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CORROSION RESISTANCE OF NIS, ZNS AND NIS/ZNS THIN FILMS DEPOSITED BY SPRAY PYROLYSIS TECHNIQUE ON LOW CARBON STEEL IN 3.5%NaCl SOLUTION

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Article Info	Abstract
Received:15.09.2023 *Accepted: 23.10.2023* **Keywords:** Thin films; Coating; spray pneumatic method; Corrosion	In this work, the main object of this research is to investigate a new material based on ZnS and NiS nanostructures. NiS and ZnS solutions were sprayed on the heated Low Carbon Steel by a spray pneumatic deposition method. Electrochemical analyses of the prepared samples were investigated. The high corrosion resistance of coated by ZnS sample have a low value of surface roughness. However, the coated sample by ZnS also has good stabilization after corrosion and high compact of the film.

1. Introduction

Steel corrosion is currently one of the problems that causes catastrophic damage to steel structures and alloys of various types, as was recently observed through several studies addressed to a range of physicochemical properties [1 - 4]. All studies have shown that material corrosion problems have a role in development, which can lead to economic consequences such as replacement, product loss, industrial control and repair, environmental pollution, and safety [1 - 6]. Therefore, several experiments have been conducted and are still being conducted aimed at further evaluating the treatments necessary to improve the performance of steel structures. For this reason, low carbon steel (LCS) can be considered a widely used material that plays a major and sensitive role in metallurgical industries [4, 5].

