Journal of
Nanomedicine & Nanotechnology

Al-Haidary et al., J Nanomed Nanotechnol 2017, 8:6
DOI: 10.4172/2157-7439.1000475

Research Article Open Access

Effect of Aging on Corrosion Behavior of Martensite Phase in Cu-Al-Be Shape Memory Alloy

Jafar Tahar. Al-Haidary*, Ali Mundher Mustafa and Ahmed Aziz Hamza

Department of Production Engineering and Metallurgy, University of Technology, Iraq

Abstract

The corrosion behavior of martensite phase in Cu-Al-Be shape memory alloy with aging at 150°C at different time and quenching media study by open circuit potential, tafal polarization and cyclic polarization. The microstructure of martensite study by optical microscope and x-ray diffraction (XRD) and transformation temperature was determined by Differential Scanning Calorimeter (DSC). The result show aging martensite at 150°C at 2 and 4 h have high open circuit potential, low corrosion current density, high corrosion potential and pitting potential than martensite without aging.

Keywords: Cu-Al-Be shape memory; Martensite phase; Corrosion behavior

Introduction

Cu-(13 wt.%) Al shape memory alloys with addition small amount of beryllium per elastic effect at room temperature, because the martensitic transformation from the austenite phase (β) have BCC crystal structure to marten site phase (18R) have monoclinic crystal structure [1-6]. The application of these alloy used as absorb vibration damping effect in bridge and building structure [7]. Heat treatment of this alloy like quenching from high temperature and then aging at different temperatures and time led to formation of different phases, and their Presence can affect their shape memory effect and corrosion behavior [8-10]. In realistic applications, as the alloy is exposure to corrosion solution for a period of time they are exhibit to corrosion and pitting, for that reason study of corrosion behavior like corrosion current and potential and pitting potential of the alloys are require to be done before they are put into biomedical and industrial applications. Since SMAs find a wide application in the marine, aerospace applications and it is also used in the surgical medical use such as guide wire, so it becomes necessary that the shape memory alloys high corrosion resistance to the environment in which it is being used, so it is important to evaluate the corrosion behavior of the SMAs [11-14].

Experimental Work

The master alloy of chemical composition Cu-13%Al-0.545%Be was received as cast from France company and chemical composition was carried by oxford foundry expert type. Figure 1 and Table 1 show oxford foundry expert type and chemical compositions.

Homogenized at 800°C for 3 h within the β phase region and then betatized at 800°C for 30 min and quenching in salt ice water. Aging at 150°C at 2, 4, 6 h and quenching in salt ice water, water and oil media. Figure 2 shows electric resistance box furnace type for aging samples.

The samples with dimensions 5 mm length and 14 mm diameter are (grinding with different wet paper 120, 320, 500, 1000, 2000 and wishing with water, polishing with cloth diamond and lubricant using polishing device then samples wishing with water, etching with solution 5 g $FeCl_3$, 10 ml HCL and 100 Ml H_2O. X-ray diffraction device type (shimadzu XRD-6000 X-Ray diffractmeter) Figures 3 and 4 devices for microstructure and XRD 6000 shimadzu type.

Figure 1: Oxford foundry master expert type chemical composition.

Corrosion testing by carried out using open circuit potential, tafel polarization and cyclic polarization. Corrosion study by electrochemical cell contains solution 1 liter and inside container there are three electrodes and these electrode are contact to the potentiostatic. Figure 5 shows cell connecting three electrode and potentiostat.

Result and Discussion

Microstructure

Heat treatment of Cu-Al-Be shape memory alloy at 800°C in

Element	Zn%	Pb%	Fe%	Si%	S%	Sb%	AL%	Be%	Cu%
Wt.%	0.003	0.0134	0.019	0.0242	0.0439	0.112	13	0.545	balance

Table 1: Chemical composition of Cu-Al-Be shape memory alloy.

Figure 2: Electric resistance box furnace type for aging samples.

***Corresponding author:** Jafar Tahar Al-haidary, Department of Production Engineering and Metallurgy, University of Technology, Iraq, Tel: 9647901449044; E-mail: ah_azez1583@yahoo.com

Received: November 01, 2017; **Accepted:** December 07, 2017; **Published:** December 13, 2017

Citation: Al-Haidary JT, Mastafa AM, Hamza AZ (2017) Effect of Aging on Corrosion Behavior of Martensite Phase in Cu-Al-Be Shape Memory Alloy. J Nanomed Nanotechnol 8: 475. doi: 10.4172/2157-7439.1000475

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a) b) c)

Figure 3: (a) Electric disk rotary grinding, (b) Polishing device (c) Optical microscope for microstructure observation.

