International Journal of
Advances in Scientific Research and Engineering (ijasre)
E-ISSN : 2454-8006
Vol. 3. Special Issue 1, August-2017

Synthesises and Characterization of Al 6061-Graphene-Silicon Carbide Hybrid Composites by Powder Metallurgy Route

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ABSTRACT

As one of the most essential industrial and engineering materials aluminium 6061 have been extensively used in automobile industry and many engineering applications due to which impending properties like low density, good structural rigidity, freeze ability to incorporate and enhance the strength by addition of various reinforcing materials. The essential criteria is enhancing the property without sacrificing the ductility is always challenging in aluminium and its alloys based composites in the recent years, enormous research carried on ceramic based and carbon based reinforcement material used in Al MMC. But combination of both is never tried so far due to lack of processing methods the current research work is carried out to process synthesis and perform the characterizations of Al 6061 matrix with grapheme of flake size 10 micron and silicon carbide of particle size is 20 micron as reinforcement combinations in various proportions (Wt.%) which will carried out through powder metallurgy approach. The powders will be processed through ultrasonic liquid processing methods and mixtures are ball milled by adding silicon carbide particles by uni-axial hot compaction. Thus prepared compacts are sintered and mechanical properties like hardness, density are investigated as a function of silicon carbide and graphene concentration (weight fraction). Relevant strengthen the mechanism involve in the Al 6061–graphene- silicon carbide composites in comparison with monolithic Al 6061 alloy are discussed.

Key words: AL-6061,Graphene,Silicon Carbide, Powder metallurgy

INTRODUCTION

The research on the composite materials is one of the interesting topics in the material science and metallurgy and it have number of applications in various engineering and structural materials. In satisfying the demands on the materials properties requirement, lot of experimentation and the research has been carried out by known methods of combining various alloy addition, aging methods and heat treatment. Metal matrix composites (MMCs) are thePotential candidate for current advanced engineering applications. Further keen attention given has been to improve their properties by incorporating advanced materials with novel processing techniques [1]. But, still the challenges related to metal matrix composites materials facing lot of issues including amalgamation, lack of processing methods, characterization and inhomogeneity for their wide range of applications in various sector [2]. On the other hand incorporation of a second reinforcing (particulate or fiber) phase in composites especially in metal matrix composites has been an effective route to enhance their strength and other physical properties for practical engineering applications [3]. Al 6061 is extensively used for automobile and transport materials; also, for a wide range of engineering applications due to superior physical properties with high strength. Also, Al 6061 posse's corrosion resistance properties which makes it suitable candidate for marine applications. Lot of work has been carried out to synthesis Al 6061-SiC composites for the sake of specific engineering applications. But there is not much literatures found on hybrid composites in combination with carbon based additives and ceramic particles so far [4]. It needs advanced processing methods to achieve the isotropic properties in the developed composite material due to unusual behaviour of the materials during high temperature conditions [5]. In the last few years, the research on metal–carbon composites was done for the diverse range of engineering material applications and Fig.1 shows various molecular forms of carbon element in the same physical state (graphitic forms). Also, research shows the considerable improvement in the materials properties [6]. Among all other graphitic forms, Graphene has fascinated by its unique strength and properties in the last few years. Graphene endowed with excellent physical and mechanical properties such as Tensile strength 130 (GPa), elastic modulus (0.5 – 1 TPa) and thermal conductivity (5.3 ×103 Wm-1K-1) and has got attention in the field of research [7]. An attempt is made to synthesis of Al 6061-SiC-Graphene composites by an innovative processing powder in liquid media through in powder metallurgy route (PM). The work is carried out to study the effect of the SiC & Graphene addition in the Al 6061-SiCGraphene. Thus prepared powder mixtures are compacted and sintered. The effects of SiC addition with different weight fractions are discussed.

