MICROSTRUCTURE AND MECHANICAL PROPERTY OF IN-SITU TiC_P/2024 COMPOSITES

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In-situ Al matrix composites were fabricated by direct reaction synthesis (DRS). Fabricate particulate composites with an extremely fine reinforcement size. Extensive analysis of the composites microstructure using SEM and TEM identify that the reinforcement formed during the DRS process is Ti carbide (TiC) particle, generally less than 1.0μm. The reacted, thermal extruded samples exhibit a homogeneous distribution of fine TiC particle in 2024Al matrix. Mechanical property evaluation of the composites has revealed a very high tensile strength relative to the matrix alloy. It is Fractographic analysis indicates ductile failure although the ductility.

1. Introduction

Because of their high specific strengths, specific module, wear resistance and thermal stability, the Al matrix composites reinforced by ceramic particles have attracted much interest in the development of manufacturing processes or such composites. The fabrication processes of ceramic particles reinforced aluminum alloy composites by casting techniques such as squeeze casting, compocasting, stirring method and die casting, process are very promising for manufacturing composite parts at relatively low cost [1-3]. However, in the above mentioned methods, the reinforcing particles are directly incorporated into liquid matrix, thus the morphology of reinforcements is not easily controlled and the reactants often appear at the interface between matrix and reinforcement, which deleteriously affects the mechanical properties of final composites [4]. Much improvement has been made not only in the decrease of the density of the material but also in the increase of the strength and stiffness of the materials. More recently, many researches have been done on a new approach- in-situ, to prepare MMC_S, including SHS (self-propagation high temperature synthesis), XD and DRS [5-9]. Because the dispersed ceramic particles are in-situ formed in the matrix, the interface between the ceramic and matrix is free from oxides, and the interfacial contact strength is high, in addition, of the particles are of submicron and the distribution of the particles in the matrix is homogeneous. As a result, the mechanical properties, such as strength, stiffness, increase markedly.

In this paper, a novel in-situ method – direct reaction synthesis (DRS) – has been reported. The process of the DRS, and the microstructure and mechanical properties of the MMC_S have been described in detail.

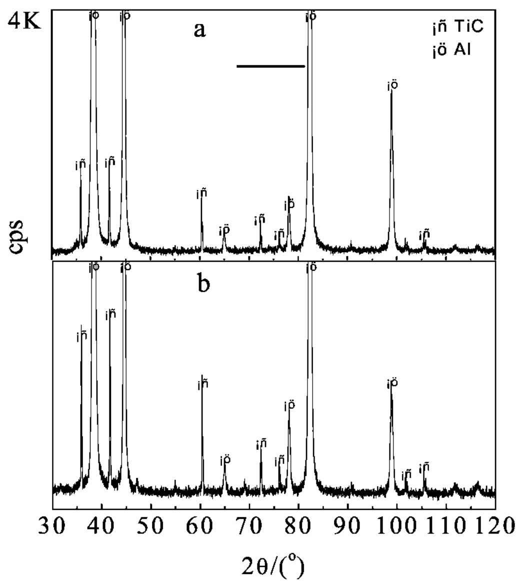

Fig .1. The XRD pattern of TiC_P/2024 composites (a)10wt%TiC (b)20wt%TiC

2. Experimental

Titanium powder (99.7%, less than 45μm) and graphite powder (99.9%, less than 5μm) were mixed with aluminum powder (99.5%, less than 29μm) according to 50Al+25C+25Ti(in at. pct), and pressed into 30mm in diameter×10mm long performs with 50% theoretical density.

Melting of 2024Al was achieved under air. Upon reaching the appropriate processing temperature, the preforms were put into the metal alloy by a tool immediately, as shown in Fig. 2, then the synthesis reaction happened in the melt immediately and intensely. The processing time ranged from 2 to 20 min; processing temperature was selected between 800~900°C. The reaction was carried out for appropriate time to completion conversion to Ti carbide. After completion of the reaction, the melt was agitated and then shaped by thermal extrusion. The phase analysis was conducted X-ray diffractometer. The microstructure of final