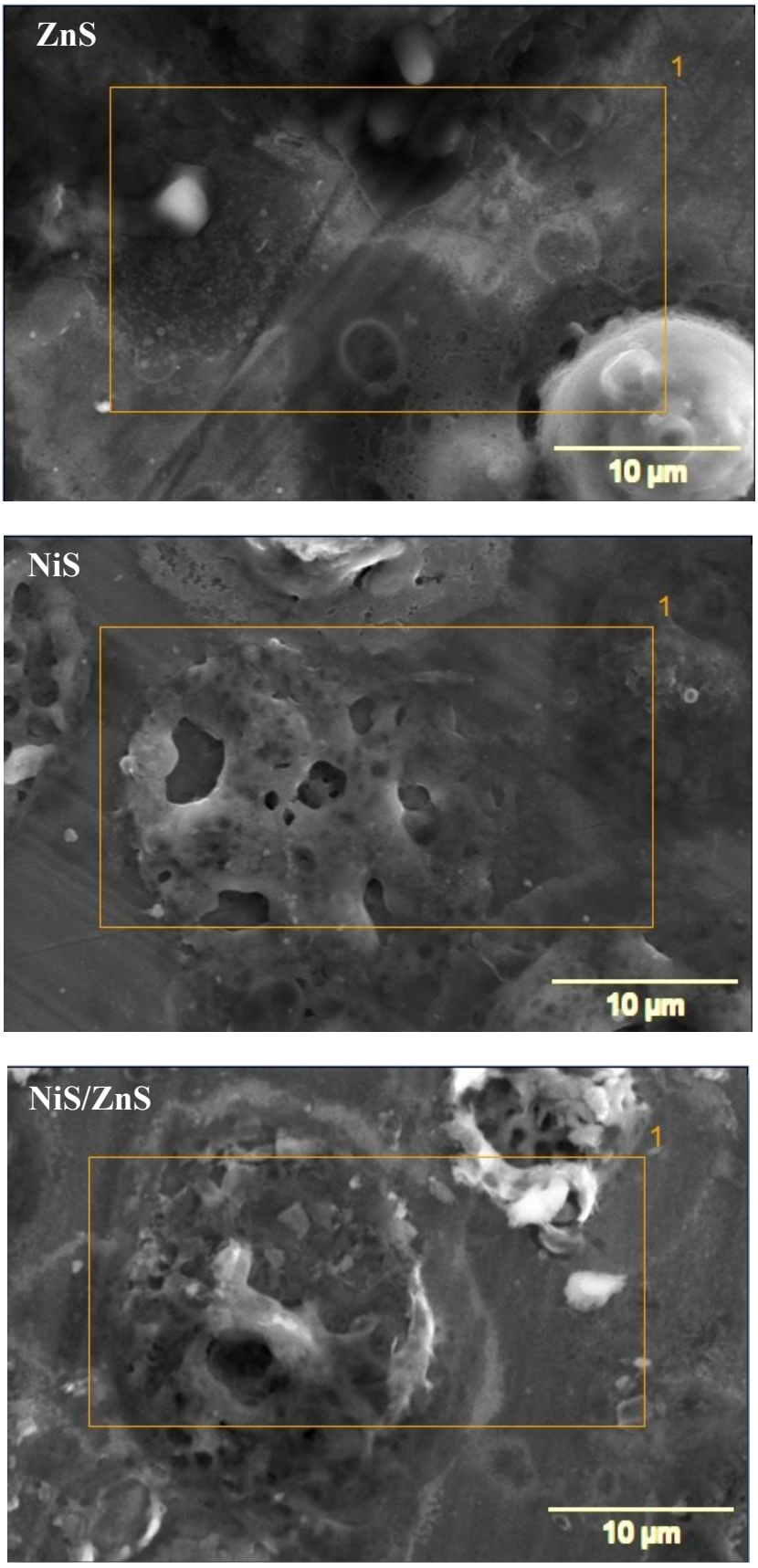


Figure 1. SEM image of the ZnS, NiS and NiS/ZnS thin films Low Carbon Steel

Various coatings are the most common means of reducing surface corrosion in metals [3-7]. These coatings are among the means required to improve metal corrosion, and they play a major role in that they are low-cost and compatible with several methods [5 - 8]. Recently, several researchers have added various experiments that rely on thin layers of metal oxides, such as zinc oxide ZnO and nickel oxide NiO, in the presence of oxygen [5 - 9]. Thin layers also play a role in increasing mechanical durability, thermal stability, and corrosion barrier properties [5 - 10]. For this reason, we are conducting a new experiment based on spraying with oxygen-free materials to notice the difference with other experiments.

The main object of this research is to investigate a new material based on ZnS and NiS nanostructures, which were utilized as conducting oxides for steel corrosion using a spray pneumatic deposition method at 450 °C. No previous studies had reported a combination of both in protective coatings.

2. Experimental procedure

Nickel sulfide NiS and zinc sulfide ZnS solutions were prepared by dissolving two produces of 0.1mol.l^{-1} of the nickel chloride hexahydrate ($NiCl_2$, $6H_2O$) with thiourea 0.05 mol.l^{-1} ($CS(NH_2)_2$, and 0.1mol.l^{-1} zinc acetate dehydrate ($Zn(CH_3COO)_2$, $2H_2O$) with thiourea 0.05 mol.l^{-1} ($CS(NH_2)_2$. The mixtures were dissolved in the solvent containing equal volumes absolute ethanol solution (99.995%) pure, and the solutions were stirred at 50 °C for 120 min to yield a clear and transparent solution.

NiS and ZnS solutions were sprayed on the heated Low Carbon Steel by a spray pneumatic deposition method, which it is transform the liquid to a stream formed with uniform and fine droplets of 25 μm average diameters. The deposition was performed at a substrate temperature of 450 °C with deposition rate of 3.5 mL/ min.

Electrochemical analysis of the prepared samples was carried out by scanning electron microscopy (SEM, EDX), and the electrochemical impedance spectroscopy (EIS) technique, which it's applied a platinum wire as a counter electrode with 3.5 wt% NaCl solution at at room temperature as working electrolyte, also the analysis of EIS was done in a frequency about of 0.05 Hz.

