



Original Article

Artificial neural network technique to predict the properties of multiwall carbon nanotube-fly ash reinforced aluminium composite



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ABSTRACT

In this study, prediction of density and hardness properties using artificial neural network (ANN) and micro structural evolution of multi walled carbon nano tubes (MWCNT) and fly ashes (FA)/Al composites produced by powder metallurgy were investigated. The influence of content (wt.%) of reinforcements (MWCNTs and FA), ball milling time and sintering time on the mechanical properties were experimentally determined by measuring density and hardness values which are the outputs obtained from the artificial neural network. It was found that amount of reinforcements, ball milling time and sintering time play a major role in dispersion and enhancement of the properties. It was also demonstrated that ANN model is a powerful prediction technique to predict the mechanical properties of the composites. Blend powder morphology and sintered composite structure were investigated by scanning electron microscope (SEM). It was found that reinforcements were well dispersed for prolonged ball milling time and sintering time.

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1. Introduction

Aluminium is one of the popular metals used extensively in many engineering domains which include aerospace, automobile applications due to its low weight, high thermal conductivity and good corrosion resistance properties [1]. However due to the limitations of not possessing high strength to weight ratio properties, composite materials are preferred

over pure aluminium. It is attractive to use aluminium based metal matrix composites (AMMCs) in aerospace, automobile and structural applications because of their high strength-to weight and stiffness to weight ratios. However, the main drawback of AMMCs is their costly fabrication methods [2]. Fabrication of AMMCs can be accomplished through many techniques such as conventional casting or stir-casting [3–5], powder metallurgy [6,7], spray deposition [8] and diffusion bonding [9]. Because of the low processing temperature avoiding undesirable phases and dispersion of uniform reinforcement's powder metallurgy is more preferred alternative than conventional method. In powder metallurgy method powders of metal matrix and reinforcements are blended to

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PAPER

Effect of fly ash and ball milling time on CNT-FA reinforced aluminium matrix hybrid composites

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Keywords: metal matrix composite, multi-Walled carbon nanotube, fly ash, scanning electron microscope, x-ray diffraction**Abstract**

In this paper, Aluminium metal matrix hybrid composite was fabricated using powder metallurgy, where MWCNT and burnt coal waste (pollutant) used as reinforcing materials. The density and hardness of specimen was calculated and influence of fly ash on them was discussed. It was observed that hardness had increasing effect for certain weight percentage of fly ash (up to 8 wt%) and above that level showed the negative effect on them. An increase of 63.6% in hardness and 107% in compressive strength was observed for the composite compared to pure aluminum. The increased ball milling time resulted in damage of CNT. Compressive strength test revealed that MWCNT along with fly ash addition resulted in the improvement of compressive strength compared to pure Al.

1. Introduction

Hybrid metal matrix composite (MMC) is gaining popularity day by day due to its capability of producing high strength to weight ratio material [1]. A lot of research has been done on composite with single reinforcing material, whereas hybrid MMCs have not been explored so much. Hence in this paper Aluminium metal matrix hybrid composite was fabricated and few of its mechanical properties were studied.

The reinforcing material defines the properties of any composite. In this study, fly ash and Multi-Walled Carbon Nanotube (MWCNT) were used as reinforcement material. Fly ash (FA) is the residue of burnt coal and largely produced in thermal power plant. This material does not have any known use, also it causes health related issue if it let free to environment. Therefore, using this material in composite material technology may help in protecting environment as well as developing material with good mechanical properties. Many literatures have proved fly ash as one of important natural source used to strengthen the materials because of its low density, available in large quantities as solid waste by-product of coal [1–17]. We can partly or amply replace the high cost material with locally available and low-priced material like Rice husk ash (RHA), Fly Ash (FA) etc which will not only take care of the problem of disposition of waste, but will also bring down the cost of material [17–24].

The CNT is an innovation by engineering, which posse's high strength and less weight. Its dimensions are in the range nano to micro metre scale. At high temperature CNT undergo thermal degradation. Because of this, there is a limited number of metal matrix that can be used with CNTs. Since aluminum has a low melting point, it is appropriate to use it with CNT.

