Electrochemical Behaviour of Al Based Hybrid Nanocomposites

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Abstract

The pure Al matrix composites reinforced with micro-Ti (Ti) particles as well as micro-Al_2O_3 (MA) or nano-Al_2O_3 (NA) particles have been developed via powder metallurgy route. Corrosion tests in aqueous 3.5 wt.% NaCl solution at neutral pH have been carried out. The same has also been investigated for the Al composites reinforced with these particles alone i.e., Ti, MA, NA. The hybrid composites i.e., Al+Ti+MA and Al+Ti+NA exhibited relatively inferior response to corrosion as compared to the composites Al+Ti, Al+MA and Al+NA. The particles are considered as defects in the passive film. Thus, it is difficult to build a dense passive layer free from defects in case of the composites reinforced with higher volume fraction of ceramic and metallic particles.

Keywords: Al; Hybrid composite; Nanocomposite; EIS; Passive film

1. Introduction

Al and its alloys are used in automobile, aerospace and marine industries. The development of Al matrix composites (AMCs) is a well-accepted method to improve the strength of Al metal and alloys. It would be interesting to take the simultaneous advantage of ductility from the addition of metallic reinforcement as well as the strength from the addition of hard ceramic particles. Ti is an attractive choice as reinforcement owing to its high specific strength and high stiffness. There is limited information about corrosion behavior of the hybrid AMCs. Specially, the number of literature on hybrid AMCs that are reinforced with metallic as well as ceramic is further fewer. Therefore, in the present investigation, corrosion

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behaviour of pure Al matrix composites reinforced with micro-Ti particles and micro-Al_2O_3/nano-Al_2O_3 particles developed via powder metallurgy have been assessed. As a basis for comparison, the same has been investigated for the Al composites reinforced with these particles alone.

2. Experimental procedure

Al powder (50 μm) was used as the matrix material. Ti powder (50 μm) and two different sizes of Al_2O_3 powder (50 nm and 300 μm) were used as the reinforcements. The various combinations of Ti and Al_2O_3 particles used in the composites and their abbreviated nomenclature are listed in Table 1. The Al matrix composites were fabricated by powder metallurgy route. Sintered was carried out in a tube furnace at 600°C for 2 h under Ar. Microstructures of all the composites were examined using a SEM. The specimens for microstructural analysis were prepared by standard metallographic technique using Keller's reagent. Electrochemical corrosions tests were carried out in aqueous 3.5 wt.% NaCl solution at neutral pH. Potentiodynamic polarization scan (PPS) started from +/-150 mV relative to the free corrosion potential. From the cathodic branch of the polarization curve the corrosion rate was determined using the Tafel slope. Electrochemical Impedance Spectroscopy (EIS) measurements at free corrosion potential then were carried out over the frequency range 10 kHz to 0.01 Hz. The EIS scans were conducted at the interval of 3 and 18 h of immersion.

Table 1. Various combinations of Ti_p and Al_2O_{3p} in the composites and their corresponding abbreviated nomenclatures

Materials used	Abbreviated nomenclature
Al+Macro Ti_p	Al+Ti
Al+Macro Al_2O_{3p}	Al+MA
Al+Nano Al_2O_{3p}	Al+NA
Al+Macro Ti_p+Macro Al_2O_{3p}	Al+Ti+MA
Al+Macro Ti_p+Nano Al_2O_{3p}	Al+Ti+NA

3. Results and discussion

3.1 Microstructure

Fig. 1 (a-e) shows the SEM micrographs for all the composites. It is evident that the metallic Ti particles were uniformly distributed in the Al+Ti, Al+Ti+NA and Al+Ti+MA composites.

Clustering of reinforcing particles in general is negligible in all the composites. The micrographs of the composites exhibited good interfacial integrity between the matrix and the reinforcements. The absence of debonding or discontinuity at the interface indicated superior sintering.

