Investigation the Effect of Chemical and Mechanical Parameters on the Electroplated Zinc Coating on Steel Substrate of st12

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1- Introduction

Zinc coated steels (Zn) and its alloys are widely used in industries. Approximately 50% of the zinc production in the world is utilized for the coating of steel sheets. The corrosion rate of zinc in most atmospheres is at least ten times lower than steel. Zinc coatings improve surface paintability and increase corrosion resistance. Thus, the use of these coatings to prevent corrosion of steel is the most widely applied. Electrochemical deposition is a relatively simple and low-cost method that is widely used for exerting metal coatings. Surface mechanical attrition treatment (SMAT) is a new and effective method to produce a nanocrystalline layer on the metals' surface. Finer grain size can also be used to create a nano-crystalline layer on the surfaces. In this study, using inexpensive methods such as SMAT and electrodeposition, a nano-crystalline layer was formed on the substrate to improve the corrosion resistance of the steel surface.

2- Experimental

St12 steel sheet with a thickness of 2 mm with dimensions of 10×10 mm was used as a substrate for zinc coating deposition. The substrates were annealed at 600 ºC for two hours and after cooling, the SMAT was performed for 30 minutes. The vibration frequency of the device was 50 Hz. Steel balls with a diameter of 3 mm were used for this purpose. Samples were prepared by sanding from the mesh number of 200 to 800. Two chloride baths (chemical compositions are listed in Table 1) were used. Gelatin was utilized as an effective additive in reducing the size of coated grains. The coating time was 5 minutes and the pH of the solution determined at 5.

Table 1: Chemical composition of electrolytes (g l^{-1})

Gelatin	H_3BO_3	NH_4Cl	$ZnCl_2$	Bath
-	20	170	60	1
0.5	20	170	60	2

The samples named S, GS, SSMAT and GSMAT as coated st12 substrate without gelatin, coated st12 substrate with gelatin, and SMATed samples with and without gelatin, respectively. A three electrodes cell was applied for all electrochemical tests in 25 °C; Steel samples were used as working electrodes, Ag/AgCl electrode as a reference electrode, and platinum with dimensions as the counter electrode. To study the behavior of coatings, they were characterized by using X-ray diffraction, field emission scanning electron microscopy, EDS, potentiodynamic polarization and EIS tests in 3.5 wt.% NaCl solution. For further investigation the voltammetry test was performed on the samples.

3- Result and discussion

Figure 1 shows voltagrams in the range of -1.5 to 0.5 V compared to the reference Electrode Ag/AgCl in the Zn coating bath for bare sample and SMATed substrate with/without gelatin.

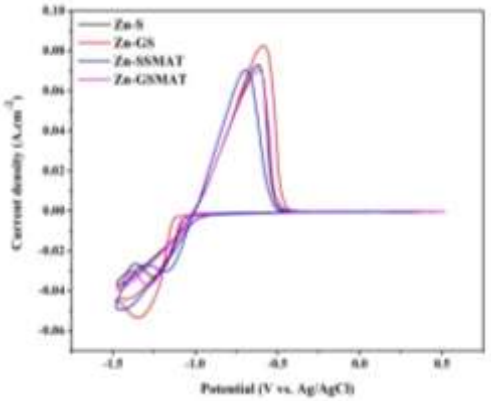

Figure 1. cyclic voltammograms of coated S, GS, SSMAT and GSMAT samples.

According to the results, for the S sample, the cathode current of Zn started from the approximate potential of -1.1 V. By adding gelatin to the solution (GS sample), the Zn reduction potential becomes more negative (-1.17). For the SSMAT sample, the potential of Zn reduction was closed to more positive values (-1.08). For the GSMAT sample, Zn reduction potential is close to the potential of the initial sample (S sample). Figure 2 shows the XRD patterns of samples. Table 2 shows the calculated values of the crystallite size of coatings using the Williamson-Hall method.

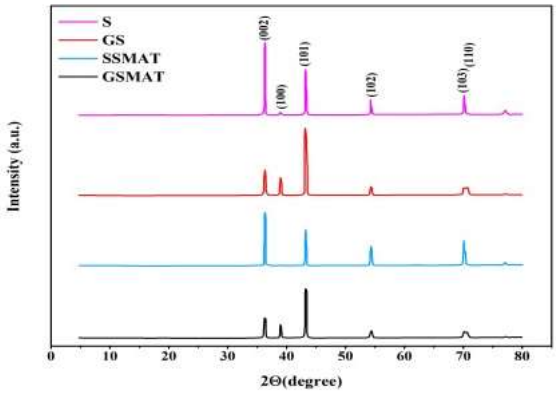

Figure 2. XRD patterns of coated S, GS, SSMAT and GSMAT samples.

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Table 2. crystallites size and micro-strain of samples.

Micro-strain	crystallite size (nm)	Sample
1×10^{4}	55	S
3×10^{5}	43	GS
1.5×10^{4}	40	S-SMAT
5×10^{5}	29	G-SMAT

Figure 3 illustrates FESEM images of the surface morphology of the coatings. According to the EDS results, only zinc element has been identified in all coatings except for S sample coating that in addition to zinc, iron, and oxygen have been characterized.