Many Researchers [25–33] have investigated their use as reinforcements in mainly polymer and ceramic matrices during last decade. There have been very few studies on CNTs-reinforced metal matrix composites.

There are several methods using which composite can be fabricated but stir-casting and powder metallurgy are the most commonly employed techniques. In this study stir casting was not employed because of low relative densities of reinforcing material in comparison with matrix material. That may result in floating and agglomeration material on surface of liquid aluminium. In order to avoid this, powder metallurgy technique was employed. This technique involves blending of matrix with reinforcing material using ball milling and then cold compaction of blend using die for required shape. Eventually sintering was employed to improve mechanical properties.



Underwater shock wave weldability window for Sn-Cu plates

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ABSTRACT

In this paper, the effects of the heat input and depth of water (d) on the welding interface of tin – copper are discussed using underwater explosive welding technique. An increase in the water depth caused a reduction in the parameters of wavy morphology at the interface. The welding window which certifies the quality of welding was determined for welded Sn – Cu plates based on numerical analysis using AUTODYN – 2D software. The velocity of the flyer plate (V_p) and kinetic energy lost (ΔKE) at the interface was found to be decreased when the increase in water depth was pronounced. The Sn and Cu plates successfully welded using underwater shock wave method under moderate condition, and the experimental parameters were discussed based on the welding window.

1. Introduction

The Explosive welding (EXW) is one of the most widely employed applications of explosives in materials processing. Crossland and Williams (1970) reported that EXW phenomenon was first observed in the First World War where pieces of launched metal projectiles got fused to the other metal surfaces to which they came into contact. Carl, 1944 and Philipchuk, 1965 recognized its commercial values. Since then, many applications for the EXW have been researched and developed. According to Carpenter and Wittman (1975), explosive welding is a solid state process used for the metallurgical joining of similar or dissimilar metals. The welding occurs under high velocity oblique collision of usually metal plates. In the EXW, the flyer plate is accelerated, by detonating of a layered chemical explosive at a high velocity, which then collides obliquely with a stationary base. The EXW is generally performed in an open atmosphere. However, Manikandan et al. (2011) reported that such a method is unsuitable for fusing of tungsten to copper due to the brittle nature of tungsten. According to Iyama et al. (2001) conventional explosive welding always poses a problem for welding of materials, particularly for thin metal plate (below 1 mm thickness) as well as brittle materials such as amorphous ribbon and ceramics. Sun et al., 2014a stated that with traditional air explosive welding, the force of explosion and high temperature at the interface destroys the thin foils. Hokamoto et al. (1998, 1999, 2004,

2009), Mori et al. (2004, 2006a, 2006b, 2014) and Saravanan et al. (2016) concluded that the underwater explosive welding is considered as one of the best welding techniques. In this method, water acts as a pressure transmitting medium. Sun et al. (2014a, 2014b) stated that, density of water is 800 times higher than that of air. Air is around 20,000 times more compressible than water. Hence, water can be considered incompressible. This ensures that the explosion forces do not produce high temperature in water, but allow the water to move forward with the foil material, maintaining their properties. The underwater shock waves prevent the distortion of the welded joint and ensure the integrity of the joints as concluded by Manikandan et al. (2011).

Hokamoto et al. (2004) proposed the underwater explosive welding technique, wherein significant decrease in kinetic energy loss at the interface of flyer plate and base plate was achieved. The use of thin plate can result in achieving high speed over a short distance, but not enough to produce the high energy required for the welding process to maintain their integrity. Thus, underwater explosive welding is considered as one of the best welding techniques to have precision and optimum control on the velocity of the flyer plate and the pressure acting on it to achieve effective fusion.

