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Analysis of Silicon Carbide Reinforced Aluminum Composite for Chip Modules

S. Rahul[1], S. Manikandan[2], P. Manokaran[3], M. Nandhakumar[4], S. Ragu[5]
Assistant Professor[1], UG Student [2, 3, 4, 5]
Department of Mechanical Engineering
KSR Institute for Engineering and Technology, Namakkal, Tamilnadu, India

Abstract:
The application of metal matrix composites are increased day by day due to high strength to weight ratio. Many different technologies for the production of Sic-Al composites have emerged over the years. In this project Sic-Al metal matrix composites is prepared from sintering of mechanically alloyed powder in powder metallurgy. Three different Combination of compositions in volume fraction were chosen 100%Al, 83%Al+17%SiC, 85%Al+15%Sic, 87%Al+13%Sic.The fabricated samples are to be tested to different properties like co-efficient of thermal expansion, electrical conductivity ,electrical resistivity , microstructure are to be analyzed. The test results are compared to the optimized characteristics volume fraction suggested for chip modules.

1. INTRODUCTION

The use and application of various composites are the key alternating materials for the existing materials. Among these composites, aluminium metal matrix is the best substitution due to their own advantages. The density of the aluminium composites is always less as compared to the most of the materials and these materials can be used in aircraft, automotive, construction, packing, electronics and military industries. Aluminium metal matrix composites (AMMCS) with different ceramic particle reinforcement are developed to suit the varying needs in aerospace and automotive application. Most of the existing materials used in aerospace and automobile industries can be replaced by these AMMCS due to its good strength and sometimes less denser than the parent material. These materials are the encouraging materials to give better properties with low density and also cheaper than the other materials like Mg and Ti. In place of steel and cast iron components, there is potential to use Aluminium composites. Al7075 was selected here on the basis of usage of material in aerospace and automobile applications which will lead to high strength to weight ratio and also having good electrical properties. Due to robust nature and having high hardness value Sic was selected as one of the best reinforcing material among all these materials. The Al was used as another best reinforcing material, which is a less dense material and can be, used as solid lubricant. To reduce the wear in between sliding elements, solid lubricant (Sic) was selected as another reinforcing material. In this context, components with excellent electrical and fatigue properties, low density, electrical behaviour, high thermal and electrical conductivity and excellent machinability can be produced by Powder Metallurgy (P/M) technique. The physical and Electrical properties like co-efficient of thermal expansion, electrical conductivity and resistivity to be analyzed of the P/M composites can be improved while performing bulk forming operations.

1.1 Composite

Composite is a material made from two or more constituent material with significantly different physical or chemical properties that, when combined, produce a material with characteristics different from the individual components.

1.2 Types of Composites

The composites can be grouped into categories based on the nature of the matrix each type possesses. Methods of fabrication also vary according to physical and chemical properties of the matrices and reinforcing fibers.

a)Metal Matrix Composites (MMCs)

A metal matrix composite material with at least two constituent parts, one being a metal necessarily, the other material may be a different metal or another material, such as a ceramic or organic compound. When at least three materials are present, it is called a hybrid composite.

b)Ceramic Matrix Composites (CMCs)

Ceramic matrix composites have ceramic matrix such as alumina, calcium, alumina silicate reinforced by silicon carbide. The advantages of CMC include high strength, high thermal stability, low density etc, example- silicon carbide, silicon nitride, aluminum oxide.

(b)Polymer Matrix Composites (PMC)

Polymer matrix composite material composed of a variety of short or continuous fibers bound together by an organic polymer matrix. The main advantage light weight, high strength and good corrosion resistance. Application is trucks and bus bodies, containers and aerospace industry