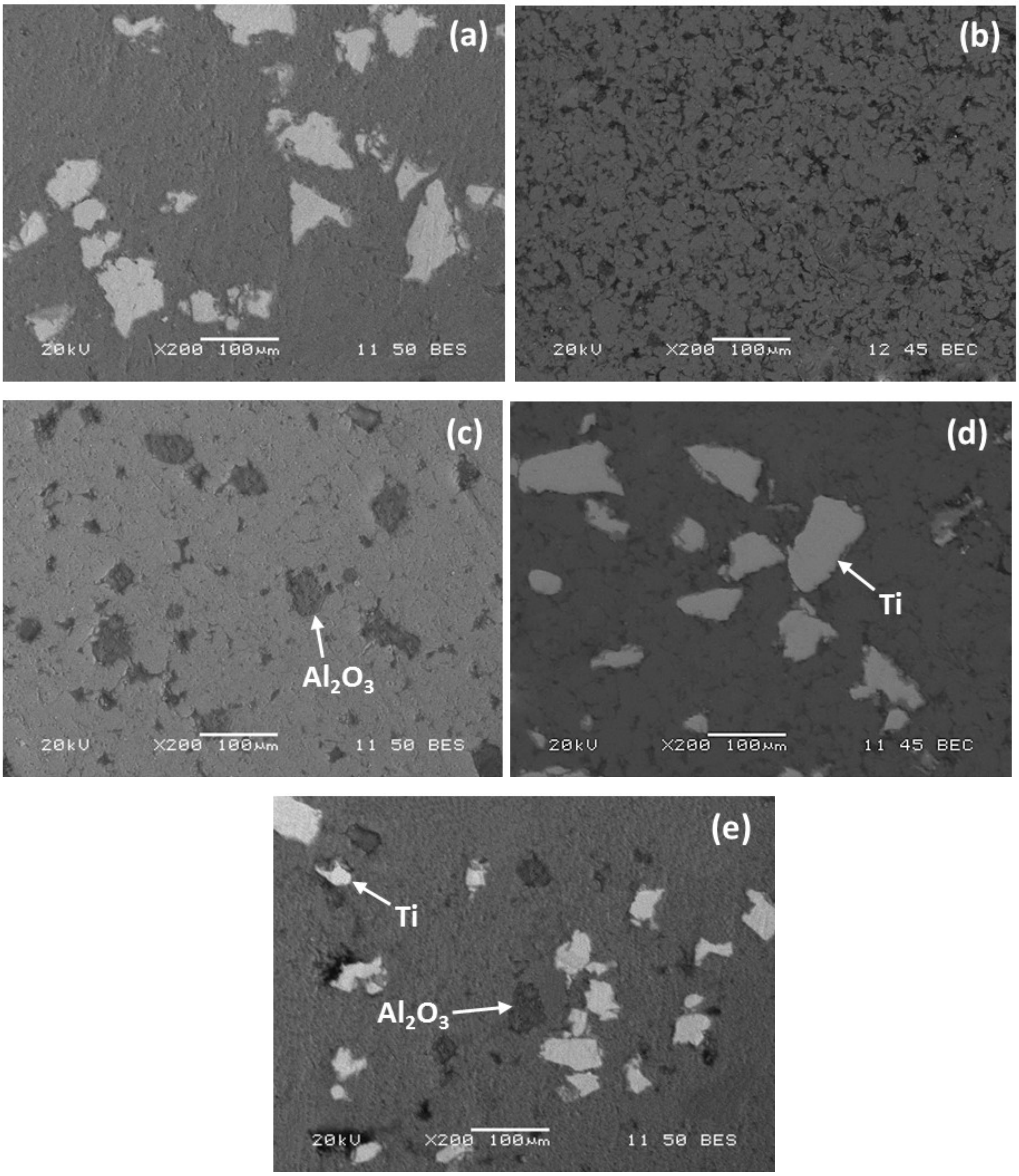

Fig. 1. SEM micrographs (in BSE mode) corresponding to (a) Al+Ti; (b) Al+NA; (c) Al+MA; (d) Al+Ti+NA and (e) Al+Ti+MA.

3.2 Corrosion behaviour

Fig. 2 shows the corrosion rates determined by PPS for all the composites. The Al+Ti composite exhibited the lowest corrosion rate. The composites reinforced with ceramic particles (micro or nano) alone exhibited higher corrosion rate as compared to the composite reinforced with metallic particles alone. In addition, the composites reinforced with nano-Al_2O_3 particles alone exhibited better corrosion resistance as compared to the composite reinforced with macro-Al_2O_3 particles alone. Further, relatively higher corrosion rates were exhibited by the composites having ceramic as well as metallic particles (i.e., HCs) as compared to the composites reinforced with individual particles. Again Al+Ti+NA HC exhibited superior corrosion resistance as compared to that of Al+Ti+MA HC.

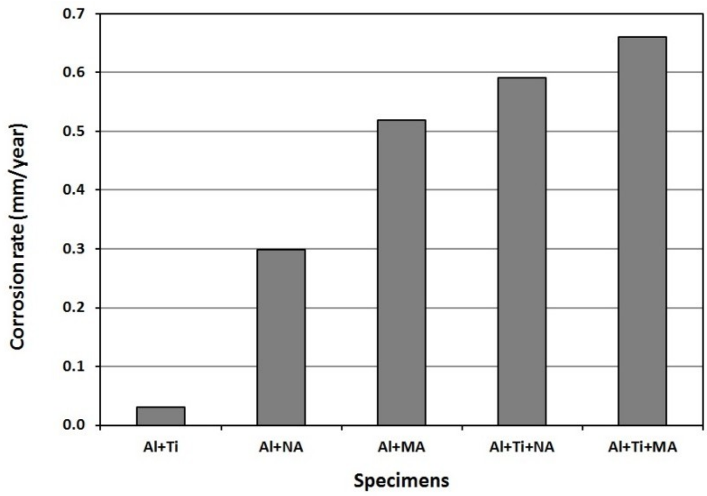

Fig. 2. Variation of corrosion rate for all the composites.

