A REVIEW ON FABRICATION OF COPPER GRAPHITE COMPOSITE MATERIAL & ITS MECHANICAL PROPERTIES

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ABSTRACT

This review paper represent both fabrication & mechanical properties of copper graphite composite material. These Composites are made up of a high electrical and thermal conductivity matrix with a Solid lubricant reinforcement, making it most suitable for sliding contacts. Copper-graphite with low percentages of graphite is also used for slip rings, switches, relays, connectors, plugs and low voltage DC machines with very high current densities. Copper–graphite metal matrix composites possess the properties of copper, i.e. excellent thermal and electrical conductivities, and properties of graphite, i.e. solid lubricating and small thermal expansion coefficient. They are widely used as brushes, and bearing materials because of the above properties.

Keyword - composite material, graphite, copper, powder metrology, mmc.

1. INTRODUCTION

Composites of copper-based sintered, especially copper– graphite compacts, produced by powder metallurgy processes are now widely used in tribological engineering parts, such as bearings, and electrical contact parts, notably carbon brushes for engines, generators, and automobile kick starters. Some of the Features that define the performance of an electrical contact are: electrical resistivity, wear, hardness, corrosion, etc. The advantage of the copper– graphite composites is the combination of the positive

Characteristics of both elements, such as electrical and thermal conductivity from the copper and a low thermal expansion coefficient and lubricating properties from the graphite [1].

Powder metallurgical processes have many advantages of using over other processes such as the possibility of obtaining uniform brushes and of reducing the tedious and costly machining processes. By contrast, there are some limitations of this technology related with the poor affinity between copper and graphite, which gives rise to weak interfaces with the consequent negative effect on the structural, mechanical and electrical properties of the product [2, 3].

A high wear resistance of this material is necessary because the brushes rub on rotating metal parts. In order to optimize the wear resistance it is important to keep porosity down to a minimum. Efforts to produce dense brush materials with lead and tin and with high electrical conductivity and elevated operating temperature resulted in a consolidation route, which utilized simultaneous pulse heating and powder compaction [4–8].

Moustafa et al. [9] have reported that copper–graphite composites manufactured from a mixture of copper and copper-coated graphite powders possessed a higher sintered density and yield strength than those produced from a mixture of copper and uncoated graphite powders.

Tribological properties of the composites depend on the structure of the matrix as well as the distribution of the graphite in the matrix. The addition of small amounts of lead and zinc to the composite increases the hardness and wear resistance [10].

The Objective of present work is to investigate the effect of compaction load on the physical and mechanical properties of copper composites. The amount of the reinforcements (mass percentage) of graphite, lead, or zinc that mixed with the copper-graphite powder is investigated with respect to the mechanical properties of compacts.

Fig1-copper graphite composite material

2- METAL-MATRIX COMPOSITES (MMC)

Advanced composites based on metallic matrices have a somewhat recent history, yet the opportunities look very promising. The first MMCs were developed in the 1970s for high performance applications using continuous fibers and whiskers for reinforcement [1].

Metal matrix composites (MMCs) combine both metallic properties (ductility and toughness) with ceramic properties (high strength and modulus) possess greater strength in shear and compression and high service temperature capabilities. The extensive use of MMCs in aerospace, automotive industries and in structural applications has increased over past 20 years due to the availability of inexpensive reinforcements and cost effective processing routes which give rise to reproducible properties [2]. The frontier zone between the matrix and reinforcement phase (interface or interphase) is an essential part of MMC. Bonding between the two phases develops from interfacial frictional stress, physical and chemical interaction and thermal stresses due to mismatch in the coefficients of thermal expansion of the matrix and reinforcement. During the design of a MMC the underlying interfacial phenomenon which governs the transmission of thermal, electrical and mechanical properties is of utmost importance [3].

