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Comparative Evaluation of Commercial Nanoceramic Conversion Coatings on SAE 1008 Steel: Surface and Electrochemical Characterization

Possani, G. K; Schneider, E. L; Scienza, L. C
Universidade Federal do Rio Grande do Sul (UFRGS)

Introduction

- Carbon steel is widely used in industrial applications due to its favorable mechanical properties, low cost, and processability. However, its susceptibility to corrosion limits service life and increases maintenance costs.
- Zirconium-based conversion coatings (Zr-CCs) have emerged as environmentally friendly alternatives to conventional phosphate- and chromate-based treatments. Their performance depends on bath chemistry, processing conditions, and substrate characteristics.

Objectives

This study compares two commercial nanoceramic treatments applied to SAE 1008 steel, correlating surface characteristics with electrochemical behavior and corrosion resistance, using untreated and zinc-phosphated steel as references.

Methodology

Material: Cold-rolled SAE 1008 steel sheets.
Surface preparation: SiC grinding (#120–#2000), ultrasonic ethanol degreasing, alkaline cleaning, rinsing, and drying.
Surface conditions:

- ✓ Bare: untreated steel.
- ✓ Nano 1: treatment with commercial Solution A.
- ✓ Nano 2: treatment with commercial Solution B.
- ✓ Zn-Phosph: commercial zinc phosphating followed by passivation

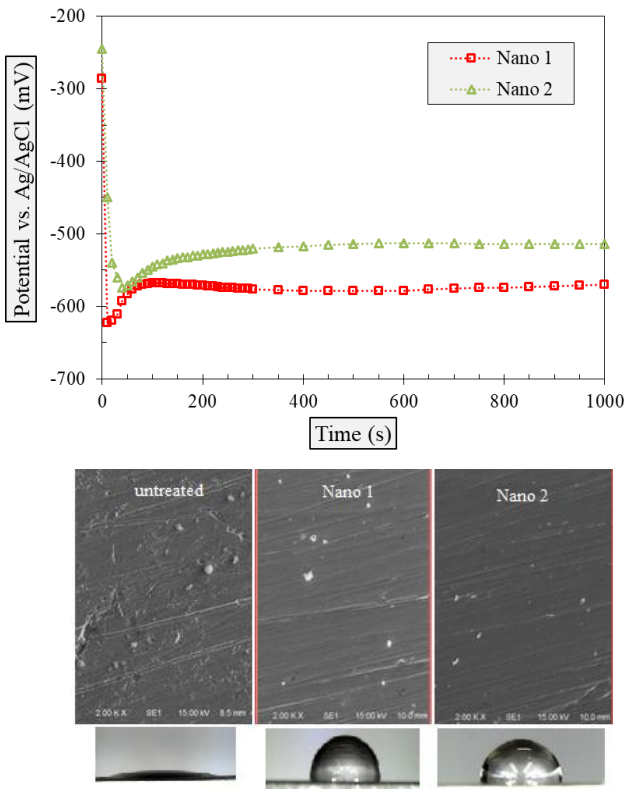


Figure 1. Above: Open-circuit potential evolution as a function of time during the Nano 1 and Nano 2 nanoceramic conversion treatments. Bellow: SEM and contact angle.

Results and Discussion

- **Surface morphology and composition.** SEM revealed relatively homogeneous surfaces after nanoceramic treatment, while grinding marks remained visible. EDS confirmed zirconium incorporation in the treated surfaces, together with titanium and chromium, indicating the presence of coating-related species.
- **Wettability and conversion kinetics.** Both nanoceramic treatments increased the water contact angle compared with untreated steel, indicating increased hydrophobicity. OCP approached a quasi-steady state after approximately 200 s, suggesting that the selected 300 s treatment time was sufficient under the investigated conditions.
- **Electrochemical behavior.** EIS revealed improved impedance responses for all treated samples compared with untreated steel. Zn-Phosph exhibited the largest capacitive loop, the highest low-frequency impedance modulus, and the highest phase angle, indicating superior barrier performance. Nano 2 showed better initial electrochemical performance than Nano 1; however, both nanoceramic treatments exhibited similar behavior after 24 h, with a decrease in impedance consistent with progressive electrolyte penetration.

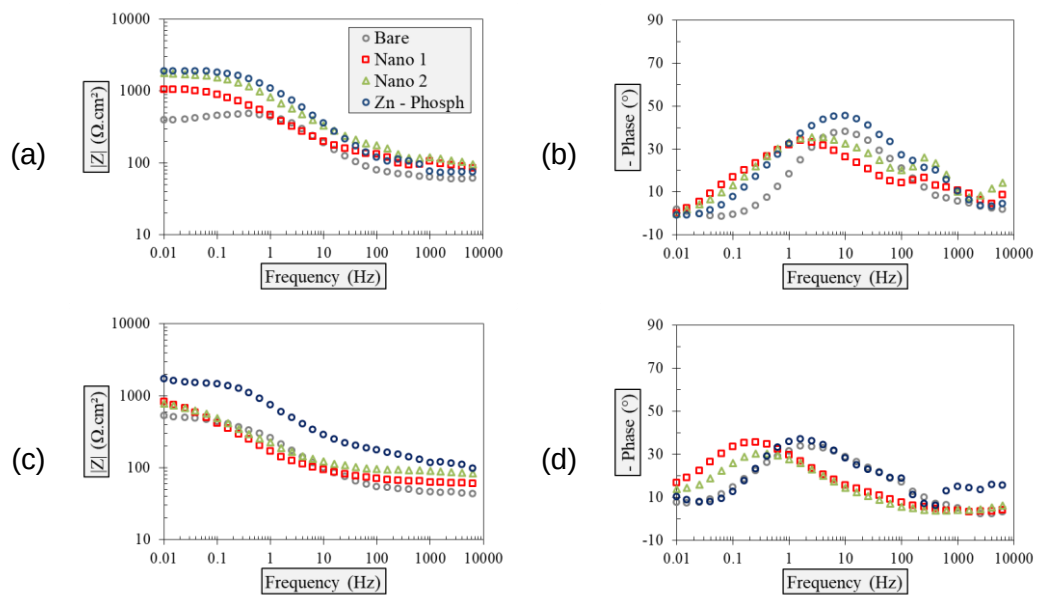


Figure 2. Bode plots (|Z| and phase angle vs. frequency) obtained by EIS in 0.1 mol L^{-1} NaCl solution (pH 3.5) after (a) and (b) 30 min; (c) and (d) 24 h of immersion.

Conclusion

- ➢ Both nanoceramic treatments modified the surface characteristics of SAE 1008 steel and improved its electrochemical corrosion resistance compared with untreated steel.
- ➢ Nano 2 showed better initial electrochemical performance than Nano 1, although their behavior became similar after 24 h of immersion.
- ➢ Zinc phosphating provided superior corrosion protection under the investigated conditions.
- ➢ Further optimization of bath chemistry and processing parameters is required to improve coating continuity, stability, and long-term corrosion resistance while preserving the environmental advantages of nanoceramic technologies.

Acknowledgments

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