Figure 4: XRD 6000 shimadzu type.

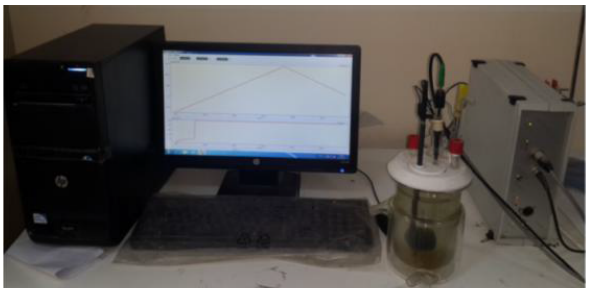

Figure 5: Cell connecting three electrode and potentiostat.

the Austenite phase region according to phase diagram for 3 h and quenching in ice water with salt transform to plate of martensite phase have monoclinic crystal structure. Figure 2 shows martensite phase at different magnifications.

Alloy that heat treatment at 800°C for 3 h and quenching in ice water have martensite phase, and this martensite phase have $AlCu_3$ phase. According to x-ray diffraction and standard cards, this x-ray diffraction identical with $AlCu_3$ card (Figures 6-8).

After quenching from 800°C, the samples were aging at 150°C in the martensite phase region according to phase diagram for 2, 4 and 6 h and quenching ice water with salt, water and oil. The martensite transformation is not appreciably effected by 100 h at 220°C or 260°C. Beyond annealing for 200 h at theses temperature, martensite transformation degradation is noticed caused by the precipitation phenomenon. The difference between martensite phases at aging 150°C have small and fine plate of martensite phase while as received have thick plate of martensite. Martensite phase that quenched in different media ice water with salt, water and oil have very small little difference in thich of plate martensite phase therefore difficult recognize between them at microstructure. Figures 8-12 show martensite phase at different aging time and quenching media at magnifications (10X).

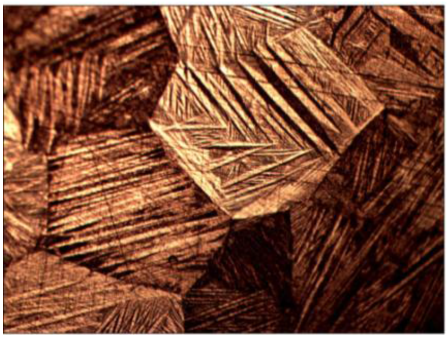

Figure 6: Martensite phase of Cu-Al-Be shape memory alloy.

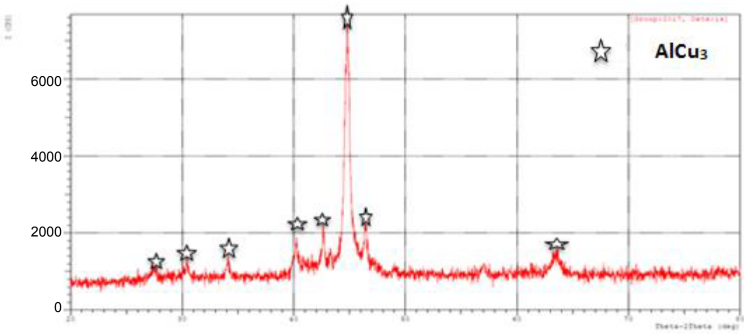

Figure 7: X-ray diffraction of Cu-Al-Be shape memory alloy.

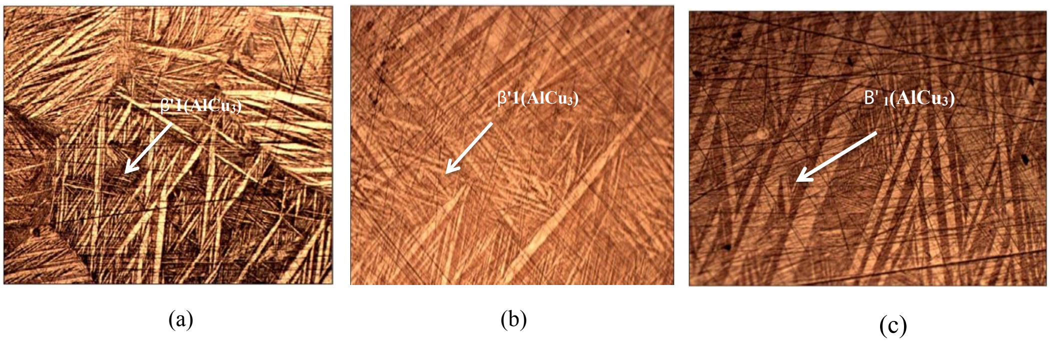

Figure 8: Effect of heat treatment on microstructure by optical microscope at magnification (10x). (a) 150°C 2 h salt ice water quenching (b) 150°C 4 h water quenching (c) 150°C 6 h salt ice water quenching.