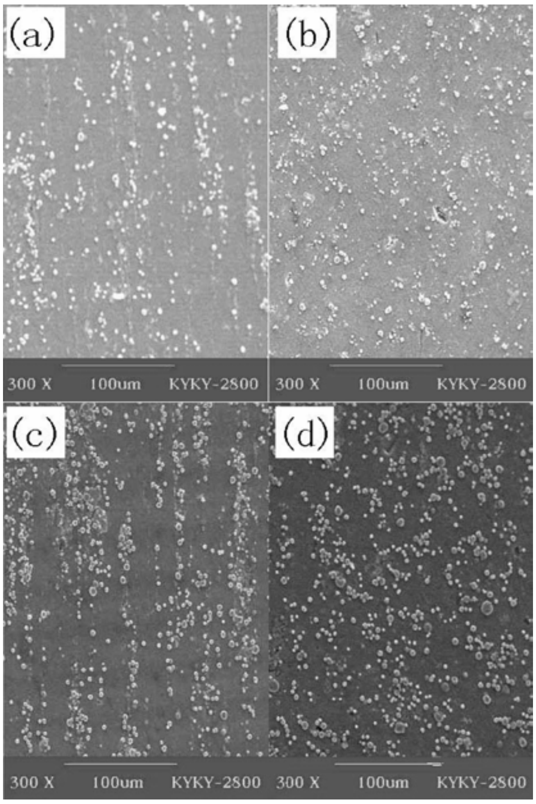

Fig.2. Microstructure of extruded of TiC_p/2024 composites (a), (b)10wt%TiC_p (c), (d) 20wt%TiC_p (a), (c) showing microstructure of longitudinal direction (b), (d) showing transverse microstructure

product was observed by KYKY-2800 scanning electron microscopy (SEM), JIM2010 transmission electron microscopy (TEM). The piece-shape tensile specimens were machined to gauge width of 6.3 mm and gauge high of 2.0 mm and gauge length 20 mm. Tensile specimens were heat-treated by solutioning at 490±5°C for 1.5h, and artificial aging at 175±5°C for 8h. All samples were tested at room temperature in an Instron testing machine. The strain rate was selected at 0.008mm·s^{-1}.

3. Results and discussion

3.1 Results of XRD

The XRD pattern of the reaction synthesized composites with 10%TiC, 20%TiC is shown in Fig.1. There are only diffraction peaks of Al and TiC phase, no evidence of residual Ti and carbon has been found, displaying that the phase constitution consists of Al and TiC.

3.2 Microstructure of in-situ TiC_P/2024Al composite

Microstructure of in-situ TiC_P/2024Al composite thermal extruded at ratio of 1:20 has been shown in Fig.2. In the transverse section, the distribution of TiC particles in the matrix is homogeneous, with a little tendency to agglomerate at grain boundary. Longitudinal section does not show any tendency for the particles to align along the extrusion direction, which can usually be observed in the other extruded composites. Fig.3(a) and (b) shown the morphology and the interface of the composites. In contrast to MMC_S produced by powder metallurgy (PM) or squeeze casting, because of being in-situ synthesized in the 2024Al melt, the TiC particles are submicron size (< 0.5μm), and have granular or partly spherical shape and smooth surface [see Fig.3(a)]. It is due to the mismatch train at the interface between TiC and matrix produced by the discrepancy of thermal shrinkage during the solution treatment. The mismatch strain will produce large stress in the matrix and high density of dislocation around TiC particle, [see Fig.3(b)].The interface between the TiC particle and matrix is clean and no reaction product has been found, [see Fig.3(c)].

3.3 Mechanical properties

Tensile data of TiC_P/2024 thermal extruded at a ratio 1:20 in condition of T6 were obtained.

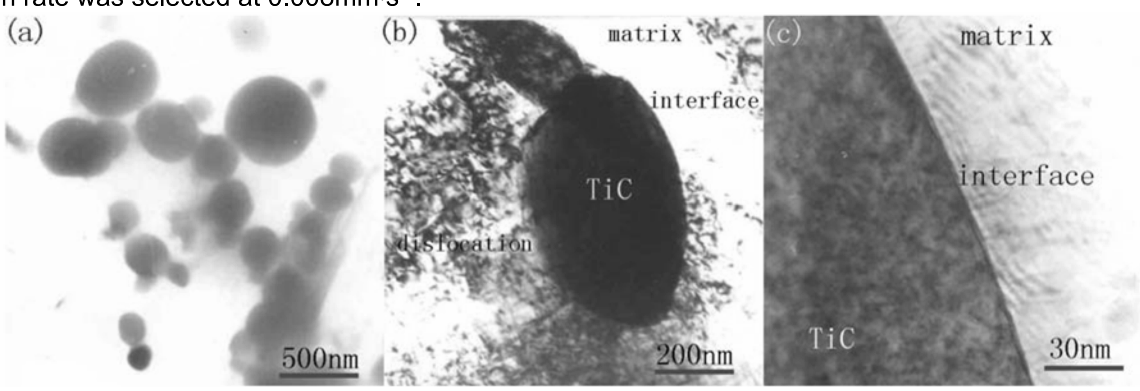

Fig.3 TEM microstructure of TiC_P/2024 composites (a) mor-phology of the TiC particle, (b) dislocation in the TiC particle near (c) the interface between Al and TiC

