Studying the Effect of Water on Electrical Conductivity of Carbon Reinforced Aluminum Composite Material

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Received 8, January, 2013
Accepted 4, July, 2013

Abstract:
The aim of this study is to understand the effect of addition carbon types on aluminum electrical conductivity which used three fillers of carbon reinforced aluminum at different weight fractions. The experimental results showed that electrical conductivity of aluminum was decreased by the addition all carbon types, also at low weight fraction of carbon black; it reached (4.53S/cm), whereas it was appeared highly increasing for each carbon fiber and synthetic graphite. At (45%) weight fraction the electrical conductivity was decreased to (4.36S\cm) and (4.27S\cm) for each carbon fiber and synthetic graphite, respectively. While it was reached to maximum value with carbon black. Hybrid composites were investigated also; the results exhibit that minimum value of the electrical conductivity at combination of (45%) weight fraction of fillers, it was (3.49S/cm).The maximum value of electrical conductivity was recorded at 3.5% NaCl solution, it reached (8.82 S/cm) with (45% C. F) for 7 week.

Key words: carbon types, aluminum & electrical conductivity

Introduction:
Composite materials consist of two or more different materials incorporated into a matrix to obtain performance characteristics beyond those could be achieved by the constituents individually. Composites typically contain one or stronger, stiff reinforcement constituent’s material embedded within a continuous constituent material (matrix). In the case of MMCs, the most common matrices are aluminum, copper, magnesium and titanium. MMC reinforcements can be metallic (such as tungsten and cobalt), non-metallic (most often carbon, graphite or boron) or ceramic [1].

A material may be required to conduct electrical currents. This includes metals and some non-metallic elements such as adhesives, greases, and other compounds loaded with graphite or metal powder. If electrical conductivity is important, then the resistivity of the material must be considered because electrical resistance creates voltage drop and heat generation, either of which may be a desirable or an undesirable consequence. In screening for electrical conductors, a maximum electrical resistance requirement must be defined, thus materials with equal or lower electrical resistivity become candidates for selection [2].

The charge is carried either by ions or electrons. The mobility of ions or electrons varies from material to material. Where mobility is high, the material is called conductor and where mobility is low the material is called insulator. The in- between materials are called semiconductors [3].

Aluminum and its alloys are widely used in a large number of industrial applications due to their excellent combination of properties. e.g. good corrosion resistance, excellent thermal

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and electric conductivity, high strength to weight ratio, easy to deform and high ductility. Aluminum alloys have been used generally in manufacturing automobile and aircraft components of high strength to weight ratio in order to make the moving vehicle lighter, which results in saving in fuel consumption, containers and electronic devices [4].

Nirvana studied Electrical conductivity behavior of Cu-powder reinforced epoxy composite material in different solutions (distilled water, tap water &3.5%NaCl) with a weight fraction (5, 15, 30 &45) was investigated for (7) weeks immersion time. The results exhibit that electrical conductivity increases as increasing immersion time due to the specimen was absorbed the solutions. The maximum values were reached with 3.5% NaCl solution because of Cl ions whereas electrical conductivity not apparent in distilled water was attributed to pure water containing no ions is an excellent insulator [5].

Soon-gi shin studied the effect of carbon content on the electrical conductivity of carbon black-filled PMC with various matrices. The electrical conductivity of carbon black-filled polymer matrix composites (PMC) with various matriceswas studied as a function of carbon content to find the break point of the relationship between carbon contentand conductivity. Conductivity jumps by as much as ten orders of magnitude at the break point [6].