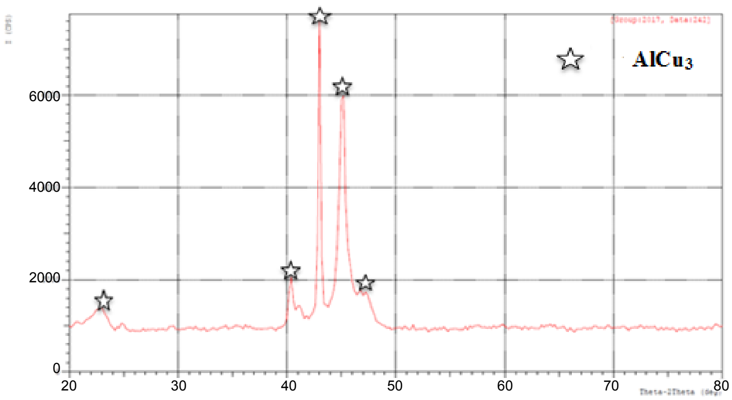

Figure 9: X-ray diffraction of Cu-Al-Be shape memory alloys that heat treatment at 150°C for 6 h and quenching in salt ice water.

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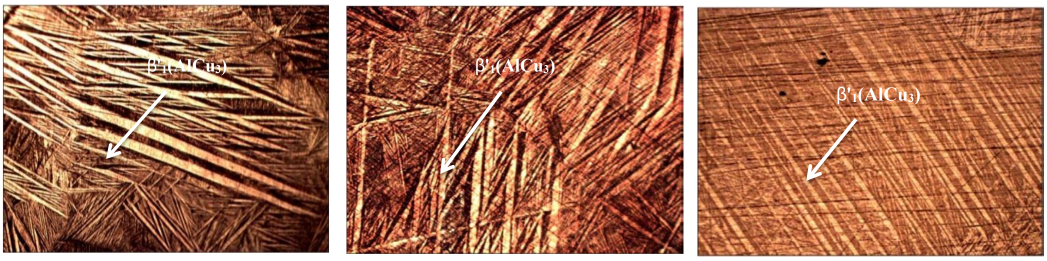


(a) (b) (c)

Figure 10: Effect of heat treatment on microstructure by optical microscope at magnification (10x). (a) 150°C 2 h water quenching (b) 150°C 4 h water quenching (c) 150°C 6 h water quenching.

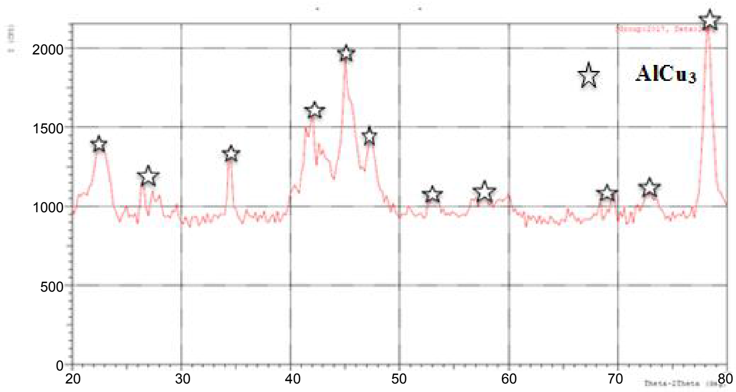
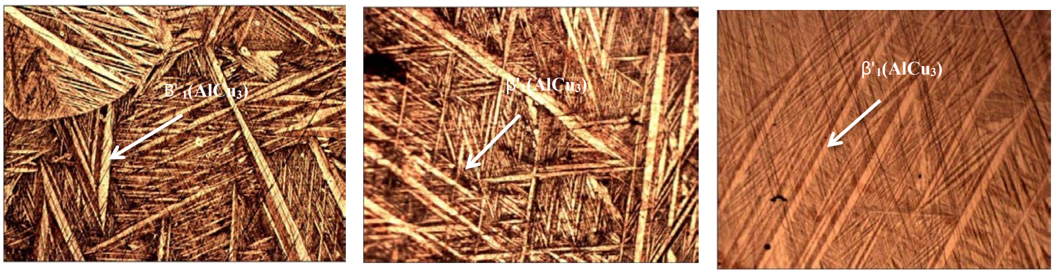


Figure 11: X-ray diffraction of Cu-Al-Be shape memory alloy that heat treatment at 150°C for 6 h and quenching in water.