The typical Nyquist plots obtained for the all the composites after 3 and 18 h of immersion are shown in Fig. 3. The Al+Ti composite maintained its best performance compared to other composites. The corrosion behaviour in EIS was similar to that observed in PPS.

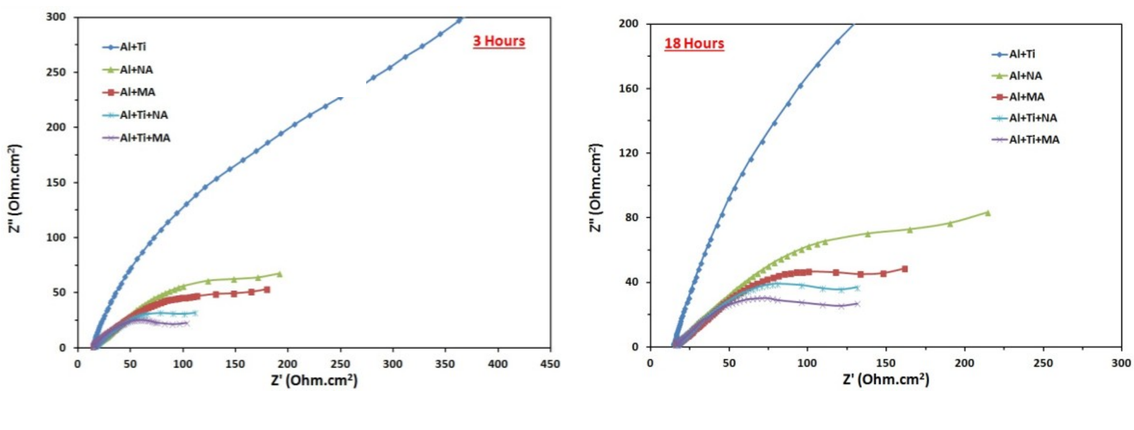

Fig. 3. Nyquist plots for all the composites after 3 and 18 h of immersion.

Fig. 4 (a & b) shows the SEM micrographs of the corroded surface of the Al+Ti and Al+Ti+MA composites. The film on the Al+Ti composite is thin and uniform. The film on the Al+Ti+MA composite is discontinuous and consists of large no of pits.

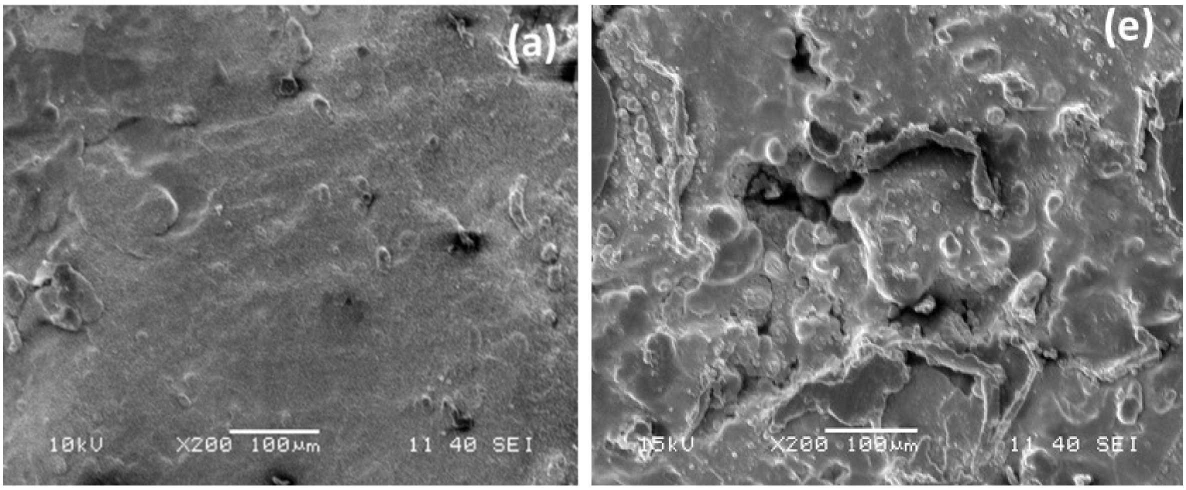

Fig. 4. Micrographs of corroded surfaces from the (a) Al+Ti and (b) Al+Ti+MA composites.

The microstructural changes introduced by addition of particles are the most likely reasons for difference in corrosion behaviour among the composites. The particles are considered as defects in the passive film and therefore, it is difficult to build a dense passive layer free from defects in the composites reinforced with higher volume fraction of ceramic and metallic particles [1].

4. Conclusions

The hybrid composites exhibited relatively inferior response to corrosion as compared to the composites reinforced with individual particles alone. The nano particle reinforced composites were better than the micro particle reinforced composites. It is difficult to build a dense passive layer free from defects in case of the composites reinforced with higher volume fraction of ceramic and metallic particles.

References

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