2. LITERATURE REVIEW

ManojSingla, D. Deepak Dwivedi, Lakhvir Singh, Vikas Chawla[1].In this author studied to develop aluminium based Sic particulate MMCs with an objective to develop a conventional low cost method of producing MMCs and to obtain homogenous dispersion of ceramic material. To achieve these objectives two method of stir casting technique has been adopted and subsequent property analysis has been made. Aluminium (98.41% C.P) and SiC (320-grit) has been chosen as matrix and reinforcement material respectively. Experiments have been conducted by varying weight fraction of Al (5%, 10%, 15%, 20%, 25%, and 30%), while keeping all other parameters constant. An increasing trend of hardness and impact strength with increase in weight percentage of SiC has been observed. The best results (maximum hardness 45.5 BHN & maximum impact strength of 36 N-m.) have been obtained at 25% weight fraction of SiC. I. A. Ibrahim, F. A. Mohamed, E. J. Lavernia [2].In this review author studied the electrical properties that can be obtained with metal matrix composites by varying reinforcement percentage by 0, 10, 15, 20% and taking different alloy AA 6061, AA 2014, AA 356. Conclusion of this paper is by increasing reinforcement % age yield strength, ultimate strength is increasing but elongation of a Alloy decreases. G. B. Veeresh Kumar, C. S. P. Rao, N. Selvaraj.[3].In this author Mechanical and tribological behavior of particulate reinforced aluminum metal matrix composites. Silicon carbide (SiC) provides aluminium the resistance to chemical attack and strength retention at high temperatures .Properties of silicon carbide are low density, high strength, low thermal expansion, high hardness, and high elastic modulus. The properties of the composites can be altered by manipulating parameters such as reinforcement particle distribution, size, orientation, and matrix micro structure S.V. Prasad and R. Asthana [4] This paper gives an overview of the tribological behavior of Al MMCs reinforced with hard particles, short fibers, and solid lubricants, and the technologies for producing automotive parts from these novel materials. The emphasis has been on developing affordable Al MMCs, reinforced with SiC and Sic, that will reduce the weight and increase the engine efficiency, and thereby reduce fuel consumption and vehicle emissions.. Considerable reduction in wear and friction is achieved by use of these particulates. Furthermore, increased cylinder pressures (and therefore, higher engine performance) are possible because Al MMCs can withstand high electrical and thermal loads, and reduce heat losses by permitting closer fit that can be achieved because of lower thermal expansion coefficient of Aluminum MMCs.

3. MATERIALS AND METHODOLOGY

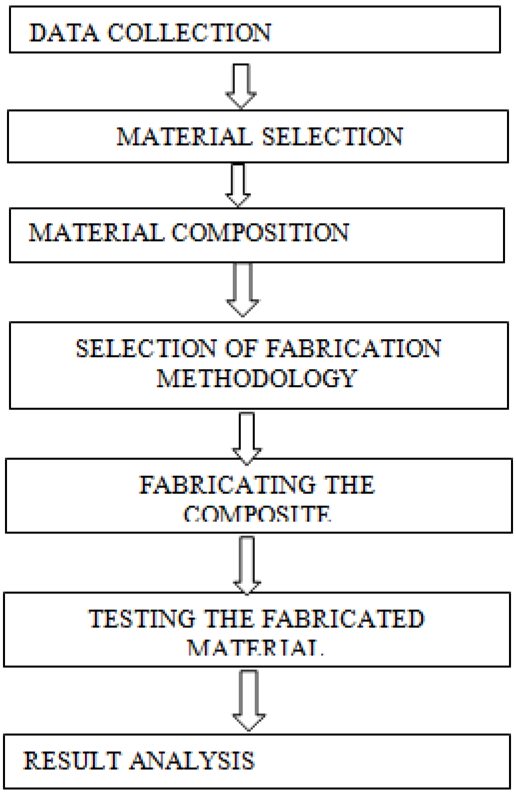


Figure.3.1. Methodology

3.1) MATERIALS

a)Aluminum powder

Aluminum powder is a powdered aluminum. This was originally produced by mechanically using ball mill. Melting point of the aluminum 660.The main advantage of the material is having lightweight, corrosion resistance, electrical, thermal conductivity. It is used in chip making, finger print and aerospace industry.

b)**Silicon carbide powder**

Silicon carbide is a semiconductor containing silicon and carbon. Synthetic Sic powder has been mass produced for use an abrasive. The properties are low density, low thermal expansion, and thermal shock resistance. The mainly used or semiconductor processing equipment, refractories and wearing applications.

3.2. METHODOLOGY

After selecting raw material like aluminum, silicon carbide, the material properties were determined and samples are making by using powder metallurgy technology.

3.2.1POWDER METALLURGY

Powder metallurgy is a metal working process for forming precision metal component from metal powders .The metal powder is first pressed into product shape at room temperature and then heating(sintering) that causes the powder particles to fuse together without melting.

a) MIXING

The mixing of powder is achieved by attrition mill to obtain homogenous mixture. An attritor consist of a cylindrical chamber in which a shaft with impeller is placed. When the shaft moves impeller agitates the steel balls, powder particles get uniformly distributed because of vibration, impact force and shear force. Rolling speed of 200 rpm and time of 1hour.

b) COMPACTION

Cylindrical compacts of 20*mm* diameter and 150mm length, were prepared using a compaction die as shown in Figure 3.1. The compacts were prepared using ball milled various sample powders. The required powders were compacted by using suitable punch and die set assembly on hydraulic press having 50tonecapacity. Compacting pressure was applied gradually and it was 12tone loadfor all the specimens. Sic was used to lubricate the punch, die and the butt. While preparing the compacts, the initial density of 85%was maintained by accurately controlling the mass and observing the compacting pressure employed. Metal powder Industries Federation standard (MPFI: 35) was used for the compaction of powders. The prepared compacted samples are shown in Figure 3.2

