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# Corrosion Activity Laser Treated Aluminum-12% Silicon Alloy with Fe and Ti Powders at Two Different Energies

***Abstract*-:** *In This work, the corrosion activity of laser treated almium-12%silicon alloy was tested. The addition of Fe and Ti as elemental powders was studied. Two different laser energies of 750 and 1000 kJ were used. Corrosion measurements by potential static at 3mV.sec-1in condensed synthetic automotive solution. The corrosion data show that laser treatment led to increasing corrosion resistance due to smoothness of the surface alloy because of high energy, and the corrosion resistance in the presence of Fe and Ti powders better than that in the absence of metallic powders were increased from (8.416 Ω.cm2) to (11.216 Ω.cm2) whereas corrosion rate decreased from (1.3194) to (0.7615) of specimens which laser treated with present Ti compared with as received , and the corrosion resistance increase with increasing laser energy.*

***Keywords***- *Laser treatment, AL-12%Si alloy, corrosion.*

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## 1. Introduction

The microstructure of modification of surface by laser that involves tailoring and mixing sclerosis melting of some surface layers with many implicit bases in this process. At the melted surface layer of the substrate is becomes more efficiency in properties of materials by laser beam, when alloying elements are added to the melted pool then they will start to inter diffusion into the substrate[1]. During solicitation with higher cooling range and added elements diffusion lead to fine crystals distribution with homogeneous of structure additionally different in range of composition of surface can be lead to get a metastable phases [2].

Melting the surface by laser process is limited to melting in thickness but can produce a rapid solidification is effective on distribution of alloying elements especially on characteristics of the surface properties such corrosion and erosion or wear rates and lead to enhance the strength compared with materials without laser surface modification[3].

Some of studies the effect for concerned laser surface melting on aluminum alloys modifying include adding copper by using laser type $CO_2$ affected on pitting corrosion of 2024 aluminum alloy, the investigation shows any improvement in pitting rates because of present of pores wit cracks in the surface[4]. Another study presented the effected of energy density of pulsed (nanosecond range) on the corrosion surface behavior of pure metals with lower anodic polarization during the both types of potential-control [5].

Performed different studies on the hardness improvement of Aluminium using Ti, Ni and SiC powders. They found out that intermetallic phases such as Al3Ni and Al4C formed after the laser process enhance the hardness values of the aluminium, in other hand used Ni and SiC of different ratio to laser alloyed of aluminium [6].

This work is focus on the insinuative corrosion resistance for laser treated Al-12%Si alloy absence and presence of Fe and Ti powders in synthetic automotive solution using potential stat at 750 and 1000 KJ of laser energies.

## 2. Experimental

### *I. Materials and chemical*

The Al-12%Si alloy was used in the present work prepared by metallic cast with rod shape with mounting by using polymer type formaldehyde and leaving out side or topside of sample has (0.38465 $cm^3$) surface area to use in electrochemical studies. Then the wet ground were used for the specimens with different degrees of silicon carbide papers (600,800,1000 and 1200) the Specimen was cut mounted grained , polished by napped polishing pad and alumina slurry by using (Grinder and Polisher) machine.

An electrolyte of concentrate synthetic automotive solution [6]. with chemical

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composition is (0.019gm/L) ammonium sulphate, ammonium nitrate (0.077 gm/L), potassium chloride (0.1345 gm/L), ammonium hydroxide (0.033m/L) and HCl acid the PH of this solution was (3.5) used to corrosion test . All materials were weighed by digital balance.

*II. Laser Surface Alloying (LSA)*

The specimens were treated (laser surface heat treatment) by using pulse Nd:YAG with 1064 nm wave length, while the frequency of laser system 6 Hz . Time of irradiation of 5 min for different respective power values of 700 and 1000 J and pulse width was 8 ns and, laser beam was applied from distance 20 cm. After covering, the specimens surface fully by Powder feed rate is 3g/min and with regular distribution to obtain the Homogeneity in hardening. This treatment is carried out in laser engineering department.

*III. Microhardness test*

Shielding gas Vickers micro-hardness tester (model FM700) was used in the determination of the hardness values of the specimens. The hardness was conducted on the cross section of the samples using a load of 4.9 N, time 30 sec and three indentations were taking and the average values were recorded to find the Vickers hardness value for all specimens after surface hardening with powder of Fe and Ti, according to ASTM E 384-99. The equation from which the Vickers micro hardness is derived is shown below: [7]:

$$Hv = 1.854 \times \frac{P}{d^2} \quad (1)$$

Where:

Hv is the Vickers micro hardness (Mpa);P is the indentation load (N);d is half the indentation diagonal (mm) and 1.854 is a geometrical constant of the diamond pyramid.

*IV. Corrosion Test*

Corrosion tests ASTM standards G29 and D2776 were carried out with and without laser treated alminum-12% silicon alloy with the Fe and Ti powder.