(a) (b) (c)

Figure 12: Effect of heat treatment on microstructure by optical microscope at magnification (10x). (a) 150°C 2 h oil quenching (b) 150°C 4 h oil quenching (c) 150°C 6 h oil quenching.

Aging in the martensitic state are termed 'stabilization of martensite. Primarily two mechanisms have been proposed for the stabilization of martensite. One is reordering in martensite, i.e., atomic rearrangement in martensite, the second mechanism for the stabilization of martensite is pinning of interfaces between parent and martensite and between martensite variants by quenched-in vacancies and/or precipitates [14-18].

Alloy that heat treatment at 150°C for 6 h and quenching in salt ice ware, water and oil also have martensite phase have $AlCu_3$ phase, and according to x-ray diffraction and standard cards this x-ray diffraction identical with $AlCu_3$ card.

Effect of heat treatment on corrosion behavior

Shape memory alloy: Corrosion test begin with open circuit potential for 60 minute to get equilibrium potential and then applied voltage under equilibrium potential approximately 500 mV to get cathodic region and after this reach equilibrium potential then anodic region, passive region and transpassive.

Aging treatment at 150°C: Aging martensite phase at 150°C and after 2 h. show decrease in corrosion current and increase in corrosion potential, and when aging 4 h also show increase in corrosion potential because these are less strain energy effect than quenching from high temperature in ice water that have high strain energy that can effect on corrosion potential, while aging 6 h will be show decrease in corrosion potential at salt ice water and water quenching because long aging time that will move nanoparticles along martenstie phase plate and along grain boundary that decrease corrosion potential. Also show increase pitting corrosion when aging 2 h and 4 h in oil quenching effect of quenching media on corrosion potential show corrosion potential increase when quenching in oil than salt ice water and water (Tables 2-4 and Figures 13-18) show effect of aging.

The effect of corrosion on microstructure of alloy studied by optical microscope. Picture of microstructure after corrosion test show general corrosion and localized corrosion. The corrosion Processes would

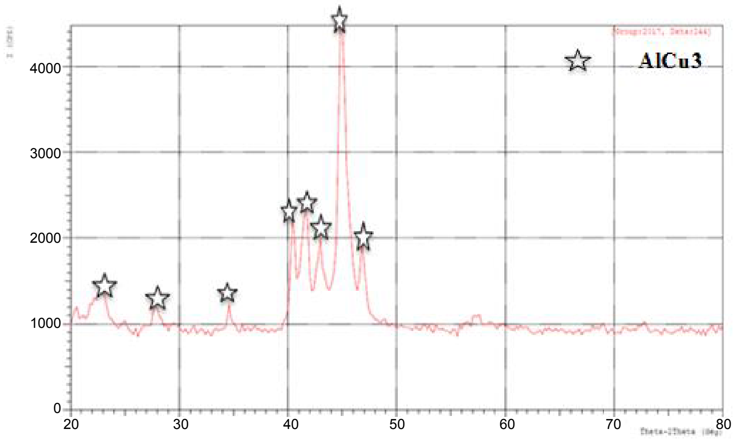


Figure 13: X-ray diffraction of Cu-Al-Be shape memory alloys that heat treatment at 150°C at 6 h and quenching in oil.

