Overview of CuSiC Composite Material

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Abstract— CuSiC composites are attractive metal composite materials due to their strength, ductility and toughness that features in thermal management and structural application for electronic component. This article focuses on techniques used to manufacture CuSiC composites, casting and powder metallurgy are extensively used to manufacture the composites. An effort has been made to highlight the material processing, properties and application of the CuSiC composite. In this review article the thermo-physical, electrical and mechanical properties have been reviewed. And future prospects also have been discussed.

Key words: Composites, SiC content, Hardness, Yield Strength

I. INTRODUCTION

Today, copper and copper composites are one of the major groups of viable metals, ranking third behind only iron/steel and aluminium in fabrication and consumption. They are widely used because of their good electrical and thermal conductivities, excellent resistance to corrosion, easy for fabrication, and good strength and wear resistance. Pure copper is used widely for cables and wires, electrical structural components and connectors, and a wide variety of other parts that are essential to pass electrical current. Copper is soft in nature, because of lacking of covalent character and because of weak metallic bond. The mechanical properties of copper can be improved radically either by age hardening or by presenting dispersed particles in its matrix. The age-hardened copper composites are disposed to rapid coarsening at elevated temperatures, thus decreasing their strength radically. In this respect, dispersion-strengthened copper has the capability to preserve most of its properties on introduction of high temperatures. Dispersed particles such as oxides, carbides, borides are unsolvable in the copper composites, and are thermally constant at high temperatures. It is well known that the Copper is best substitute of Aluminium and Silver in field of elevated temperature application [1]. Now a day's requirement of thermal management materials in microelectronics and semiconductor drives increases. The development of composite materials with high thermal and electrical conductivity. These material leads to effective coefficient of thermal expansion, to reduce thermal stress. To achieve such properties addition in Cu composites includes SiC, Carbon and Diamond. The addition of SiC in Copper increase the mechanical and thermo-electrical properties, these materials are widely used in heat sink application [2, 3, 4]. The aim of this work is to discuss the key factor that hamper the manufacturing and the thermo-physical performance of structures/components, by experimental and finite element simulation. The method to overcome these difficulties are discussed. This review consist review on thermal-electrical conductivity, and mechanical. The material processing method is also discussed.

II. LITERATURE SURVEY

A. *Material Processing and Microstructure:*

Many researchers worked on material processing of Cu-SiC composites fabrication. Kuen-Ming Shu, Th. Schubert, G. Celebi, had been discussed the Cu-SiC composite prepared by powder metallurgy route, with focusing on the bonding improvement between Cu and SiC [5, 6, 7]. C. Bindal, O.S. Fatoba, had also been discussed the fabrication by powder metallurgy and liquid metallurgy route, with affecting factor of SiC particles in thermal-physical properties of Cu-SiC composite [1, 8, 9]. P. Asadi had been discussed the mechanical properties of Cu-SiC composite manufactured by friction stir processing (FSP), with the effect of particle size and volume fraction of SiC in composite [10]. G. Celebi Efe and A. S. Prosviryakov, studied the effect of particle size on properties of Cu-SiC composite fabricated by cementation and mechanical alloying method, the had also focused on density, coefficient of thermal expansion and hardness of Cu-SiC composite with different particle size and different wt.% of SiC [11, 12]. M. Sumathi, has been studied the workability behaviour of Cu-SiC composite with 10 wt. %, with different initial density, and determined the triaxial behaviour of Cu-SiC composite [13]. Andrey M. Abyzov, has been discussed about the thermal conductivity of copper composite for heat sink application, also focused on the microstructure of Cu-SiC composite by X-ray diffraction [14]. Majid Asnavandi has been studied the hardness of Cu-Sn-graphite-SiC composite [15]. Omid Ghaderi and M.R. Akbarpour has been studied the microstructure with mechanical properties of Cu-SiC composite and nano composites of Cu-SiC, and defined some strength improvement points [16, 17]. H. Sarmadi, Soheila Faraji and Zhenu yang also studied the same, additional focusing on wear resistance, corrosion resistance and molecular dynamics simulation to describe the crack propagation [18, 19, and 20]. Mohamed Zakaulla had been done the optimization of, Al606 hybrid composite reinforced with copper coated SiC and Gr powder using Taguchi method [21]. Edward Joshua T. Pialago, had been studied the deposition of Ternary Cu-CNT-SiC composite powder formed by mechanical alloying process, and the microstructure was also evaluated by SEM, EDX and XRD, porosity also defined [22]. Many other researcher have also studied the improvement in Copper based composites. If we talk about specific application i.e. thermal management applications such as electronic packaging and heat sink. For example, the packaging materials in field of microelectronics should have low thermal capacity which in reverse related to thermal conductivity in dispersing the heat, and low CTE to reduce the thermal expansion, which prevents the discrepancy among the devices. Low and suitable CTE, together with poorer specific heat capacity, can be achieved by appropriate blending of metallic and ceramic phases to procedure a composite.

The microstructure study has been done by many researchers, the SEM, TEM, EDS and XRD had been done basically for the evaluation of microstructure [1, 4, 6, 7, and 8]. It the particle size of Cu and SiC was optimized and required development were discussed. The particle size from 1µm to 30 µm had been studied. Somewhere slight amount of oxygen noticed in the EDS analysis of Cu powder, possibly results from the reaction of copper powder with air. As it is known well that copper oxides are not protecting oxides [10, 11, and 12].

B. Hardness:

An effort has been made to elaborate the hardness of CuSiC composite, with respect to change in wt.% and particle size variation of SiC content. Fig. 2 showing the effects of the wt. % and size of added SiC content on the hardness of sintered composites. For hardness measurements various test were done. The hardness of Cu–SiC composites ranged from 133 to 277 HV for SiC having 1 µm to 30 µm particle size. Hardness is directly proportional to addition of wt. % of SiC element. This result was consistent with the other researches. The average hardness of Cu–SiC composite increases with increment of particle size variation from 1µm to 5 µm [1, 7, 8, 11, and 12].

