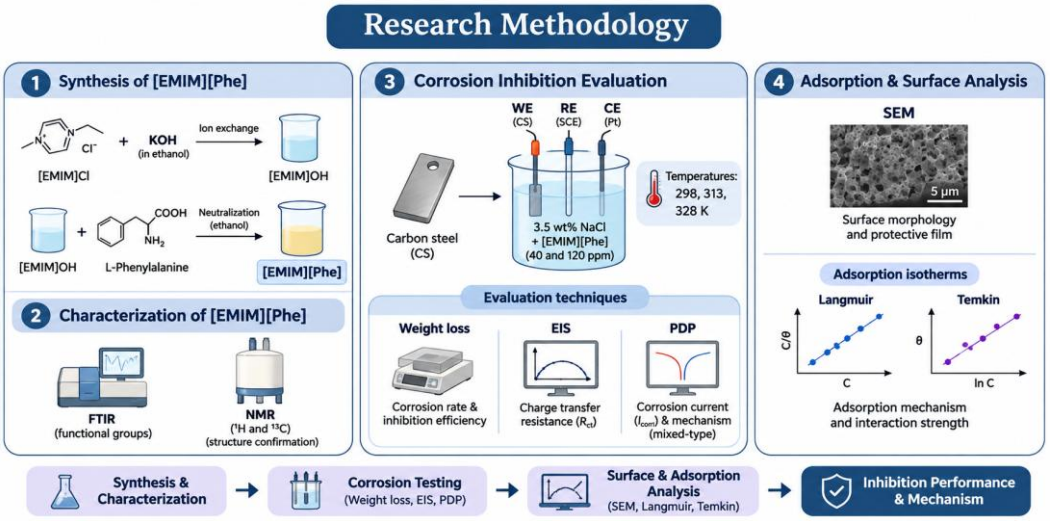
Abstract

Corrosion inhibition of carbon steel (CS) in chloride-containing environments remains a significant industrial challenge. This study investigated 1-ethyl-3-methylimidazolium phenylalaninate ([EMIM][Phe]) as a green corrosion inhibitor in 3.5 wt% NaCl solution. The synthesized ionic liquid was confirmed using FTIR and NMR spectroscopy. Inhibition performance was evaluated through weight loss, electrochemical impedance spectroscopy (EIS), and potentiodynamic polarization (PDP) at different concentrations and temperatures. A maximum inhibition efficiency of 98.118% was achieved. Electrochemical results indicated mixed-type inhibition through surface adsorption, while SEM confirmed protective film formation. Langmuir and Temkin isotherms were employed to investigate the adsorption mechanism.

Keywords: Ionic liquid; corrosion inhibitor; Carbon steel corrosion; Adsorption mechanism

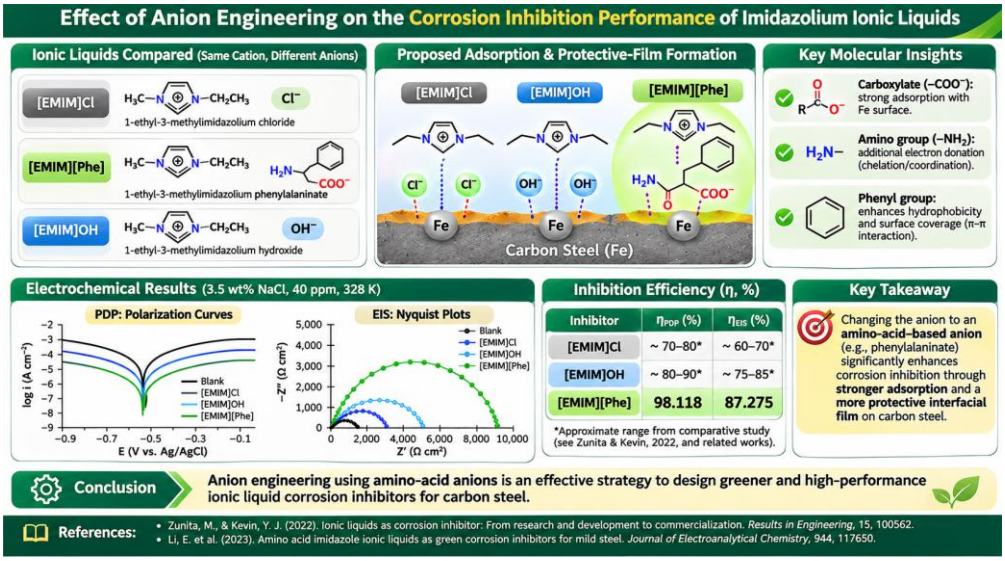
Introduction

Carbon steel is widely used in industrial applications due to its excellent mechanical properties and affordability. However, exposure to chloride-containing environments, particularly seawater, accelerates corrosion, resulting in material degradation and economic losses. Conventional corrosion inhibitors often raise environmental and toxicity concerns, encouraging the development of greener alternatives. Ionic liquids (ILs) have attracted considerable attention because of their tunable chemical structures, low volatility, and strong adsorption capabilities (Kobzar & Fatyeyeva, 2021). In particular, amino acid-based ionic liquids offer potential advantages in corrosion protection (Li et al., 2023). This study investigates [EMIM][Phe] as a corrosion inhibitor for carbon steel in 3.5 wt% NaCl solution.



Discussion & Result

FTIR and NMR confirmed the successful synthesis of [EMIM][Phe]. Its corrosion inhibition performance was evaluated in 3.5 wt% NaCl at concentrations of 40 and 120 ppm and temperatures of 298–328 K. PDP measurements demonstrated a maximum inhibition efficiency of 98.118%, indicating excellent protection. Electrochemical results revealed mixed-type inhibition through suppression of anodic iron dissolution and cathodic reduction. This performance is attributed to adsorption of [EMIM][Phe] on the carbon steel surface, forming a protective barrier. SEM observations confirmed reduced surface corrosion and protective film formation. Langmuir and Temkin isotherms were applied to investigate adsorption behavior and interfacial interactions, highlighting [EMIM][Phe] as a promising green corrosion inhibitor.



Conclusion

1. Successful Synthesis and Characterization: The ionic liquid [EMIM][Phe] was successfully synthesized and characterized using FTIR and NMR spectroscopy, confirming its potential as a green corrosion inhibitor for carbon steel in chloride-containing environments.
2. Excellent Corrosion Inhibition Performance: [EMIM][Phe] achieved a maximum corrosion inhibition efficiency of 98.118% in 3.5 wt% NaCl solution. Electrochemical measurements demonstrated mixed-type inhibition by suppressing both anodic and cathodic reactions.
3. Effective Surface Protection and Adsorption: SEM analysis confirmed the formation of a protective adsorbed layer on the carbon steel surface. Langmuir and Temkin adsorption models provided insights into the inhibition mechanism, highlighting [EMIM][Phe] as a promising corrosion inhibitor for industrial applications.