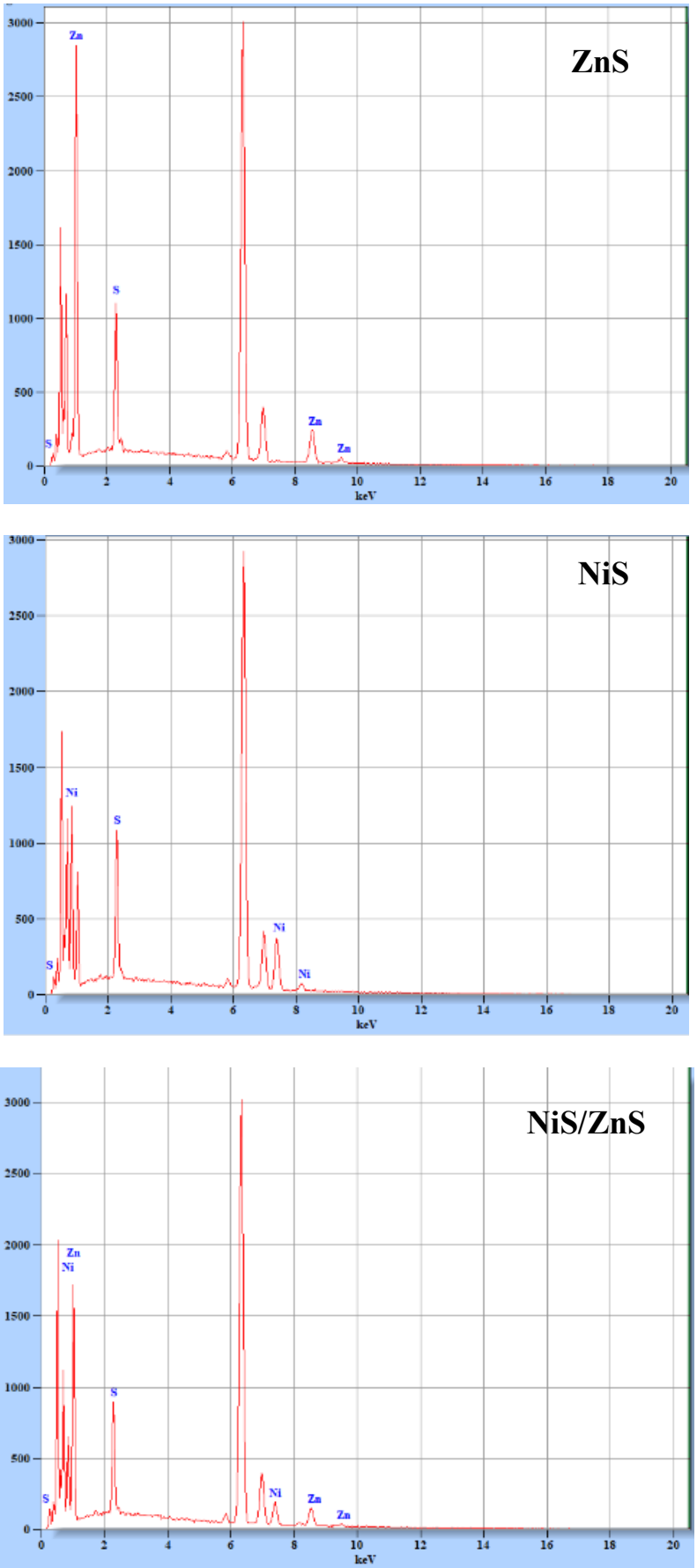


Figure 2. The EDX analyses of the ZnS, NiS and NiS/ZnS thin films Low Carbon Steel

3. Results and discussion

To obtain three-component thin-film coatings, the corrosion morphology of the ZnS, NiS and NiS/ZnS thin films Low Carbon Steel was observed by SEM image in Figures 1a, 1b and 1c, respectively. Which are observed after the corrosion measurements at ambient temperature. As shown, all coated samples have different surface in the crystal size and well faceted grains. On the other hand, we also notice that the ZnS thin film coated sample is the best surface that there is no major corrosion.

Figure 2 shows the EDX analyses of the ZnS, NiS and NiS/ZnS thin films Low Carbon Steel, all coated samples confirmed that the preparations the thin films for the presence of nickel, zinc and sulfur.

