

# Formation and Characterization of Inter Metallics in 316L SS During Al-Zn-Mg-Si Electroplating

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**Abstract** - This study looked into how changes in temperature and time during the electrodeposition process affected the mechanical characteristics of stainless steel coatings. In order to enhance their mechanical properties, stainless steel substrates were coated with aluminium, zinc, magnesium, and silicon alloys. While SS 316L exhibited superior mechanical properties at an optimum temperature, its topographical features were found to be diminished during the galvanizing process. To address this issue, the study immersed SS 316L plates in the electrodeposition process for varying durations, ranging from 30 to 60 minutes, at different temperatures. The microstructural analysis revealed the effects of these modifications on the coatings. In this research, we take six specimens. Three specimens are coated without annealing and three specimens are coated with annealing at different immersion time.

**Keywords:** Al-Zn-Mg-Si alloy, 316L SS, Electrodeposition process, Intermetallic compounds.

## I. INTRODUCTION

To safeguard SS 316L from harsh environmental conditions, it is often coated with aluminium, zinc, magnesium, and silicon alloys. In recent times, various surface coating techniques have been employed through the electrodeposition process to enhance the mechanical properties, such as hardness, wear resistance, and corrosion behaviour, of SS 316L.

Due to its unique properties, such as a minimum tensile strength of 75 ksi and a strength yield of 0.2% of 30 ksi, SS 316L is used in a variety of industries, including the chemical and petrochemical industries, food a manufacture, medical devices, including medical devices, wastewater treatment, drinking water, marine applications; construction projects and near coastal or urban areas. Nevertheless, at high temperatures, the topographical features of SS 316L are altered.

Consequently, surface coating has emerged as a promising technology to overcome this limitation and improve the mechanical properties of SS 316L.

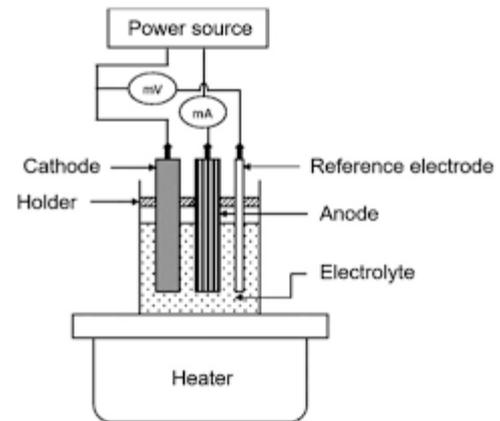


Figure 1: Electrodeposition Process

## II. MATERIALS AND METHODS

Austenitic stainless steel 316L was brought by Local Supplier. Its composition is:

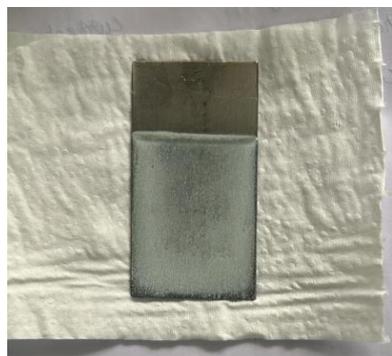
Elements	Mn (grams)	Si (grams)	Al (grams)	Zn (grams)
Composition	5	2	12	5



(a)



(b)



(c)

Figure 2: (a), (b), (c) describes the electrodeposition process and the coated specimens

Certain rectangular plate samples measuring  $7.3 * 3.5 \text{ cm}^2$  were subjected to mechanical polishing using grinding papers, brass, and 316L SS. The 316L SS samples, as well as the ultrasonically cleaned brass samples, were cleaned with water (H<sub>2</sub>O) for 20 minutes.

Additionally, the 316L SS and brass samples were subsequently cleaned with deionized water for a duration of 10 minutes.