The recent recognition that addition of ceramic reinforcements enables manipulation of physical as well as mechanical properties of MMCs has led to increasingly widespread use of these materials in electronic packaging and thermal-management applications. Recent market forecasts suggest the prospect for accelerating growth of MMC use as the materials are more widely understood and are cheap, suggesting a bright future for this class of materials.

Research and development on MMCs have increased considerably in the last 10 years due to their improved modulus, strength, wear resistance, thermal resistance and fatigue resistance and improved consistency in properties and performance in general compared to the unreinforced matrix alloys. The reinforcements are added extrinsically or formed internally by chemical reaction. The properties of MMCs depend on the properties of matrix material, reinforcements, and the matrix reinforcement interface [4].

3-COPPER-GRAPHITE COMPOSITE

Copper-Graphite composites are an example of metal matrix composites. Basically they are a dispersion of graphite in pure copper matrix. The composite that we will be studying about has been fabricated by Casting. They exhibit excellent lubricating and anti-seizing properties due to the presence of graphite and good electrical conductivity due to the pure copper. But there is also the problem of poor interfacial bonding between copper and graphite. The properties of the copper-graphite composites are a function of the type and amount of graphite fiber incorporated in the composite [28] Casting is a manufacturing process in which a liquid material is usually poured into a mold, which contains a hollow cavity of the desired shape, and then allowed to solidify. The solidified part is also known as a casting, which is ejected or broken out of the mold to complete the process. Casting materials are usually metals or various cold setting materials that cure after mixing two or more components together; examples are epoxy, concrete, plaster and clay. Raw castings often contain irregularities caused by seams and imperfections in the molds,[3] as well as access ports for pouring material into the molds.[4] The process of cutting, grinding, shaving or sanding away these unwanted bits is called "fettling".[5][6] In modern times robotic processes have been developed to perform some of the more repetitive parts of the fettling process, but historically fettlers carried out this arduous work manually, and often in conditions dangerous to their health.

4-LITERATURE REVIEW

In order to gain background knowledge on the previous work done in similar fields, various papers and journals were studied. The findings of some of the journals are enumerated below:

K. Rajkumar and S. Aravindan (2009) [2] studied microwave sintering of copper–graphite composites. Coarser microstructure with larger porosity is obtained by this conventional sintering process which decreases the strength, wear resistance as well. In microwave sintering, heat is generated internally within the material and the sample becomes the source of heat. The direct delivery of energy to the material through the molecular interaction, results in volumetric heating. Microwave sintering offers many advantages such as faster heating rate, lower sintering temperature, enhanced densification, smaller average grain size and an apparent reduction in activation energy in sintering. The finer microstructure with relatively smaller and round pores, resulted due to microwave heating, enhances the performance of the composite.

H. Yang et al. (2010) [8] studied the effect of the ratio of graphite/pitch coke on the mechanical and tribological properties of copper–carbon composites. Addition of pitch coke in the matrix can much improve the interfacial bonding strength between carbon particles and phenolic resin (binder). The bending strength and micro-hardness of the copper–carbon composites increased with increase in the content of pitch coke and reached a maximum. The friction coefficient of copper–carbon composites increased significantly with increasing the content of pitch coke. The wear rate of composites initially decreased as the content of pitch coke increased and obtained a minimum and then ascended.

J.F. Silvain et al. (1993) [9] studied the elastic moduli, thermal expansion and microstructure of copper-matrix composite reinforced by continuous graphite fibers. Copper matrix composites reinforced by continuous graphite fibers (Cg) were processed by hot-pressing layers of metallic pre-pregs, each fiber within the yarns having previously been coated with copper by electroplating. Composites processed according to this procedure were evaluated by tensile testing and by determination of thermal expansion coefficients and chemical and structural characterizations of the graphite/copper interface. An electroplate coating followed by diffusion bonding was found to be a successful and original way to produce fully dense Cg/Cu laminated composites.
Chromium can be added to improve the chemical bonding.