The data for several loading fracture of TiC are shown in Fig.4. The strength of the composites

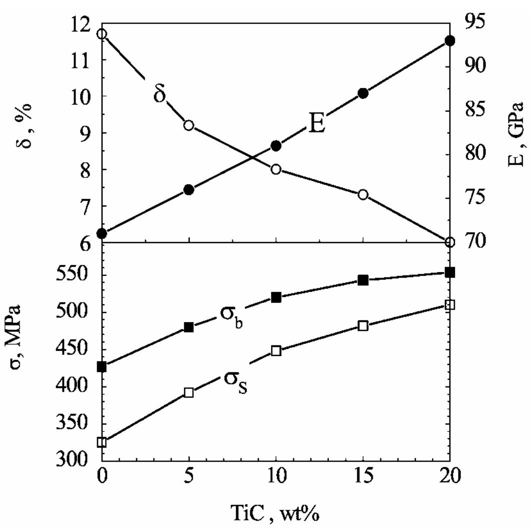

Fig. 4 The relationship between the mechanical properties of in-situ TiC_P/2024 composites and TiC_P content

have been improved greatly over the unreinforced alloy, e.g. for TiC_P/2024 composites, the YS and UTS are up to 510MPa and 554MPa, the elasticity modulus is 92GPa at 20wt%TiC, corresponding to 51% and 30%, 31% increase, respectively. At the same time, the elongation of the composites is still more than 5%. As expected, strength of the composites increase with increase with reinforcement. On the other hand, the elongation of the composites are inversely related to the weight percent of TiC particles.

3.4 Fractography

Fig.5 shows the fracture morphology of the composite specimen at (a) 5 vol.%TiC_P/2024Al, (b) 10 vol.%TiC_P/2024Al, and (c) 20 vol.%TiC_P/2024Al, All three display cup-cone dimpled rupture typical of ductile behavior. Decohesion between the fine TiC, i.e. 1-2 μm, particle and the matrix is not observed indicating good, interfacial bonding.

Fracture of ductile materials occurs by void nucleation, growth and coalescence stages. These are affected by both the volume fracture and particle size. In the simple void growth model proposed by Brown and Embury it is suggested that void linkage occurs when the void height in the loading direction has grown to a size equal to that of the intervoid spacing. As an approximation. it may be assumed that if a void nucleates at the titanium carbide particle either by cracking or by decohesion, one can equate the void spacing to the particle spacing. By increasing the volume percentage of the reinforcing particles, the interparticle spacing is reduced, ad a result of which the strain to failure is reduced. Approximate calculations indicate that above 16 Vol.% of particles, the growth strain becomes zero. Thus, above 16 Vol.%, the fraction strain is controlled entirely by the nucleating strain. In the present study, since the volume fraction was lower, the growth strain of th voids add to the total strain to failure [6].

4. Conclusions

Based on the above studies, the following conclusions are presented:

(1) a new technique for the processing and production of TiC reinforced composites has been developed.

(2) the extruded and heat-treated structure of the composites exhibits a homogeneous distribution of fine (0.5~1.0μm) TiC particles in the 2024Al matrix alloy which lead to significant strength enhancement.

(3) compared with the conventional samples, the yield strength increases by 51% and the ultimate tensile strength by 30%, elasticity modulus by 31%.

(4) the fracture surface exhibits a fine-grained

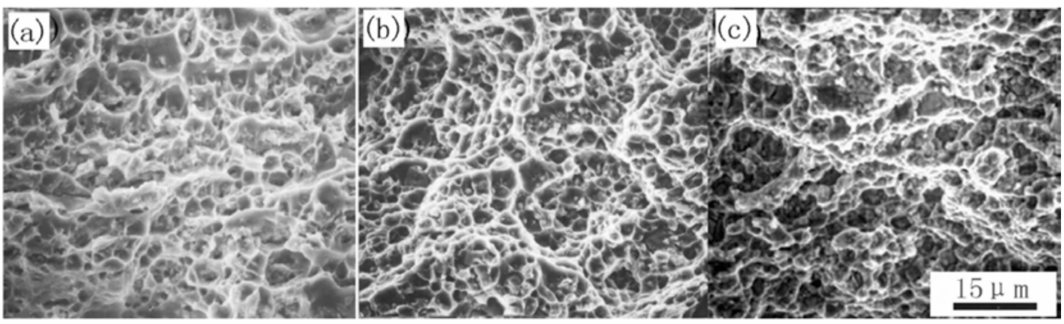

Fig. 5. The fracture morphology of TiC_P/2024 composites (a) 5wt%TiC_p (b) 10wt%TiC_p (c) 20wt%TiC_p

dimpled structure indicative of ductile failure.

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