### III. METHODOLOGY



Figure 3: Specimens without Annealing



Figure 4: Specimen after Annealing

An electrodeposition process was performed using a bath containing 0.1M concentrations of aluminium magnesium sulphate, sodium chloride, and magnesium sulphate. The bath temperature was maintained at 40°C, and six samples were subjected to the electrodeposition process for 30 mins, 45 mins, and 60 mins at 0.1A, with SS serving as anode and 316 SS as cathode. After rinsing the samples with deionized water and drying them at room temperature, three additional samples were subjected to the same temperature and time, but this time, the temperature was raised to 300°C for further analysis using SEM, EDS, XRD, microhardness, and surface roughness. To prepare the substrate, it was cut into dimensions of length=7cm, breadth=3cm, thickness=1mm, and the corner wraps and burrs were removed.

The substrate was cleaned using brass and then immersed in a hydro sonic cleaner. Finally, it was dipped in a solution of sulphuric acid and distilled water. The pH value of the bath was checked and set to 1, and the bath temperature was adjusted based on the sample requirements, with temperature set to 40°C. At ordinary intervals, the 316L SS rods have been taken out of the alloy soften and allowed to chill earlier than being cut into sections for extra examination.

Three specimens were acquired at 40°C after the dipped a part of the rods turned into prepared for metallographic studies the usage of a mounting press. Besides the six samples that had been kept at 40°C for distinct amounts of time. But this time, when the coating process became finished, the 3 samples were annealed for one hundred twenty mins at three hundred°C in a muffle furnace. Energy-dispersive X-ray spectroscopy (EDS), scanning electron microscopy (SEM), and X-ray diffractometry (XRD) had been then used to study the samples' mechanical and metallurgical microstructural characteristics.

#### IV. RESULT AND DISCUSSION

##### A) SEM

SEM analysis is a highly effective test method for microanalysis and failure analysis of solid inorganic materials. It employs an electron beam to provide a magnified image for analysis. In this study, SEM analysis was utilized to examine a coating composed primarily of aluminium, zinc, magnesium, and silicon alloy. Figure 3(a), 3(b), and 3(c) depict SEM images of specimens immersed at a temperature of 40°C for 30, 45, and 60 minutes, respectively. Figure 3(d), 3(e), and 3(f) show SEM images of specimens immersed at a temperature of 40°C for 30, 45, and 60 minutes respectively, and then annealed in a muffle furnace at a temperature of 300°C for 120 minutes.