Wenlin Maa and Jinjun Lu (2010) [10] studied the effect of surface texture on transfer layer formation and tribological behavior of copper–graphite composite. Metal matrix composites (MMC) containing graphite particulates usually have reduced friction under dry sliding, which is closely dependent on the formation of continuous transfer layer on the sliding surface of counterpart. Friction and wear tests were conducted under low and high load conditions and various sliding distances to evaluate the validity of the textures and their effect on the formation of the transfer layer of Cu/Gr composite.

Haijun Zhao et al. (2006) [11] investigated the wear and corrosion behavior of Cu–graphite composites prepared by electroforming. Cu–graphite composites were prepared by electroforming technique in an acidic sulfate bath with graphite particles in suspension. The interfacial bonding between metal matrix and particles is much strengthened and porosity is eliminated in the composites in case of electroforming. Corrosion takes place at grain boundaries rather than the interface between graphite particles and Copper matrix. Wear resistance is improved after the incorporation of graphite particles into copper matrix.

Simon Dorfman & David Fuksb (1996) [12] studied the stability of copper segregations on Copper/Carbon Metal-matrix Composite interfaces under alloying. Stability of interfaces in MMCs is linked to the conditions of the formation of segregations of the metal alloy at the metal/fiber interface. It is shown that alloying of the matrix, substituting copper in the interstitial metalmetalloid solid solution, changes the value of the mixing energy and influences the volume fraction of twodimensional segregations of copper. We expect that the wettability of carbon fibers by the pure copper matrix may be improved by the addition of small amounts of zirconium or iron to the matrix.

Dash, K., Ray, B.C. and Chaira, D. (2011) [13] synthesized copper–alumina metal matrix composite by conventional and spark plasma sintering and then performed characterization. The composites fabricated by SPS route do not show any peak of cuprous oxide as sintering was carried out in vacuum atmosphere. Presence of cuprous oxides was observed in the Cu/Al2O3 interface in the EDS of the sample fabricated by conventional sintering in hydrogen, nitrogen and argon atmosphere. The density of composites sintered by spark plasma sintering technique is quite high as compared to the other techniques. The average micro hardness value for 5% alumina reinforced Cu–Al2O3 composite is 67.8 HV for conventionally sintered samples, whereas in the present study, nano-composites fabricated by SPS method produce an average of 124.5 HV for the same composition.

S.F. Moustafa et al. (2002) [14, 15] studied the friction and wear of copper– graphite composites made with Cucoated and uncoated graphite powders. They have shown that composites made by Cu-coated and uncoated graphite have lower wear rates and friction coefficients than those made from pure copper which can be attributed to the fact that the smeared graphite layer present at the sliding surface of the wear sample acts as a solid lubricant.

Jaroslav Kovacik et al. (2007) [16] investigated the effect of composition on the friction coefficient of copper–graphite composites in the range of 0–50 vol. % of graphite at constant load to determine critical graphite content above which the coefficient of friction of composite remains almost composition independent and constant. They investigated that up to critical concentration threshold of graphite the decrease of the coefficient of friction is governed by the synergic effect of graphite phase sliding properties and its spatial distribution within composite microstructure. Better homogeneity of graphite phase spatial distribution leads to lower coefficient of friction of composite. Then the coefficient of friction of composites becomes independent on the composition and corresponds probably to the dynamic coefficient of friction of used graphite material whereas the wear rate decreases.

C G Kang et al. [17] in their paper have described the one-dimensional heat-transfer analysis during centrifugal casting of aluminum alloy and copper base metal matrix composites containing Al2O3, SiCp, and graphite particles. The model of the particle segregation has been calculated by varying the volume fraction during centrifugal casting, and a finite difference technique has been adopted. The results indicated the thickness of the region in which dispersed particles are segregated due to the centrifugal force is strongly influenced by the speed of rotation of the mold, the solidification time, and the density difference between the base alloy and the reinforcement. This study also indicated the presence of particles increases the solidification time of the casting.