LITERATURE REVIEW

V. Umasankar, et al. [1] Has analyzed that the sintering temperature on microhardness and density. Further to evaluate the fracture resistance strength, sintered composites have been subjected to static ball indentation. It has been and de terials quality l matr prove the damage tolerant properties particularly fracture toughness and ductility in AMCs. This calls for proper selection of sintering conditions, contents of reinforcement and the nature of reinforcement.The Silicon carbide (SiC) reinforced AMCs have considerable potential as an engineering material. SiC retains room-temperature ductility and increases the stiffness and high-temperature strength nd reinforcement ogy. Also, there is of reinforcement ade, funct of reinforc when com against the rheological limitations of casting processes [mechanical properties of the powder metallurgy (PM) pa comparable to wrought or cast alloy. Yet, sintering of alum and its alloys is difficult due to the presence of the stable aluminum oxide layer covering the powder restraining the atomic diffusion between each particle. The compact is said to have ‘‘poor sinterability’’ as the powders are weakly bonded with each other.

M. Bastwros, et al.[2]In this study the main aim is to fabricate magnesium reinforced metal matrix composites using graphene nanoplatelets (GNPs) via powder metallurgy processing in order to enhance room temperature mechanical properties. The microstructural evaluation and mechanical behaviors of composite powders and extruded bulk materials were examined by X-ray diffraction (XRD), differential scanning calorimetry (DSC), Raman spectroscopy, transmission electron microscopy (TEM), scanning electron microscopy (SEM) equipped with energy-dispersive spectrometer and mechanical tests. The uniform dispersion and large specific surface area per volume of GNPs embedded in magnesium matrix led to increament in microhardness, tensile strength and fracture strains of the composites. For example, when employing the pure magnesium reinforced with 0.30 wt% GNPs, the increase of Young′s modulus, yield strength, and failure strain of extruded nanocomposite was +131%, +49.5% and +74.2% respectively, compared to those of extruded materials with no GNPs additive. Additionally, mechanical properties of synthesized composites were compared with previously reported Mg–CNTs composites. It was found that GNPs outperform CNTs due their high specific surface area.

Baradeswaran and E. Perumal [3] In this study, ANFIS was combined with PSO in order to optimize the parameters in pressure assisted semi solid processing of A360 aluminum matrix nano composites. ANFIS was utilized to calculate the objective function, which was later minimized using PSO. Combination of EMS semi solid processing and pressure assistance during solidification resulted in improvement of microstructural features and tribological properties. Globular grain structure was formed in the pressure assisted EMS parts. Tribological properties were investigated using pin on disk. It was noted that wear properties of EMS parts were benefited from the refinement of the primary α-Al phase and uniform distribution of the particles. EMS composites showed higher hardness than conventional cast parts, consequently there was a lower real area of contact and therefore lower wear rate. Moreover, hard dispersoid made the virgin alloy plastically constrained and improved their wear resistance.

Sharma, S.C, et al. [4]In this study Al 6061 alloy is widely used for commercial applications in the transportation, construction and similar engineering industries. It possesses excellent mechanical properties in addition to good corrosion resistance due to which the alloy finds extensive application in naval vessels manufacturing. Al-TiB_2 composite is a metal matrix composite (MMC) that can be manufactured using the in-situ salt-metal reaction. With TiB_2 as the particulate addition the properties of Al 6061 alloy can be greatly improved. A comparison of the mechanical properties and the microstructure of Al 6061 alloy with Al–TiB2 metal matrix composite containing 12% by weight TiB_{2p} manufactured through the in-situ process were presented.