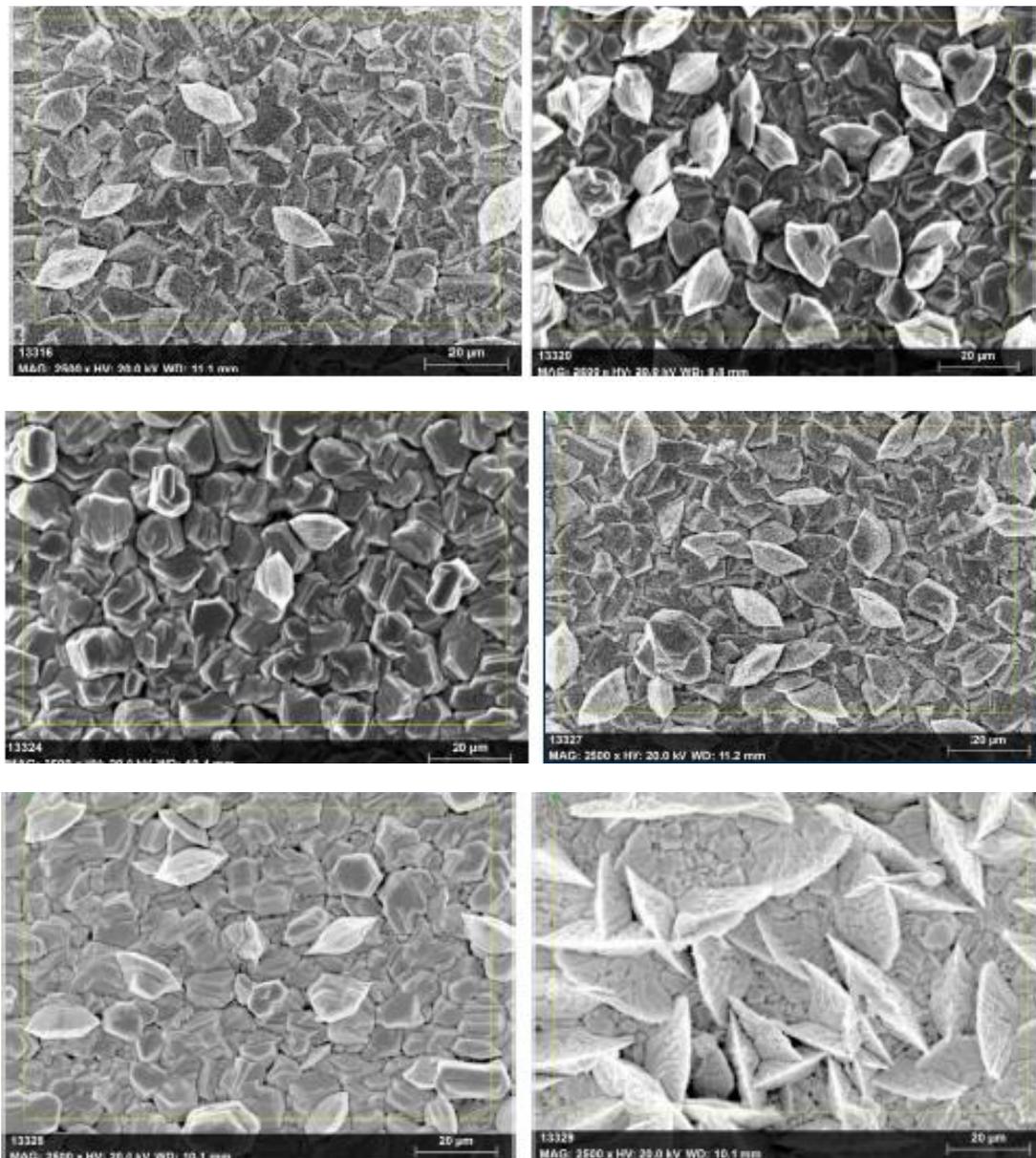


Figure 5: SEM micrograph of specimens at 40 °C with different immersion time

##### B) Composition Analysis of the Layers of IMC

EDS analysis was applied for the chemical composition determination of both 316L SS substrate and interfacial IMC layers. The results of an EDS analysis that was applied to construct a line scan across the intermetallic layers are shown in Figure 3. On

the other hand, zinc was also the most predominant element existing in every specimen from a SEM-SEI image of the selected area of the SS.

### C) EDS

EDS is a method of non-destructive testing that can determine the crystal structure of a material and provide details about its elemental composition. The technique involves the use of an electron microscope to emit a precise scanning electron beam, which stimulates the atoms in the sample to emit specific spectrums of x-rays. EDS shows the composition present in the coating of 316L SS.