J. Zhang et al. [18] have investigated the effect of Silicon Carbide and Graphite particulates on the resultant damping behavior of 6061 A1 metal matrix composites to develop a high damping material. The microstructural analysis has been performed using scanning electron microscopy, optical microscopy and image analysis. It was shown that the damping capacity of Al 6061 could be significantly improved by the addition of either Silicon Carbide or graphite particulates through spray deposition processing.

M. L. Ted Guo et al. [19] in their research paper have studied the tribological behavior of selflubricated Aluminium/Silicon Carbide/Graphite hybrid composites with various amount of graphite addition synthesized by the semi-solid powder densification (SSPD) method. It has been found that the seizure phenomenon which occurred with a monolithic aluminium alloy did not occur with the hybrid composites. The amount of graphite released on the wear surface increased as the graphite content increased, which reduced the friction coefficient. Graphite released from the composites bonded onto the wear surfaces of the counter faces.

R.F. Cooper et al. [20] in their study have presented Silicon Carbide continuous fibre-reinforced glass and glass-ceramic matrix composites showing high strength and fracture toughness using thin-foil transmission electron microscopy and scanning transmission electron microscopy (AEM). The exceptional mechanical behaviour of these materials is directly correlated with the formation of a cryptocrystalline carbon (graphite) reaction-layer interface between the fibers and the matrix. AEM results are used to comment upon a possible mechanism for the hightemperature embrittlement behavior noted for these materials when they undergo rupture in an aerobic environment.

L.C. Davis et al. [21] in their research thesis have explained the thermal conductivity of metal matrix composites, which are potential electronic packaging materials, has been calculated using effective medium theory and finite element techniques. It has been found that Silicon Carbide particles in Al must have radii in excess of 10 μm to obtain the full benefit of the ceramic phase on the thermal conductivity. Comparison of the effective medium theory results to finite element calculations for axisymmetric unit cell models in three dimensions and to simulation results on disordered arrays of particles in two dimensions confirms the validity of the theory.

SCem Okumus, Sredar Aslan et al. [22] in their paper have studied on Thermal Expansion and Thermal Conductivity behaviours of Al/Si/SiC hybrid composites. It clearly highlights that Aluminium-Silicon based hybrid composites reinforced with silicon carbide and graphite particles has been prepared by liquid phase particle mixing and squeeze casting. The thermal expansion and thermal conductivity behaviours of hybrid composites with various graphite contents (5.0; 7.5; 10 wt.%) and different silicon carbide particle sizes (45 µm and 53 µm) has been investigated. Results indicated that increasing the graphite content improved the dimensional stability, and there was no obvious variation between the thermal expansion behaviour of the 45 µm and the 53 µm silicon carbide reinforced composites.

Na Chen, Zhang et al. [23] have reviewed on metal matrix composites with high thermal conductivity for thermal management applications, it emphasizes that the latest advances in manufacturing process, thermal properties and brazing technology of SiC/metal, carbon/metal and diamond/metal composites has been presented. Key factors controlling the thermo-physical properties were discussed in detail. The problems involved in the fabrication and the brazing of these composites were elucidated and the main focus was put on the discussion of the methods to overcome these difficulties. This review shows that the combination of pressure-less infiltration and powder injection molding offers the benefits to produce near-net shape composites.

5-Conclusion

In this paper, we generate Cu-Gr metal matrix composite by casting route and analyses the fabrication of Cu-graphite MMC by casting Process and different mechanical properties like tensile and hardness, microstructure are also analyzed. And we examined that tensile strength increases as wt% of graphite increases and hardness increase as wt% of graphite increases. Microstructure study shows the existence of both copper and graphite (carbon) phases along some copper oxide in samples. The casting samples were devoid of any oxide inclusions because of the vacuum conditions. Microstructure study suggests proper bonding between matrix and reinforcement along their interface Density study shows an increasing trend with increase in content of graphite.

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