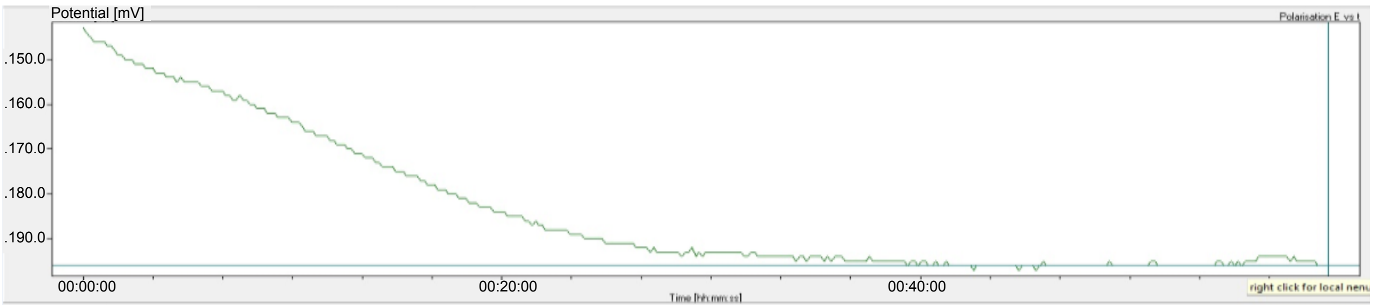


Figure 14: Open circiut potential (ocp) of Cu-Al-Be shape memory alloy.

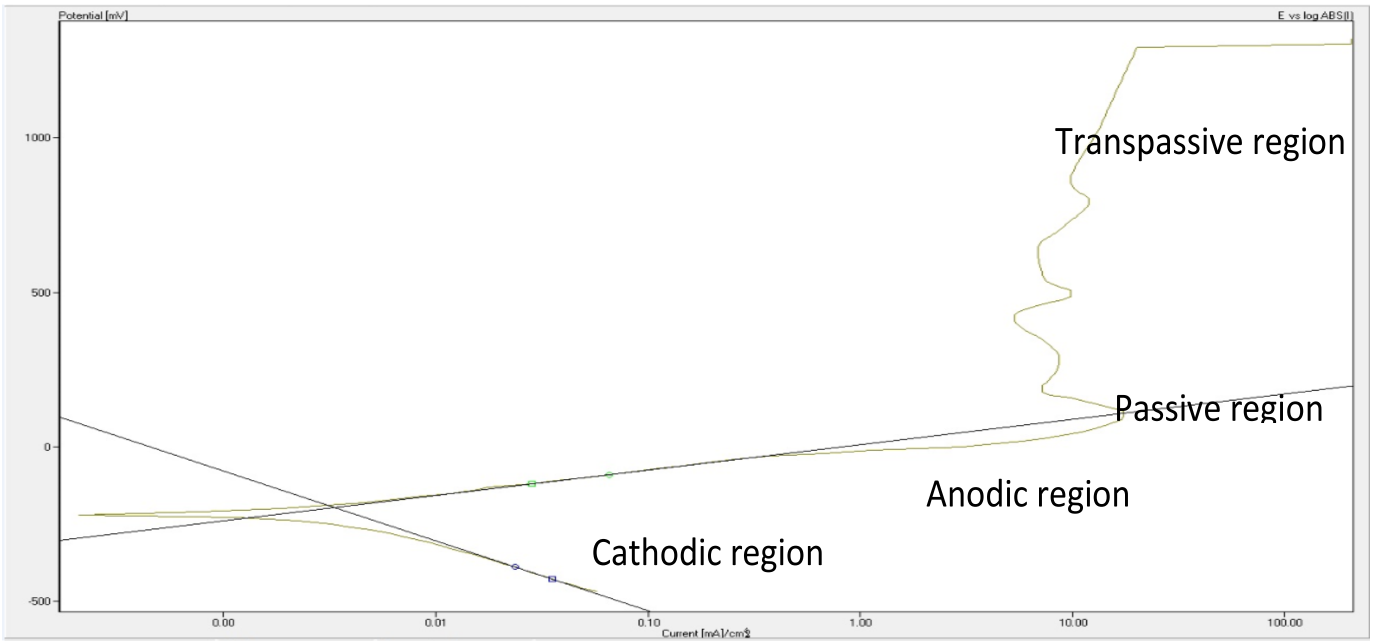


Figure 15: Tatal polarization of Cu-Al-Be shape memory alloy.