Surappa M.K [5] Has analyzed the reinforcement in AMCs could be in the form of continuous/discontinuous fibers, whisker or particulates, in volume fractions ranging from a few percent to 70%. Properties of AMCs can be tailored to the demands of different industrial applications by suitable combinations of matrix, reinforcement and processing route. Presently several grades of AMCs are manufactured by different routes. Three decades of intensive research have provided a wealth of new scientific knowledge on the intrinsic and extrinsic effects of ceramic reinforcement vis-a-vis physical, mechanical, thermo-mechanical and tribological properties of AMCs. In the last few years, AMCs have been utilized in high-tech structural and functional applications including aerospace, defence, automotive, and thermal management areas, as well as in sports and recreation. It is interesting to note that research on particle-reinforced cast AMCs took root in India during the 70's, attained industrial maturity in the developed world and is currently in the process of joining the mainstream of materials. This paper presents an overview of AMC material systems on aspects relating to processing, microstructure, properties and applications.

Jaroslaw Wozniak, et al. [6]In this study, AA6061-base composites reinforced with graphene (Gn(12)), hexagonal boron nitride (hBN) and molybdenum disulphide (MoS2) particles were analyzed. The composites were prepared by powder metallurgy processing using the Spark Plasma Sintering to consolidate powders. Microstructure, physical and wear properties were investigated and compared with unreinforced AA6061. For all composites, high relative density were obtained. The tribological studies showed that the friction coefficient significantly decreased with 2D crystals content increase. The results indicated that abrasive mechanisms have dominated during the wearing of the composites. Moreover, in composites with Gn(12) and MoS2, a film on the worn surface was observed.

M. A. Xavior, et al. [7]As one of the most essential industrial and engineering materials, Aluminum alloy 6061have been extensively used in automobile industries and many engineering applications due to its impending properties like low density, good structural rigidity, feasibility to incorporate and enhance the strength by addition of various reinforcing materials. The essential criteria in enhancing the properties without sacrificing the ductility is always challenging in Aluminum and its alloys based composites. In the recent years, enormous research has been carried on ceramic based and carbon based reinforcement materials used in Aluminum metal matrix composites. But the combination of both is never tried so far due to lack of processing methods. The current

research work is carried out to process, synthesize and perform the characterization of Al 6061 matrix nanocomposites with Graphene of flake size 10 nm and SiC of particle size 10 μm as reinforcement combinations in various proportions (weight percentage) which are carried out through powder metallurgy (PM) approach. The powders are processed through ultrasonic liquid processing method and the mixtures were ball milled by adding SiC particles followed by uniaxial hot compaction. Thus prepared compacts are sintered (conventional and microwave) and mechanical properties like hardness, density are investigated as a function of Graphene and SiC concentrations (weight fraction). Relevant strengthening mechanism involved in the Al6061 – Graphene -SiC composites in comparison with monolithic Al 6061 alloy were discussed.

Rathod abhik, et al [8] has studied the evaluation of the properties for Al-SiC reinforced metal matrix composites produced by powder metallurgy process.in this work they studied the mechanical and wear properties of aluminium 2014 reinforced with 10wt% and 20wt% of SiC, the model is compacted under the load

150 KN and sintered at a temperature of 550ºC. They concluded that increased with reinforcement increases the hardness and decreases the wear rate and they obtained higher wear rate at 10wt% and higher density at 20wt% of reinforcement.

D M Nuruzzaman, et al [9] investigated the processing and mechanical properties of aluminium reinforced with SiC metal matrix composites. In this work Al-SiC particles reinforced with 10, 20 and 30 volume fraction of SiC were fabricated by conventional powder metallurgy process. The model is compacted at different loads of 10 and 15 tons and sintered at temperature of 400ºC. Concluded that density of the composite increased with increases the SiC particulate volume fraction, higher density and improved microstructure is at 15 tons compaction load. Average Hardness valve of all compaction is higher at 10 tons compaction load.

H. M. Zakaria, et al [10] researched the Microstructure and corrosion behavior of Al/SiC metal matrix composites, with the different compositions of 5, 10 and 15vol% of the SiC with average piratical size of 60µm. Fabricated by conventional powder metallurgy route, the powders are compacted at 500KN and sintered at 600ºC. Concluded that the increase in the volume fraction of SiC particles increased the corrosion resistance of the Al/SiC composites.