Figure.3.1 Hydraulic punching press

Figure.3.2. Compacted composite samples

c)SINTERING

After the compaction, the compacts were immediately taken out from the die set assembly and loaded into the sintering furnace for sintering. Figure 3.3 shows the schematic diagram of sintering furnace. To prevent oxidization, the green compacts were initially covered with inert argon atmosphere in the furnace. The sintering was carried out in an inert gas circulated electric muffle furnace at various sintering temperature of 450°*C* respectively for a holding period of one hour. As soon as the sintering schedule was over, the preforms were cooled inside the furnace itself to the room temperature. If the sintering temperature is 450°C, the center part of the composite was in powder form and 850°C the formation of minor cracks along the specimen wall was noticed. So it was carried out in between 450 and 500°*C*. After the completion of sintering, the preforms were cleaned by using a fine wire brush. The sintered work piece as shown in figure 3.3.

Figure.3.3 Sintering furnace

4. EXPERIMENTAL ANALYSIS

After completion of four different composite specimen, the test like co efficient of thermal expansion, electrical conductivity and electrical resistance was carried in the respective equipment.

4.1LINEAR THERMAL EXPANSION ASTM E831

Linear Thermal Expansion is used to determine the rate at which a material expands as a function of temperature. This test can be used for design purposes and to determine if failure by thermal stress may occur. Understanding the relative expansion/contraction characteristics of two materials in contact can be important for application success. In a TMA, the specimen is placed in the holder at room temperature. The height is measured by the probe. The furnace is raised and the temperature is brought to 20 degrees below the lowest temperature of interest. The specimen is heated at a specified rate, often ten degrees a minute, over the desired temperature range. A graph is produced. Alternatively, a dilatometer can be used. The specimen is placed in the Dilatometer at room temperature, and the height gauge is positioned and zeroed. The apparatus is placed in a temperature bath and the movement of the sample is measured from -30° C +30°C. The specimen must be flat on both ends. The coefficient of linear thermal expansion is calculated between the desired temperature ranges. The equipment used is Perkin Elmer Diamond TMA Perkin Elmer TMA-7, Dilatometer, Instrulab PRT.

Table 4.1 Linear thermal expansion test result

sample	Percentage of aluminum powder	Percentage of silicon carbide powder	displacement/ Expansion in mm±2.2%
1.	83	17	21.4×10^{-6}/°C
2.	85	15	23.1×10^{-6}/°C
3.	87	13	24.6×10^{-6}/°C
4.	100	0	26.3×10^{-6}/°C

4.2ELECTRICAL RESISTIVITY ASTM D25

Surface resistivity is the resistance to leakage current along the surface of an insulating material. Volume resistivity is the resistance to leakage current through the body of an insulating material. The higher the surface/volume resistivity, the lower the leakage current and the less conductive the material. A standard size specimen is placed between two electrodes. For sixty seconds, a voltage is applied and the resistance is measured. Surface or volume resistivity is calculated, and apparent value is given (60 seconds electrification time). Surface and Volume resistivity are calculated. Surface resistivity is expressed in ohm/ square Volume resistivity is expressed inohmcm. The equipment used: Quad tech 1865 Me ohmmeter/IR,Tester.

Table 4.2 electrical resistivity test results

Sample	Percentageof aluminum powder	Percentageof silicon carbide powder	Electrical resistivity(x $^{10-8}$ Ωm) at 45^{0}C
1.	83	17	2.732
2	85	15	2.578
3	87	13	2.541
4	100	0	2.322

4.3 ELECTRICAL CONDUCTIVITY ASTM E1004

The electrical conductivity test has been performed using the SIGMATEST 2.069 device. An eddy current instrument that measures the electrical conductivity of non-ferromagnetic metals in units of %IACS or MS/m. Electrical conductivity measurements can be used to determine material composition, structure, and heat-treat condition. The capabilities of presented device are as follows: Fast and reliable determination of electrical conductivity with high accuracy. Large measuring range from 0.5 to 65 MS/m (1% to 112% IACS).Distance correction up to 500µm for maintaining high accuracy when measuring on painted, coated, or dusty surfaces. Five selectable operating frequencies (60 / 120 / 240 / 480 / 960 kHz) consistently high accuracy on test pieces of various thickness.