Experimental Work

1- Material

- Al powder (99.9%purity), Germany
- carbon black, carbon fiber&synthetic graphite,Germany

2- Equipments

- Dies
- LCR- meter

Experimental set up

1. Weight amount of Al-powder were mixed with measured carbon at different weight fraction (5, 15, 30& 45) %.
2. The mixture was mould and the samples of composite were cutting by(2&.5) cm dimensions.
3. The sample surface was Polishing to improve smoothing.
4. Silver was electroplating on the sample surface to improve the electrical properties.
5. The simplest capacitor structure disc form, consisting of a layer of dielectric material sandwiched between two silver layers.
6. The device precision LCR meter was accurately adjusted then used to measure the resistivity (R) values on the electronic screen. From those value done at the electrical conductivity was found by equation 1. These measurements test for (1 KHz.) at room temperature.
7. Whole Samples were immersed in distilled water, tap water &3.5%NaCl at room temperature for different periods of time (1, 2, 3, 4, 5, 6&7) weeks.
8. The samples were dried at room temperature for two hours after immersion test.

$$\sigma = \frac{d}{R.A} \quad \text{-------} \ (1)$$

Where:

σ:electrical conductivity (S/cm), d: diameter of specimen, cm

R.: electrical resistivity, Ω/cm, A:cross- section area, cm^2

Results and Discussion:

The charge is carried either by ions or electrons. The mobility of ions or electrons varies from material to material. Where the mobility is high, the material is called conductor and where mobility is low the material is called insulator. In between materials are called semiconductors.

If a material is placed in an electric field, the charged particles interact with the field. If the material is a conductor, the free electrons simply move to the nearest positive electrode; with no field is needed, thus, left within the material. If the material is non-conducting or an insulator the electrons are only locally displaced, because they are bound to individual atoms.

The properties of the filler play a significant role in determining the conductivity of the composite materials. Carbon, when used as filler, comes in many different forms, from small carbon particles to graphite fibres. Typical electrical conductivity values for other materials are 10^2 s\cm for electrically conductive carbon black, 10^4 s\cm for carbon fibres and 10^5 s\cm for graphite [2].

The Effect of weight fraction:

The effect of weight fraction (0, 5, 15, 30 &45) % of carbon reinforced aluminum composite materials was investigated in this work. When a small quantity of carbon, which is lesser than aluminum, is added to aluminum, which is good conductor, reduces the conductivity of aluminum. Thus the conductivity of metals is always, reduced by the addition of second metal.

The Effect of solutions

Electrical conductivity behavior of carbon reinforced aluminum composite material in different solutions (distilled water, tap water &3.5%NaCl) with a weight fraction (5, 15, 30 &45) for 7 week immersion time as shown in figures (4-5), The results exhibit that electrical conductivity increases as increasing immersion time due to the specimen was absorbed the solutions. After that time will be constant because the specimen was saturated with solution.

The electrical conductivity values were different from solution to another according to ions in aqueous solution, therefore the maximum value was recorded at 3.5% NaCl solution, it reached (8.82S/cm) with (45% C. F) for 7 week.Electrical conductivity for different fillers as shown in table (1-5)

The conductivity of a solution of water is highly dependent on its concentration of dissolved salts, and other chemical species that ionize in the solution, Pure water containing no ions is an excellent insulator, but not even "deionized" water is completely free of ions.

If water has even a tiny amount of such an impurity, then it can conduct electricity readily, as impurities such as salt separate into free ions in aqueous solution by which an electric current can flow. Any electrical conductivity observable in water is the result of ions of mineral salts dissolved in it.

Conclusion:

1. The electrical conductivity of aluminum will be reduced by the addition of all carbon types.
2. The results exhibit that carbon black was effective more than other fillers at low weight fraction.
3. Carbon fibers and synthetic graphite were influence on electrical conductivity at high weight fraction.
4. Combination of fillers was favorite for electrical conductivity at any weight fraction.
5. The electrical conductivity values were different from solution to another according to ions in aqueous solution.