Manoj Singla, et al [11] has development of aluminium based silicon carbide particulate metal matrix composites, was produced by stir casting technique. The aluminium is reinforced with the 5, 10, 15, 20, 25 and 30% weight fraction of the SiC. The experimental study reveals that increase in composition of SiC, an increase in hardness and impact strength, the best results has been obtained at 25wt% of SiC the maximum hardness valve is 45.5 BHN and maximum impact strength is 36 N-m

Amir Hussain Idrisi, et al [12] has researched development and testing of Al5083 alloy reinforced by SiC particles, present work was focused on the study and behavior of Al5083 with SiC particles. The composites are fabricated by using ultrasonic stir casting process for Al5083 reinforced with 0, 3, 5, 8 and 10wt% of the SiC particles, they carried out tensile and compressive tests. From the study is concluded that tensile and compressive strength is increased with increased wt% of SiC increases along with modulus of elasticity.

Anil Kumar Bodukuri, et al [13] evaluating the mechanical properties of Al reinforced with SiC and B_4C particles was fabricated by powder metallurgy technique. In this work different combination of compositions in volume fraction are chosen, they are 90%Al, 8%SiC, 2%B_4C and 90%Al, 3%SiC, 7% B_4C. The powder is compressed at pressure 150Mpa and sintered at temperature of 610ºC, is concluded that the percentage of boron carbide is increasing the hardness valve is also increasing, the hardness valve for above compositions is 21.02VHN and32.7VHN.

Y. Sahin, et al [14] preparation and some properties of SiC particles reinforced with aluminium alloy , the composites are prepared by squeeze casting the matrix material used, Al2014 alloy reinforced with the 10 and 20wt% SiC particles, with the practical size of
29µm. Authors concluded that SiC particles distribution were homogeneous and no interface porosity observed , hardness of the aluminium alloy improved significantly by adding SiC particles into it.

Mr. prashanth Kumar Suragimath el at [15] study the mechanical properties of aluminium alloy (LM6) reinforced with SiC and Fly ash. They studied the Microstructure and mechanical properties of composites, with the varying weight fraction of fly ash (5 and 15%) while keeping 5% SiC constant which produced by stir casting technique. The results revels that increases in addition of fly ash with SiC increases the tensile strength, impact strength, wear resistance and brittleness of the material and decreases the percentage of elongation.

Mohan Vanarotti el at [16] investigated the synthesis and characterization of aluminium alloy A356 and SiC MMCs produced by stir casting process, aluminium alloy A356 reinforced with 5 and 10wt% of SiC. Author revels that increase the silicon carbide content reasonably increase in hardness and decreases of ductility i.e. the material tends to fail in brittle mode. The tensile strength, % of elongation and hardness valves of 5wt% of SiC is 187Mpa, 2.8, 70 BHN and 10wt% of SiC is 188Mpa, 2.4 and 78BHN.

Puneeth H M el at [17] experimental investigation of mechanical properties of A365.1 aluminium alloy reinforced with SiC MMCs. Aluminium A365.1 reinforced with the 0, 5, 10 and 15wt% of silicon carbide through stir casting technique. The results revels that hardness ,wear resistance and impact strength of the MMCs is increased with increase SiC practical content, the maximum strength was achieved A365.1 aluminium alloy reinforced with 15wt% of SiC practical content.

CONCLUSION

1)The composites containing 6061Al with different wt% of SiC & Graphene particulates may successfully synthesized by Sintering method with varying wt. % of reinforcements.

2) The compacts are sintered in conventional sintering method successfully.

3) XRD analysis has revealed the existence of all major alloying elements of Al 6061 including Graphene in the developed composites.

4) Oxides present as constituents may help to gain high modulus and strength thereby improving specific strength and stiffness along with lower densities compared to unreinforced 6061Al.

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