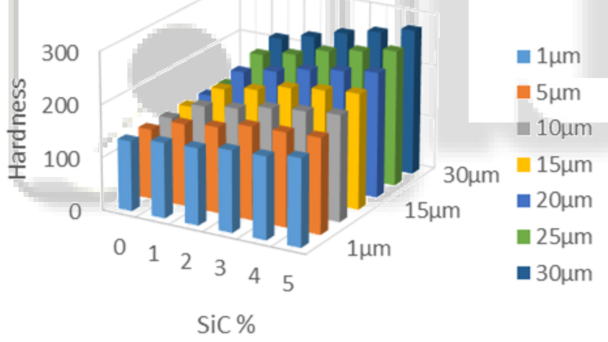

Fig. 2: Hardness of Cu-SiC composite [1, 7, 8, 11, and 12]

C. Relative Density:

In order to determine the variation of relative density, hardness and electrical conductivity of test materials are required to determine. It is clear from the figure that, the density increases with the size of SiC but declines with weight percentage of SiC. Maximum density was extended for a SiC size of 30µm. This is also due to the density of SiC particles being much lower than that of copper. Similarly with increasing particle size of SiC, diffusion barriers of composite declines and hence relative density upturns [8]. The figure 3 showing the relative density with the variation of wt. % of SiC and particle sizes [1, 2, 7, 8, 11 and 12].

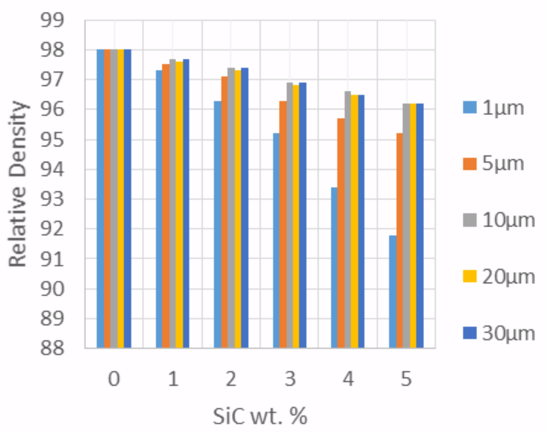

Fig. 3: Relative Density

D. Electrical and Thermal Conductivity

The electrical conductivity increases with increase particle size but decrease with increasing volume fraction of SiC in the copper composite and with smaller particle size of SiC, thermal conductivity decreases, to improve thermal conductivity the particle should be large. The strengthening of the Copper composite with inclusion of SiC shows to an appreciable extent to the influence of the volume fraction and particle size on the electrical conductivity and thermal conductivity. Figure 3 showing the electrical conductivity with respect to SiC content wt. % and particle size [1, 4, 7, 8, 9, 11, and 12].

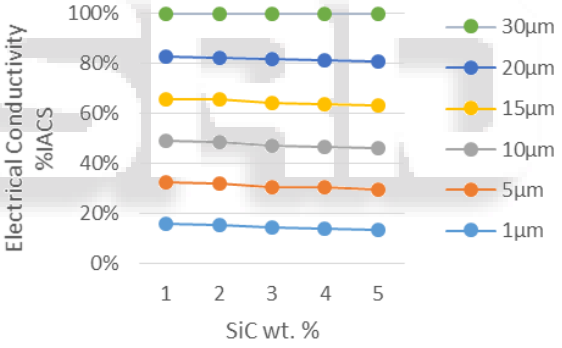

Fig. 4: Electrical conductivity with respect to SiC wt. % and Particle size

It has been noted that the coefficient of thermal expansion (CTE) of pure copper is higher comparative to the Copper composites. The CuSiC composite are best suited for thermal application, and for this purpose low CTE is required and it can be achieved best in addition of SiC content in copper, which decreases the CTE and increases the thermal conductivity [2, 4, and 5].

E. Mechanical Properties:

It is well known that the mechanical properties of composite material increases with homogeneous mixture of added contents. In case of Cu-SiC composite, the homogeneous addition of SiC particle enhances the mechanical property of composite. The composite becomes harden with increasing addition of SiC wt. % [8, 11]. If we talk about the tensile property of CuSiC its yield strength is comparatively low as compared to pure copper, this is because of inclusion of SiC content, whereas it's compressive and wear property is good. Many researchers had been widely studied the mechanical property of CuSiC composite fabricated by powder metallurgy route and many other route Table 1 showing the CuSiC composite mechanical property [3,7,10].

SiC wt. %	Modulus of Elasticity (GPa)	Yield Strength (MPa)	Ultimate Tensile Strength (MPa)
0.6	81	159	253
2	83	178	292
4	84	175	277
6	85	138	243
8	86	132	229
10	86	119	210

Table 1: Mechanical Property of CuSiC composite

III. CONCLUSION AND FUTURE PROSPECT

There are many opportunities for producing exceptionally strong, light weight, wear resistant CuSiC with acceptable thermo-electrical and mechanical properties by different fabrication route. From the various fabrication process discussed in this review article. The material processing and studies done on this material has been discussed in this article. This effort is focused on physical, thermo-electrical, and mechanical properties. Powder metallurgy route for fabrication of CuSiC composite has been widely studied, there have been very few details available for the fabrication of CuSiC composite by liquid metallurgy route, so the future research must be focused on this area. Fundamental research on the improvement of wettability, liquid metallurgy route, controlling of interfacial structure and thermal conductance mechanism is of vital important. Continue improvements in thermal management application, electronic packaging design and process, are required.

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