Polarization test were performed on winking lab Potentiostat from Bank- lektronik were in University of Technology – Materials Engineering Department, with electrochemical standard cell with provision for working electrode (Al-12%Si),auxiliary electrode (Pt electrode), and a luggin capillary for connection with an (SCE) [saturated calomel electrode] as reference electrode. Electrochemical measurements were complete with a potentiostat at a scan rate 3mV.sec$^{-1}$. The main results obtained were expressed in terms of the corrosion potentials (Ecorr) and corrosion current density (icorr) to calculate corrosion rate (Rmpy) and polarization resistance. The penetration rate was calculated from the corrosion current values by the following equation [8].

$$R\,(mpy) = 0.13 \times i(corr)\frac{\rho}{e} \quad (2)$$

Where:

R(mpy) : - corrosion rate (mil per year), corrosion current density icorr (μA/cm$^2$), alloy density ρ (gm/cm$^3$), alloy equivalent weight e (gm/equivalent).

The resistance calculated Tafel slopes and by using the Stern-Geary equation [8].

$$\mathrm{Rp} = \frac{\mathrm{bc \times ba}}{[2.303 \times \mathrm{icorr(bc+ba)}]} \quad (3)$$

Where

RP: Polarization resistance (Ω.cm$^2$)

icorr: corrosion current density ( μ A.cm$^{-2}$).

ba: Cathodic slope (mV.dec$^{-1}$ )

bc: Anodic slope (m V. dec$^{-1}$)

**Table 1: Chemical composition of commercial aluminum- silicon alloy**

| Name | Wt%. element |
|---|---|
| Sı | 12.1 |
| Cu | 0.83 |
| Fe | 0.65 |
| Zn | 0.45 |
| Mg | 0.27 |
| Mn | 0.2 |
| Ti | 0.02 |
| Al | Rem. |

## 3. Result and Discussion

The micro-hardness depth profiles of the three laser alloyed surfaces with Fe and Ti powders is showed in Figure 1. the hardness values of the samples increase after the laser alloying. This improvement of the hardness values was attributed to the formation of the intermetallic phases after the laser process. From Figiure 1, it can be observed that samples exhibited the higher microhardness values. A hardness value higher that of the substrate was observed using of Fe and Ti metals powders. The hardness values obtained depend on the laser parameter used. The optimum conditions were obtained with Ti powder, a power of 1000J a hardness value of 248HV.

**Table 2: Average hardness value of the alloyed surface layers**

| Samples | Energy of laser | Average hardness N/mm$^2$ |
|---|---|---|
| As received | - | 122 |
| Laser treatment | 750 | 124 |
| Laser treatment with Fe powder | | 159 |
| Laser treatment with Ti powder | | 186 |
| Laser treatment | 1000 | 178 |
| Laser treatment with Fe powder | | 210 |
| Laser treatment with Ti powder | | 248 |

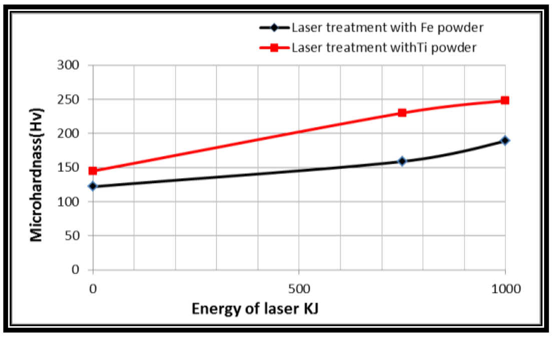


**Figure 1: Show the variation of microhardness for as received and laser treatments samples.**

*I. Potential-time measurements:*

Figures 2 and 3 show the variatce of potential with time for with and without laser treated aluminum - alloy at two energies. The figures indicate that open circuit potentials at 1000kJ more noble than it's at 750kJ. Also can be seen that laser treated alloy with Ti metal gave the noblest potential. This means that Ti powder inters the surface of Al- alloy and from protective layer on its surface.

*II. Linear Polarization Tests*

Figures 4 and 5 shows the polarization behavior of untreated alloy and laser treated alloy with metallic powders (Fe and Ti powder) at tow energies 750 and 1000kJ. The curves divided in two regions, anodic region, via dissolution of metals or oxidation can be take place by the reactions:

$Al \rightarrow Al_{3}+ + 3e-$ (3)

[The lower side represents reduction reactions which comprise hydrogen evolution molecules because of electrolyte as follows:

$2H+ + 2e- \rightarrow H_2$ (4)

In addition to reduction of oxygen is as follows:

$O2 + 4e + 4H+ \rightarrow 2H_2O$ (5)

This treatment shows the variety in polarization type linear for the alloys in experimental electrolytes with two powers. Potentiodynamic polarization curves (Figsures 4 and 5) show laser treatment affecting on the cathodic and anodic regions. This behavior show that the laser treatment in the absence and presence of metallic powers (Fe and Ti) lead to the shifting potential corrosion value (Ecorr) toward noble direction, in addition to get less corrosion current densities (icorr), e.i., significantly decreasing in corrosion rate, The current densities (icorr) were observed from the polarization by extrapolation of the side of cathodic part of the curves to the corrosion potential Ecorr. The corrosion parameters are clarified in Table 2.