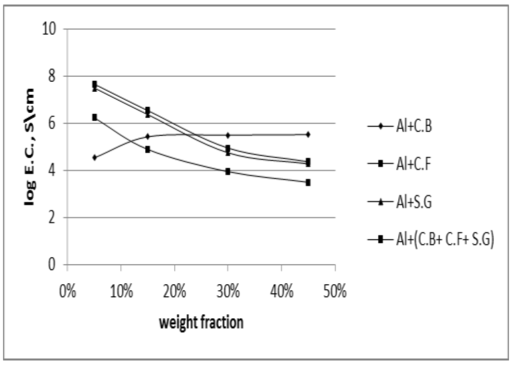

Fig. 1: log E.C. of aluminum reinforced with carbon types

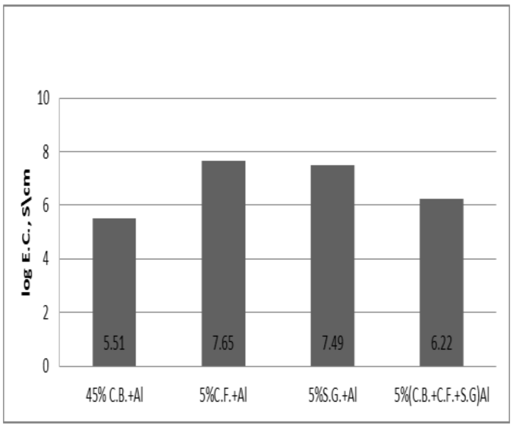

Fig. 2: maximum values of E.C. of aluminum reinforced with carbon types

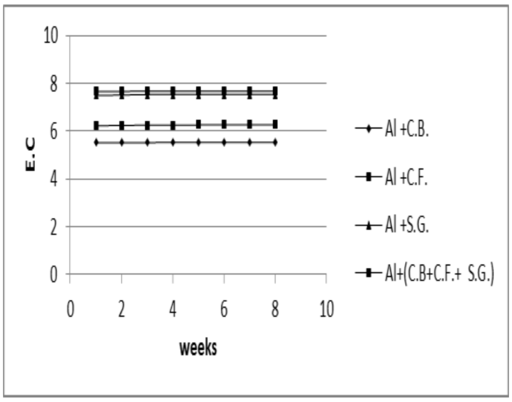

Fig.3: the variation of electrical conductivity (σ) with immersed in distilled water

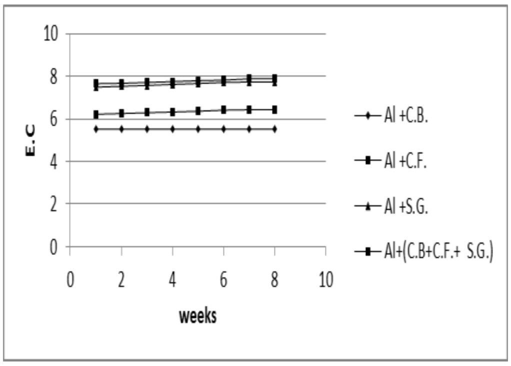

Fig.4: the variation of electrical conductivity (σ) with immersed in tap water

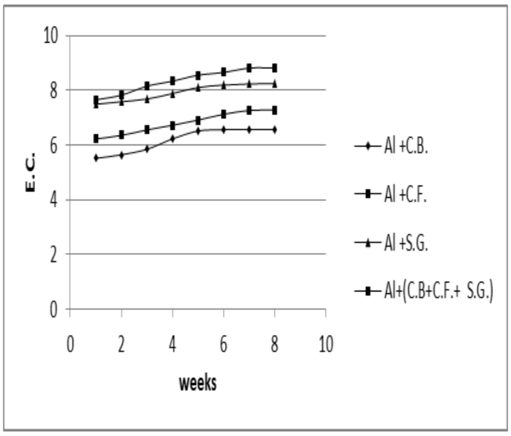

Fig.5: the variation of electrical conductivity (σ) with immersed in (3.5%NaCl)

Table 1: electrical conductivity for different fillers

Samples	E.C, *S/cm*			
	5%	**15%**	**30%**	**45%**
Al+C.B	$3.44*10^3$	$2.67*10^4$	$3.1*10^4$	$3.3*10^4$
Al+C.F	$4.5*10^6$	$3.42*10^5$	$0.89*10^4$	$2.33*10^3$
Al+S.G	$3.1*10^6$	$2.33*10^5$	$0.55*10^4$	$1.87*10^3$
Al+(C.B+ C.F+ S.G)	$1.66*10^5$	$0.77*10^4$	$0.88*10^3$	$3.12*10^2$