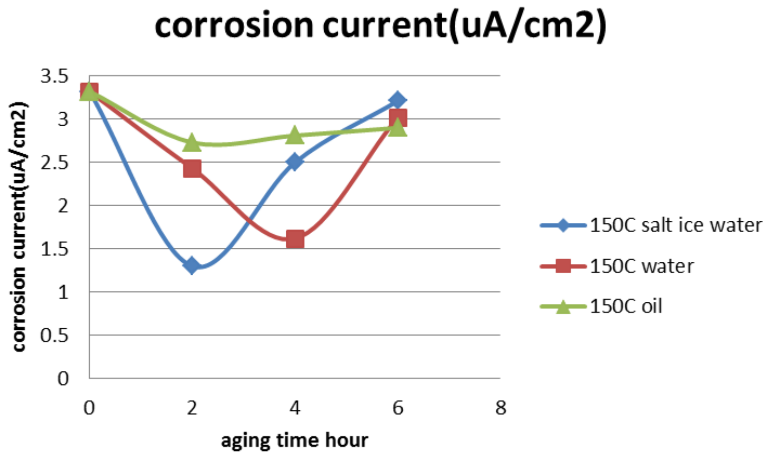


Figure 16: Effect of aging time, temperature and quenching media on corrosion current.

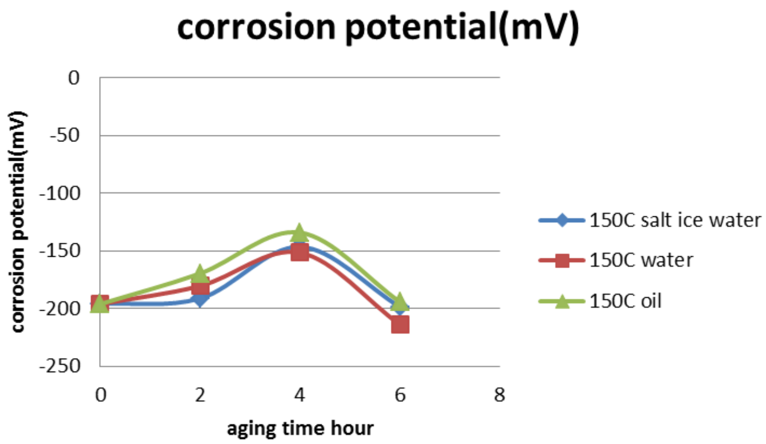


Figure 17: Effect of aging time, temperature and quenching media on corrosion potential.

(a) (b) (c)

Figure 18: Microstructure of martensite phase general corrosion and localized corrosion in Cu-Al-Be shape memory alloy.

Salt	g/L
NaCl	8.036
KCl	0.225
$CaCl_2$	0.293
$NaHCO_3$	0.352
K_2HPO_4	0.230
$MgCl_2.6H_2O$	0.311
$NaSO_4$	0.072

Table 2: Percent of salt in distillation water of simulation body fluid at pH 7.4 and temperature 37°C.

Heat treatment	Open circuits potential (ocp) (mV)
Shape memory alloy	-196
150°C 2 h ice water quenching	-191
150°C 2 h water quenching	-180
150°C 2 h oil quenching	-169
150°C 4 h ice water quenching	-146
150°C 4 h water quenching	-192
150°C 4 h oil quenching	-134
150°C 6 h ice water quenching	-199
150°C 6 h water quenching	-214
150°C 6 h oil quenching	-195

Table 3: Effect of heat treatment on open circuit potential (ocp).

Heat treatment	I_{corr} (uA/Cm^2)	E_{corr} (mV)	$E_{pitting}$ (mV)	Corrosion rate (mpy)
Shape memory alloy	3.32	-196.1	1292.6	1.6324
150°C 2 h ice water quenching	1.3	-191.2	1092	0.64
150°C 2 h water quenching	2.43	-180.4	1093.2	1.195
150°C 2 h oil quenching	2.73	-169.6	1255.8	1.3432
150°C 4 h ice water quenching	2.5	-146.6	1172.7	2.085
150°C 4 h water quenching	1.62	-151.6	955	0.7966
150°C 4 h oil quenching	2.81	-134.2	1450	1.3817
150°C 6 h ice water quenching	3.21	-198.7	1052.3	1.58
150°C 6 h water quenching	3.02	-214.1	1155	1.5
150°C 6 h oil quenching	2.9	-194.4	111.7	1.43

Table 4: Effect of heat treatment on corrosion current, corrosion potential and pitting potential.

occur mainly by the dissolution of both copper and aluminum. Samples present some zones with severe localized dealuminization [1,2].

Conclusion

- Open circuit potential of aging simple at 2 and 4 h more than sample without aging.
- Corrosion current density of sample at 2 and 4 h less than simple without aging and corrosion potential more than simple without aging.
- All simple approximately have same passivssion range.
- Simple aging at 4 h and oil quenching have high pitting potential than simple without aging.
- Aging at 6 h increase corrosion density and decrease corrosion potential.

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