ScienceDirect

Materials Today: Proceedings

Volume 92, Part 2, 2023, Pages 1122-1128

Microstructure mechanical behavior of Cu-Sn alloy reinforced with Al_2o_3 and Graphene metal matrix composite

Raja Shakarappa [a], A. Arul Peter [b], P. Rathna Kumar [a], M.V. Mallikarjuna [a], S. Padmanabhan [c]

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https://doi.org/10.1016/j.matpr.2023.05.145

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Abstract

In the present study, an effort has been made to examine the Microstructure and Wear characteristics of composites manufactured from Cu+10wt% Sn alloy as matrix and reinforced with Graphene Oxide (GO) and Alumina. Cu+10wt% Sn alloy hybrid composites is prepared reinforced with alumina (10vol%) and altering weight percentage of Graphene oxide (0.25wt%, 0.5wt% and 1wt%) by spark plasma sintering technique. Wear characteristics of developed composites is studied using Pin on Disc Wear Testing machine. Utilizing optical microscopy the microstructural investigation is conducted. The results revealed that (Cu+10wt% Sn alloy-10vol% Al_2O_3-0.25wt% GO) and (Cu+10wt% Sn alloy-10vol% Al_2O_3 − 0.5% wt%) of hybrid nanocomposite showed an increase of 25 % in the hardness, a reduction of 25% in the wear rate for Cu+10wt% Sn alloy-10vol% Al_2O_3-0.25wt% GO and Cu+10wt% Sn alloy-10vol% Al_2O_3 − 0.5% wt% GO of hybrid nanocomposite, and an increase trend wear rate is observed with increase in applied load and disc speed in dry pin on disc wear testing. The result also revealed the uniform reinforcement distribution in microstructure and more than 95 % densification of all composites with spark plasma sintering process.

Introduction

Researchers have extensively studied copper-matrix composites for use in tribology, heat sinks, and electronic packaging. Due to their superior mechanical qualities, strong thermal conductivity, excellent electrical conductivities, also with superior corrosion and wear resistances [1]. The Reinforcements for composite adds unique properties, and they are frequently employed to modify the composites properties to satisfy unique prerequisites. For example, a slight increase in volume of TiC particles can enhance their strength, wear resistance and hardness while reducing the ductility and fracture toughness of Cu matrix composites [2].

There are two phases in composite materials that are Fibers and sheets, or other particles which are embedded in matrix phase are known as reinforcing phases. The reinforcing component and matrix component could be separated in a variety of materials, including metals, ceramics, and polymers. While matrixes are favored due to their ductile or tough nature, reinforcing elements are used in composites because they deliver exceptional outcomes at low densities. Composite materials are classified into three types based on the methods employed for reinforcement: dispersion-, particle-, and fiber-reinforced. To make a perfect composite, the reinforcement's strength and the matrix's toughness must be perfectly balanced. As a result, composites can acquire desired properties that are not feasible in a single material [18]. It has been observed that the orientation of the reinforcing material allows for the easy modification of properties like strength and stiffness in a variety of composites. A composite material is extremely helpful due to its extraordinary properties, which include improved electrical and thermal conductivity, excellent temperature stability, minimal density, good stiffness, and uplift strength. As we can see, due to the constant innovation of new materials, processes, and applications, such as speedier and more automated production and hybrid virgin and recycled fibres, the global market for composites has increased from 5% to 12%, which has favorable condition.

Tin is the primary alloying component of copper-based tin bronze (Cu-Sn), which is the principal base metal. Practical composition ranges include 75% to 95% Cu and 5–25% Sn [4]. Because of its excellent corrosion resistance and strength, tin bronze is commonly used in applications like gears and bearings [3], [5]. In addition to other items, they are frequently used in the production of hydraulic fittings, pump linings, cookware, bearings, sheets, rods, and wires [6]. Its mechanical properties, which include great hardness, tensile strength, wear resistance, good corrosion resistance, and ductility, are primarily to account for this [17].

Tin bronzes, which are technically Cu-Sn alloys, often have a solution structure. According to the Sn concentration, they are divided into low-tin bronzes (less than 5% Sn) and high-tin bronzes (more than 5% Sn) [16]. The wide variation in crystallization temperatures of bronze solution is conducive to the segregation phenomenon. As a result, in the alloys cooling under actual conditions, Existence of phases predicted to form at greater tin contents under equilibrium conditions also observed at lower tin contents. The technological properties of the alloy, especially the sliding properties, improve with increasing tin content. Additionally, better cast ability, decreased hydrogen solubility, and increased corrosion resistance, especially in single phase alloys, are observed [7]. The high-tin bronze alloys were used, in bearing manufacturing [8]. It should be noted that the current bearings alloy is made up of Cu and Sn at a ratio of around 4:1. It is understandable why bearings bronze is renowned for its ability to resist corrosion while still being a very attractive alloy. Its strength characteristics present a different issue [9].