This increasing in corrosion resistance attributed to the melting in the metallic surface, which leads to get softer surface which led to decreasing of cathodic and anodic sites after laser treatment. This mean the specimen output hydrogen action as an electron donor to electrolyte [9].

Corrosion resistance probably increase type means result at the surface have been dissolved in the structure because of the melting [10].

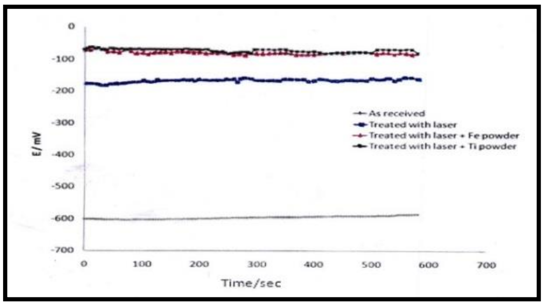


**Figure2: The different of open circuit potential – time] for as received and laser treatments 750 kJ.**

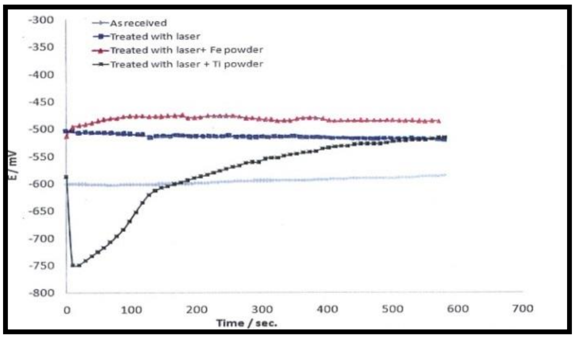


**Figure 3: The different of open circuit potential – time for as received and laser treatments 1000 kJ**

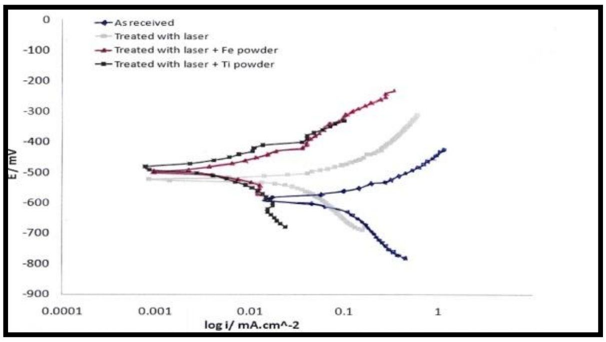


**Figure.4: Potentiodynamic polarization for as received and laser treatments 750 kJ.**

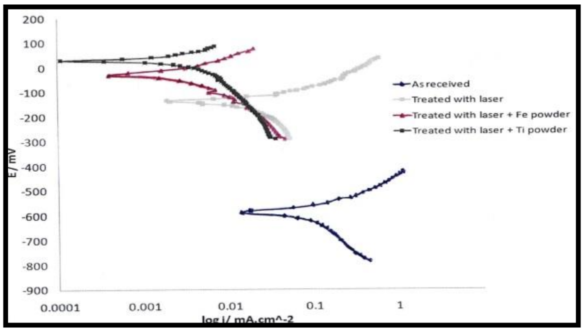


**Figure 5: Potentiodynamic polarization for] base and laser treatments 1000 kJ.**

## 4. Conclusion

1. Improve the polarization resistance for specimens which hardening by laser in the presence of metallic powders.
2. The effect of titanium (Ti) powder better than effect of Iron (Fe) powder on Al-12%Si alloy with used laser hardening.
3. Increasing laser energy of hardening lead to increasing the corrosion strength of alloy in the presence metallic powders.
4. Influence increasing of Nd:YAG laser power value led to information of precipitates and dislocations density the leads to improve microharrdness of Al-12%Si alloy.

**Table 2: Corrosion parameters for base and laser treatments at two energy.**

| **Samples** | **Energy of laser** | **-Ecorr mV** | **icorr $\mu A.cm^{-2}$** | **-bc $mV.dec^{-1}$** | **ba $mV.dec^{-1}$** | **Rmpy** | **Rpx$10^{+6}$ $\Omega.cm^2$** |
|---|---|---|---|---|---|---|---|
| As received | - | 586.4 | 59.09 | 174.7 | 92.2 | 26.163 | 0.443 |
| Laser treatment | | 522.3 | 19.10 | 125.3 | 66.0 | 8.457 | 0.982 |
| Laser treatment with Fe powder | 750 | 499.4 | 3.08 | 62.3 | 88.0 | 1.3637 | 5.142 |
| Laser treatment with Ti powder | | 489.9 | 2.98 | 117.2 | 115.1 | 1.3194 | 8.416 |
| Laser treatment | | 142 | 10.72 | 122.2 | 64.8 | 4.7466 | 1.715 |
| Laser treatment with Fe powder | 1000 | 30.1 | 1.76 | 114.9 | 95.4 | 0.7792 | 12.859 |
| Laser treatment with Ti powder | | 30.5 | 1.72 | 92.5 | 85.5 | 0.7615 | 11.216 |

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