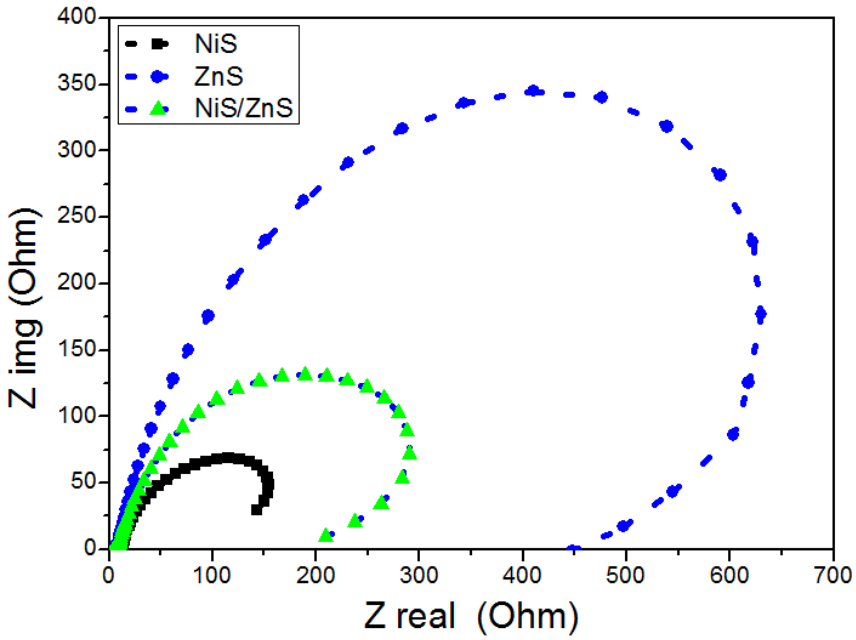


Figure 3. The Nyquist plots of the ZnS, NiS and NiS/ZnS thin films Low Carbon Steel in 3.5 wt% NaCl solution.

The Nyquist plots showing the relationship between the real and imaginary impedance for the ZnS, NiS and NiS/ZnS thin films Low Carbon Steel with 3.5 wt% NaCl solution fabricated via spray pneumatic deposition method, are shown in Figure 3. As can seen that the curves have a overall shape of the plots was the same for all specimens, with only single capacitive semicircle for all samples. As compared with the elaborated sample having a larger diameter of the semi-circle which corresponded to sample prepared with ZnS can be explained by increases in coating thickness and have a higher the corrosion resistance.

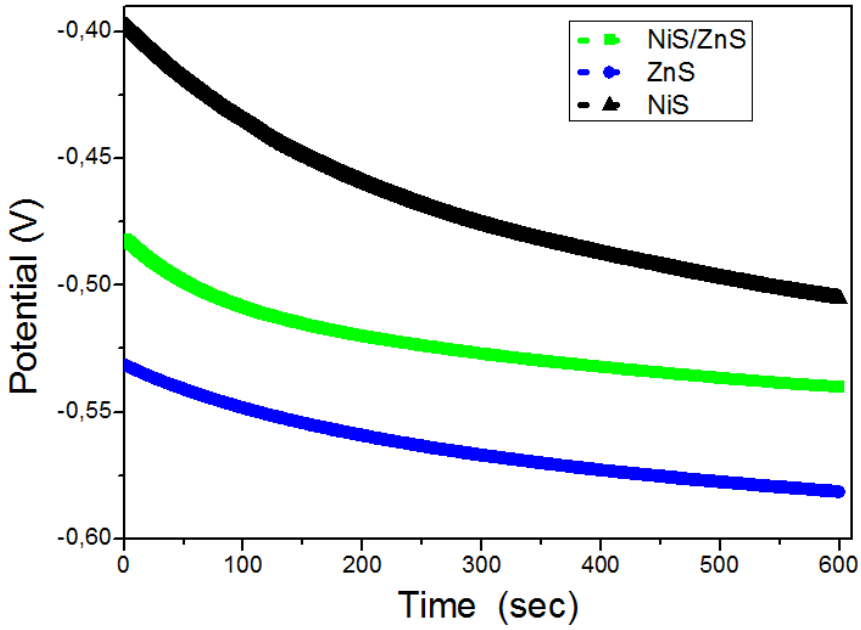


Figure 4. The Open circuit potential OCP curves for the ZnS, NiS and NiS/ZnS thin films Low Carbon Steel in 3.5 wt% NaCl solution