Enhanced corrosion resistance, wear resistance, and micro-hardness have been noted in Silicon Carbide or Molybdenum di Sulphide in biphasic mode reinforced with Aluminum or Copper Metal matrix composites.TiB_2 nanoparticle powders improves the homogenous scattering of carbon nanotubes (CNTs) throughout the matrix and stimulate thermal mismatch with load transfer processes in Aluminum or Copper Metal matrix co-reinforced with Silicon Carbide or Molybdenum di Sulphide, exhibiting the synergistic strengthening impact of nano and micro reinforced composites. [10], [11].

Scientific literature reveals that tin increases the tensile strength and hardness of copper alloys while decreasing linear elongation when the alloys are formed in sand moulds [12]. Tin additions up to or around 4% increase unit elongation when alloys are poured into metal moulds [13]. Tin content if more than 4 %, then unit elongation decreases. Tin content upto 5% increase the impact strength of Cu alloy before it starts to deteriorate [14]. It is observed that with 10% Sn and 20% Sn Tensile strength and yield strength increases by 10% and 20% respectively and hardness increases by continuing to expand the amount of tin in the material. The alloy with 4% Sn has stronger fatigue strength than the alloy with less Tin content [15].

Good formability, low coefficient of thermal expansion, improved mechanical properties, excellent electrical and thermal conductivity are the characteristics of Copper-alumina (Cu-Al_2O_3) composites which exhibits dual characteristics of alumina and copper [19]. In the various engineering applications, copper matrix with the addition of alumina is used in electronic components, electrical contacts, and bearing materials [20], [21]. The Cu-Al_2O_3/GNPs coated silver (Ag) nanocomposite was prepared by using electro-less deposition method. By incorporating GNPs, the nanocomposites shown improvements in mechanical and thermo-electrical properties [22]. The previous literature review indicated that there are numerous studies available focusing on the creation of Cu- Al_2O_3 and Cu graphene composites. However, the impact of graphene content on properties of Cu- Al_2O_3 composites is yet to be investigated. The Cu- Al_2O_3/graphene nanocomposites have been prepared using SPS method and high-energy ball milling.

Section snippets

Material selection and composite preparation

The basic matrix material is copper alloy (Cu+10wt% Sn) in powder form commercially purchased with purity of 99.5 % and particle size of 40µm, density 8.95g/cm^3(Table 1), Aluminum oxide (Al_2O_3: 99.88% pure, particle size 300nm and approximate density 3.95g/cm3) was procured from BRM Chemicals Ltd Bangalore as first reinforcement. The graphene oxide (GO) reinforcement (density: 2.26g/cm^3) 99% purity purchased from Ultra Nanotech Bangalore.

Ball Milling steel balls (Dia=5mm) were used…

Microstructure, density, hardness and wear properties

Samples from the post Spark plasma sintering are taken to ensure uniform reinforcing particle distribution and to describe the component's microstructure. Using bench grinder it was initially ground, and then the burrs were taken out with a finishing polisher. Surface was polished to mirror finish using Emery papers of various grit size. (1000, 2000 and 3000). In order to generate a flat surface for seeing the microstructure, the specimen was lastly prepared by polishing it with a disc while…

Microstructural examination

Fig. 5a depicts the Cu-Sn10% alloy's microstructure, which exhibits a typical dendritic structure as a result of the creation of a temperature gradient during solidification. Similar findings have been found in studies on in situ AlSi12alloy [16]. Fig. 5b shows the microstructure of the composites containing Cu+Sn alloy+10 vol% Al_20_3+0.25 wt% GO. It is evident that the reinforcement particles in the Copper alloy reinforced with Cu+Sn alloy+10 vol% Al_2O_3+0.5 wt% GO hybrid composites…

Conclusion

- The influence of 10 vol% Al_20_3 and Graphene oxide of 0.25 wt%,0.5 wt% and 1 wt% on the microstructure, hardness, Densification behaviour, wear behaviour and other parameters of a bronze with a composition of 90% copper and 10% tin has been the subject of research.…
- The microstructural investigation demonstrated that the particles are spread out in a consistent manner across the matrix structure.…
- Utilizing Spark plasma sintering, the Cu+Sn alloy with Al_2O_3 and Gr (0.25, 0.5 and 1 wt% composites…

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CRediT authorship contribution statement

Raja Shakarappa: . **A. Arul Peter:** . **P. Rathna Kumar:** . **M.V. Mallikarjuna:** Conceptualization, Formal analysis, Supervision, Validation. **S. Padmanabhan:** Conceptualization, Formal analysis, Supervision, Validation.…

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.…

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