Table 3.3 Electrical conductivity

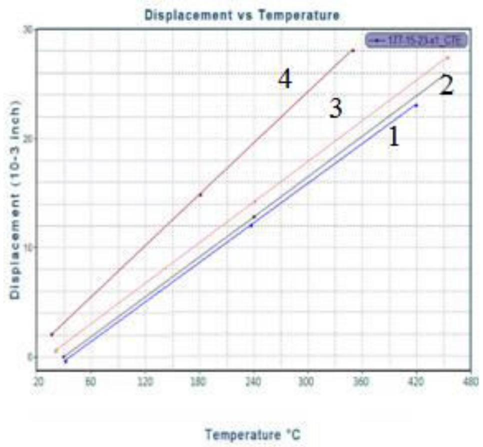
Sample	Percentage of aluminum powder	Percentage of silicon carbide powder	ElectricalConducti-vity (S/m) $x10^6$
1.	83	17	2.72
2	85	15	2.63
3	87	13	2.61
4	100	0	2.58

5. RESULT AND DISCUSSION

This section focuses on presenting the observation and findings gathered during the course of experiments. The data analysis provides the basis and justification for the conclusion drawn in this work. Four types of experiments were carried out which are co-efficient of thermal expansion, electrical determining electrical properties.

5.1 LINEAR THERMAL EXPANSION TEST RESULTS

From the above test it is clear that when 17% of silicon carbide reinforced with aluminium it shows best result for minimum displacement/expansion (21.4×10^{-6}mm/°C) compared to 15%, 13%, 0% silicon carbide reinforced composites.



Sample1-83%Al+1 SiC
Sample2-85%Al+1 SiC
Sample3-87%Al+1 SiC
Sample4-100%Al+ SiC

Figure.5.1 Linear thermal expansion result

5.2 ELECTRICAL RESISTIVITY TEST RESULT

From the above test it is clear that when 17% of silicon carbide reinforced with aluminium it shows best result for maximum electrical resistivity 2.732×10^{-8}Ωmcompared to 15%, 13%, 0% silicon carbide reinforced aluminium composites.

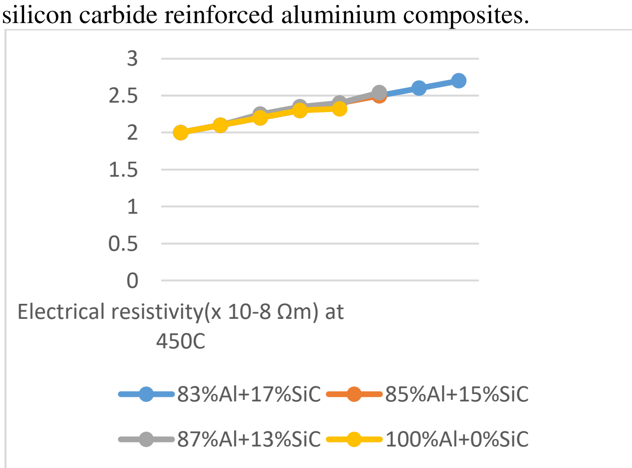
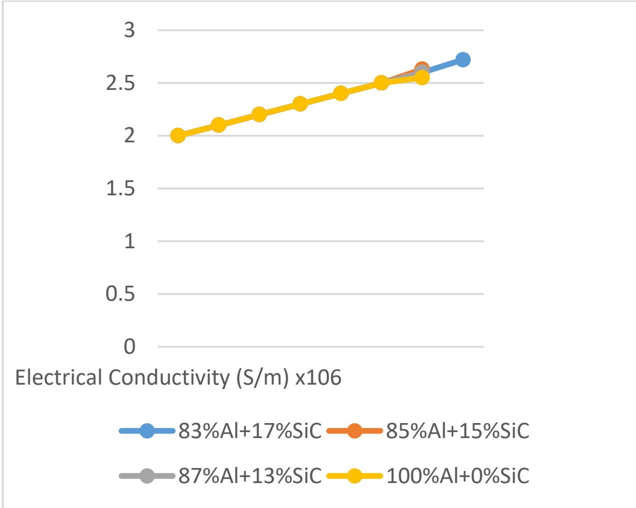


Figure.5.2 Electrical resistivity result

5.3 ELECTRICAL CONDUCTIVITY TEST RESULT

From the above test it is clear that when 17% of silicon carbide reinforced with aluminium it shows best result for maximum electrical conductivity 2.7x10^6(S/m) compared to 15%, 13%, 0% silicon carbide reinforced aluminium composites.



Figur.5.3 Electrical conductivity result graph

6. CONCLUSION

The aim of the project is to finding the best composition materialfor chip module. When comparing four composite sample in tests likeco-efficient of thermal expansion, electrical conductivity and electrical resistivity.We find that the composition of 17% silicon carbide reinforced aluminium is best suited in chip module because of having low thermal expansion, high electrical resistivity and high electrical conductivity.

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