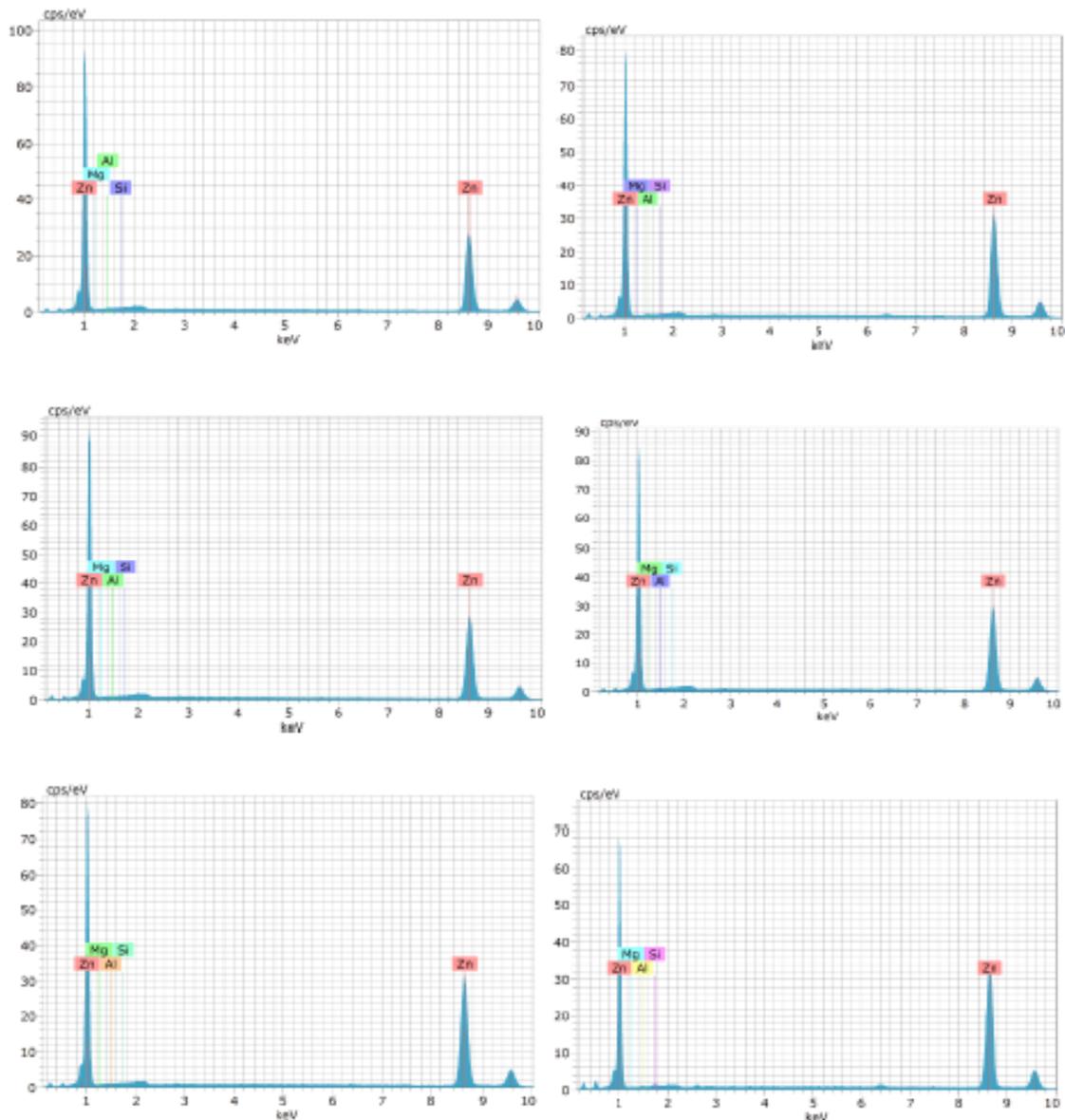


Figure 6: EDS composition present in the coating

### D) EIS CORROSION

Electrochemical Impedance Spectroscopy (EIS) is a proven quantitative technique that accelerates the assessment of protective coating's ability to prevent corrosion. EIS measurements yield dependable data within a brief testing period, enabling the forecast of the coatings' long-term efficacy. Fig 2 describes the Nyquist plot for specimens at different immersion time.