Table 2: electrical conductivity for different fillers

Samples	Log E.C, *S/cm*			
	5%	**15%**	**30%**	**45%**
Al+C.B.	4.53	5.42	5.49	5.51
Al+C.F.	7.65	6.53	4.94	4.36
Al+S.G.	7.49	6.36	4.74	4.27
Al+(C.B+ C.F.+ S.G.)	6.22	4.88	3.94	3.49

Table 3: the variation of electrical conductivity (σ) with immersed in distilled water

Samples	Log E.C, *S/cm*(σ)							
	0 week	1 week	2 week	3 week	4 week	5 week	6 week	7 week
Al +C.B.	5.51	**5.52**	**5.52**	5.53	5.53	5.53	5.53	5.53
Al +C.F.	7.65	7.66	7.67	7.67	7.67	7.67	7.67	7.67
Al +S.G.	7.49	7.51	7.53	7.53	7.53	7.53	7.53	7.53
Al+(C.B+C.F.+ S.G.)	6.22	6.24	6.25	6.25	6.26	6.26	6.26	6.26

Table 4: the variation of electrical conductivity (σ) with immersed in tap water

Samples	Log E.C, *S/cm*(σ)							
	0 week	1 week	2 week	3 week	4 week	5 week	6 week	7 week
Al +C.B.	5.51	5.51	5.51	5.51	5.51	5.51	5.51	5.51
Al +C.F.	7.65	7.67	7.71	7.75	7.79	7.82	7.88	7.88
Al +S.G.	7.49	7.53	7.57	7.62	7.66	7.71	7.73	7.73
Al+(C.B+C.F.+ S.G.)	6.22	6.25	6.29	6.32	6.36	6.41	6.43	6.43

Table 5: the variation of electrical conductivity (σ) with immersed in (3.5%NaCl)

Samples	Log E.C, *S/cm*(σ)							
	0 week	1 week	2 week	3 week	4 week	5 week	6 week	7 week
Al +C.B.	5.51	5.64	5.84	6.22	6.51	6.56	6.57	6.57
Al +C.F.	7.65	7.82	8.15	8.33	8.55	8.65	8.81	8.82
Al +S.G.	7.49	7.58	7.68	7.88	8.1	8.19	8.23	8.25
Al+(C.B+C.F.+ S.G.)	6.22	6.35	6.55	6.72	6.91	7.12	7.26	7.28

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دراسة تأثير الماء على التوصيلية الكهربائية للالمنيوم المدعم بانواع مختلفة من الكاربون

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الخلاصة:

تهدف الدراسة لمعرفة تأثير اضافة انواع الكاربون على التوصيلية الكهربائية للالمنيوم . اظهرت النتائج العملية ان التوصيلية الكهربائية للالمنيوم قلت عند اضافة كل انواع الكاربونوكذلك عند الكسور الوزنية القليلة لاسود الكاربون، حيث وصلت الى (4.53S/cm) في حين وصلت الى قيم عالية لكل من الياف الكاربون والكرافيت. اما عند الكسر الوزني(45%) فنجد ان التوصيلية الكهربائية قلت الى (4.36S\cm) و (4.27S\cm) لكل من الياف الكاربون والكرافيت بينما وصلت الى اعلى قيمة عند التدعيم باسود الكاربون. كذلك تم دراسة المواد المتراكبة الهجينة، اظهرت النتائج ان اقل قيم للتوصيلية الكهربائية كانت عند التدعيم ب (45%) من الحشوات، حيث كانت (3.49S/cm). سجلت اعلى قيم للتوصيلية الكهربائية عند المحاليل الملحية حيث وصلت (8.82 S/cm) عند النسب الوزنية (45% C. F) لمدة 7 اسابيع.