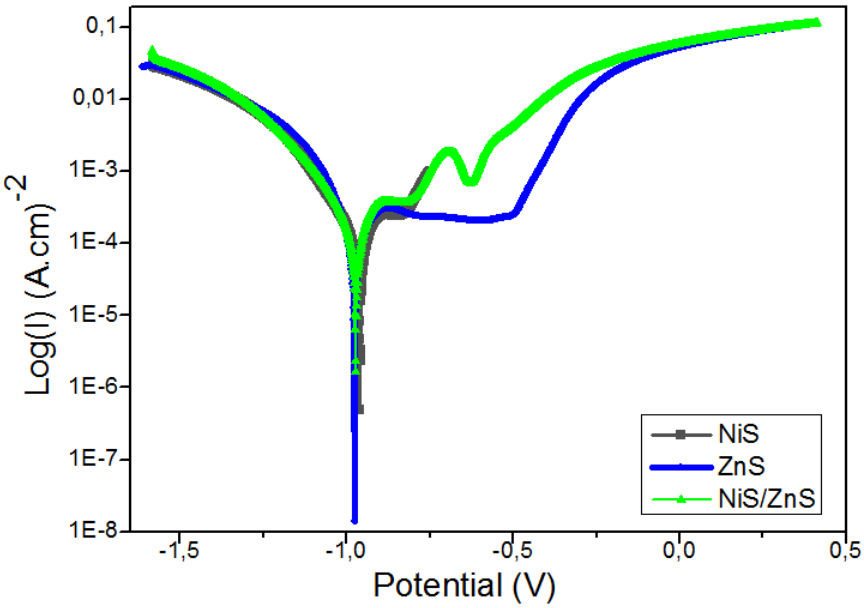


Figure 5. The potentiodynamic polarization curves of the ZnS, NiS and NiS/ZnS thin films Low Carbon Steel in 3.5 wt% NaCl solution

Moreover, the Open circuit potential OCP curves for the ZnS, NiS and NiS/ZnS thin films Low Carbon Steel with 3.5 wt% NaCl solution as shown in Figure 4. The open-circuit potential (OCP) was measured at time of 600 s, monitored at 600 s it stabilized after this time in all samples. As observed that all samples having stabilization after immersion in NaCl solution, the sample coated by ZnS thin film has a good stabilization.

Figure 5 shows representative potentiodynamic polarization curves of the ZnS, NiS and NiS/ZnS thin films Low Carbon Steel with 3.5 wt% NaCl solution. It can be stated that these

thin films decrease the corrosion rate of the coating during electrochemical tests. Table 1 present the corrosion characterizations, Represented to Rs is the resistance of solution, Rct charge transfer resistance in steel surface, Qdl constant phase element, i_{corr} is the corrosion current density, i_{pass} is the current density in the passivation area, Ecorris the corrosion potential and Ep is the critical pitting potential. As can be seen, the coated sample by ZnS thin film has a good corrosion resistance of carbon steel.

Table 1. The Electrochemical of the ZnS, NiS and NiS/ZnS thin films Low Carbon Steel

Sample coated	Rs (Ω)	Rct (Ω m^2)	Qdl ($\mu F cm^{-2}$)	i_{corr} ($\times 10^{-6}$ A/cm^2)	i_{pass} ($\times 10^{-6}$ A/cm^2)	Ecorr (mV)	Ep (mV)
ZnS	11.4	322	0.09	0.415	2.125	-0.987 ±0.002	-0.175
NiS	6.2	180	0.22	0.432	2.082	-0.942±0.002	-0.217
NiS/ZnS	5.1	76	0.49	0.476	1.890	-0.967±0.002	-0.314

4. Conclusion

In this study, the main object of this research was to investigate a new material based on ZnS and NiS nanostructures. NiS and ZnS solutions were sprayed on the heated Low Carbon Steel with 3.5 wt% NaCl aqueous solution by a spray pneumatic deposition method. Electrochemical properties of the prepared samples were investigated. The corrosion potential for the coated samples has improved. The high corrosion resistance of coated by ZnS sample have a low value of surface roughness. However, the coated sample by ZnS also has good stabilization after corrosion and high compact of the film.

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