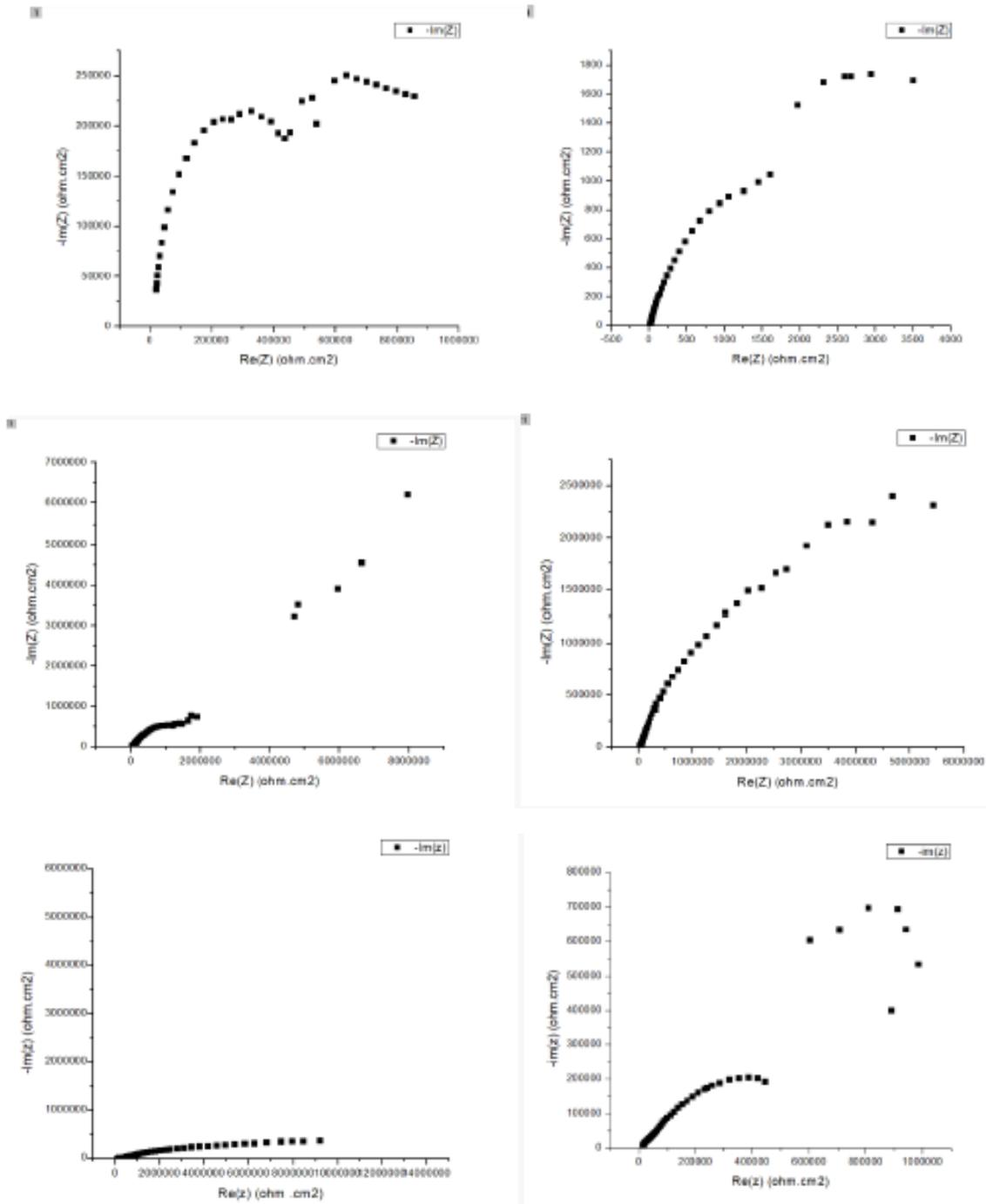


Figure 7: The specimens were subjected to EDX analysis at 40°C while immersed for varying durations

### E) XRD

One technique used in materials research to determine a material's crystallographic arrangement is X-ray diffraction analysis, or XRD. By subjecting the material to incident X-rays, the technique measures the angles and intensities of the X-rays that the substance emits.



## V. CONCLUSION

The study examined how altering time and temperature affects the microstructure of Al-Zn-Mg-Si coating, using SEM, EDS, and XRD. Analysis of EIS corrosion and XRD results showed that the sample immersed at 40°C for 30 minutes and annealed for 120 minutes exhibited the most favourable corrosion rate. Furthermore, the microhardness results indicated that the presence of metal in this coating improves the mechanical properties of 316L SS.

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