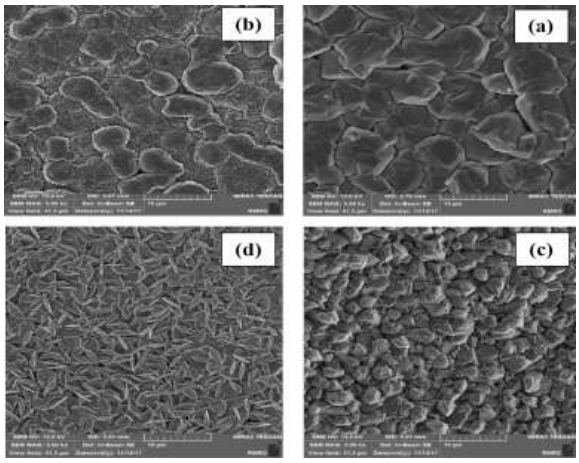

Figure 3. FESEM images of: (a) S, (b) GS, (c) SSMAT and (d) GSMAT samples.

Figure 4 shows the cross-section of coatings and their thicknesses (S:23.41µm, GS:30.31 µm, SSMAT: 22.85 µm, GSMAT: 29.17 µm). The results of the micro-hardness test shows GSMAT sample has the highest microhardness among other coatings (98.9 Vickers).

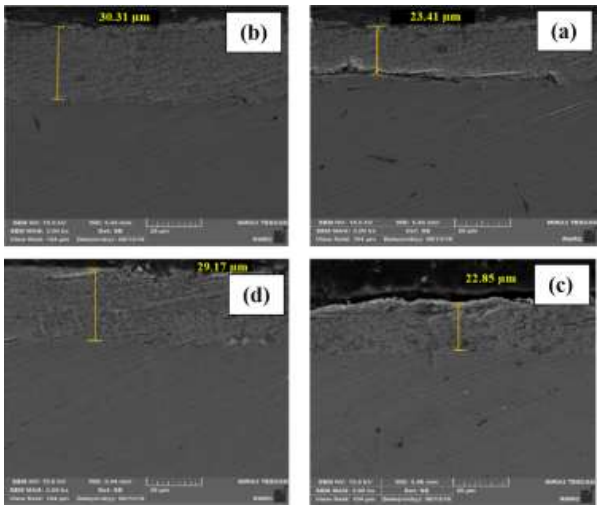

Figure. 4 FESEM cross-section images of: (a) S, (b) GS, (c) SSMAT and (d) GSMAT samples.

Figure 5 shows the polarization curves and table 3 lists polarization data.

Figure 6 and table 4 show EIS plots and achieved fit data, respectively.

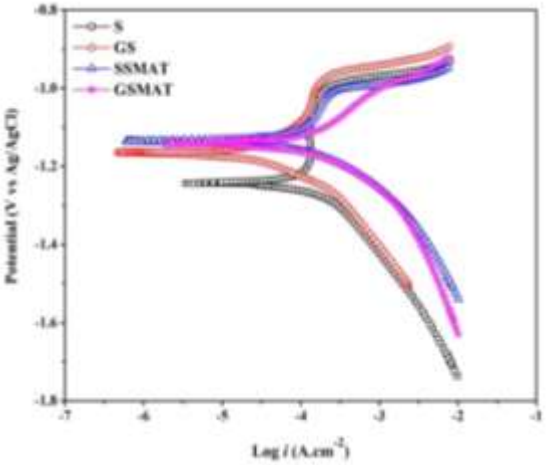

Figure. 5. Polarization curves of samples in 3.5%NaCl.

Table 3. Electrochemical data extracted from potentiodynamic polarization curves.

R_p (ohm.cm^{-2})	E_{corr} (V)	I_{corr} (µA.cm^{-2})	Samples
197.8	-1.2	80.8	S
232.8	-1.1	74.5	GS
233.2	-1.1	60.6	SSMAT
828.1	-1.1	20.1	GSMAT

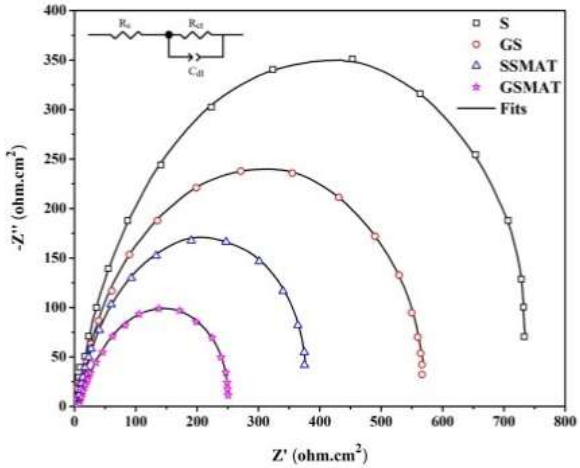

Figure 6. EIS curves of samples in 3.5%NaCl.

Table 4. Fitting results of the EIS data in Fig. 6.

Porosity (%)	n	C_{dl} ($\times10^{-5}$ F)	R_t (ohm.cm^{-2})	Sample
60.3	0.83	12.4	1.25	S
41.2	0.96	20.0	369.9	GS
27.2	0.98	21.9	561.5	SSMAT
20.8	1	22.0	732.5	GSMAT

4- Conclusion

The results showed that SMAT process reduced the size of the crystallites and the presence of gelatin caused the induced orientation of Zn deposition so that the grain size in the presence of gelatin and SMAT reached from 55 to 29 nm and the rate of its corrosion reached from 80.8 to 20.1 µA.cm^{-2}.