

Impedance Study of Coffee Waste As Eco-Friendly Inhibitor in Hybrid Sol-Gel Coating For Corrosion Mitigation of Mild Steel in NaCl

Sharifah Nurul Aqilah Syd Sharuddin^a, Amirah Amalina Ahmad Tarmizi^{a*}

Structured Abstract

Background: The corrosion of mild steel poses significant challenges across industries due to structural degradation, safety risks and maintenance costs especially in saline environments. However, a recent study shows the drawbacks of conventional coatings which contain hazardous substance, therefore there is a need for developing an eco-friendly coatings alternative. The study utilized coffee waste contains polyphenols and caffeine which rich in natural antioxidants that offers corrosion-inhibitive properties and utilized hybrid sol-gel coatings formed by organic and inorganic compounds that known for their strong adhesion and barrier performance. This study investigates the coffee waste incorporation hybrid sol-gel coatings to enhance corrosion resistance of mild steel in 0.5 M NaCl solution.

Methods: The hybrid sol-gel coatings were synthesized using TEOS and APTES as silane precursors. Coffee waste extract was obtained by boiling dried coffee waste in distilled water and were added into the sol-gel coatings at concentrations of 100 to 1000 ppm. The coated mild steel specimens were then immersed in 0.5 M NaCl for 24 hours. The corrosion resistance was evaluated using impedance study which consists of Electrochemical Impedance Spectroscopy (EIS) and Potentiodynamic Polarization (PDP).

Results: The impedance study shows that the hybrid sol-gel coating with 1000 ppm coffee waste extract showed the highest corrosion resistance. The results in EIS analysis indicate that the 1000 ppm coating has the largest diameter of Nyquist plot semicircles and highest charge transfer resistance (R_{ct}) as well as Bode plots indicate the improvement in the barrier performance through increased impedance modulus and phase angles. Additionally, PDP analysis was further confirmed that 1000 ppm coating had the lowest corrosion current density (i_{corr}) indicating minimal corrosion activity. The corrosion potential (E_{corr}) shifted to more noble values confirming a mixed-type inhibition mechanism. Both analyses identified that 1000 ppm as the optimum concentration with the best inhibition efficiency and film stability observed after 24 hours of immersion.

Conclusion: In conclusion, coffee waste incorporated hybrid sol-gel coatings significantly improve the corrosion resistance of mild steel in saline environments, thereby offering a promising, sustainable and non-toxic alternative to substitute conventional coatings.

Keywords: Corrosion inhibition, hybrid sol-gel coating, coffee waste extract, mild steel, green corrosion inhibitor

*Correspondence: amirahamalina@uitm.edu.my

^aSchool of Chemistry & Environment, Faculty of Applied Sciences, Universiti Teknologi MARA, Shah Alam, Malaysia