Dissimilar foil material combinations such as amorphous/stainless steel, metallic glass/stainless steel were welded by Hosokawa et al. (2009). Manikandan et al. (2011) had successfully welded thin tungsten foil to copper plate using underwater explosive welding method. The

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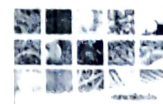
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Processing, characterization and property evaluation of seashell and glass fibre added epoxy based polymer matrix composite

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ABSTRACT

Seashell is an organic substance which is abundantly available in the seashores. The present work focuses on the processing of seashell powder into micron size and utilization of the same as reinforcement with glass fibers and epoxy resin in the preparation of the composite. Three different compositions are used for the synthesis of the composite. The prepared seashell powder was studied with scanning electron microscopy and energy dispersive analysis of x-rays. The composite samples were also subjected to physical and mechanical testing by preparing the samples as per ASTM standards. Results show that the elements found in the sea shell such as Na, Ca, Al and C along with the glass fibre and the binding provided by the resin are responsible for enhancing hardness and tensile strength of the composite.

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1. Introduction

Composite materials are among the most significant inventions of the material sciences. Composite materials are used in furniture, packaging, assembly boards, panelling, fencing, kitchen to civil constructions, automobile and marine industries, military and even space or aircraft manufacturing. Hence, composites are a versatile and valuable family of materials that can be used in many fields with high quality and low cost applications. Currently, synthetic fiber-reinforced thermoplastic composites are widely used because of their excellent mechanical properties and durability [1]. Composite materials produce a combination property of two or more materials that cannot be achieved by either fiber or matrix when they are acting alone. Fiber-reinforced composites were successfully used for many decades for all engineering applications. Glass fiber-reinforced polymeric (GFRP) composites are most commonly used in the manufacture of composite materials due to their low cost, high tensile strength, high chemical resistance and insulating properties. The matrix comprised organic, polyester, thermos-stable, vinylester, phenolic and epoxy resins. Suitable compositions and orientation of fibers made desired properties and functional characteristics of GFRP composites almost equal

to steel, had higher stiffness than aluminum and with specific gravity one-quarter of that of steel. The various GF reinforcements like long longitudinal, woven mat, chopped fiber (distinct) and chopped mat in the composites have been produced to enhance the mechanical and tribological properties of the composites [2,3]. Glass fiber reinforced unsaturated polyester resin (UPR) composite materials have become the alternatives of conventional structural materials, such as wood and steel in some applications, because of its good mechanical properties. Mechanical properties of fiber-reinforced UPR composites depend on the properties of the constituent materials, the nature of the interfacial bonds, the mechanisms of load transfer at the inter-phase and the adhesion strength between the fiber and the matrix [4].

Fibre reinforced composites have been widely explored in the literature in view of its lightness and improved modulus. These materials have demonstrated in many engineering applications. Use of polymer materials in many engineering applications has enhanced the corrosion resistance and strength of many structures as witnessed in construction and building industries. The factors that influence the properties of these composites are determined by fibre loading and orientation. Biswas, et al. [5], have reported that fibre loading enhances the strength of polymer composite and this property also determines the mechanical and corrosion wear behaviour of any reinforced composites.

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Influence of WC-Co addition in the improvement of mechanical properties of aluminium matrix composite via liquid metallurgy route

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ABSTRACT

The demand for high quality materials are increased in the applications of aerospace and automobile industries. The main requirement in the industrial products looking towards the lightweight aluminium (Al) matrix composites lead us to prepare the same with improvisation of physical, mechanical and tribological properties of the composites. In this view the present paper opens up towards the new approach of the utilization of hard ceramic (WC) and soft metallic (Co) blend particulates as reinforcements in Al7075 matrix to prepare the composite via liquid metallurgy route. Composites are prepared for 6 and 9 wt% addition of reinforcement. Samples are characterized by using SEM and EDAX analysis. Evaluation on mechanical properties of the samples over the base alloy exhibits a significant improvement in the tensile strength of the composite material.

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1. Introduction

Composites are the materials having prevalent mechanical properties. For example, solidness, high load bearing limit, resistance to wear and more quality due to the addition of reinforcements. Erosion obstruction and low thermal coefficient of expansion are the properties which make them predominant than customary materials [1]. These properties contribute for less weight, which makes them reasonable for aviation and automobile applications [2]. The qualities and properties of a composite rely upon the manufacture strategy. Solid phase processes like powder metallurgy, liquid phase process like stir casting and semi-solid phase castings are the three sorts of processing techniques [3] commonly used in the processing of the composite. Poor wettability between reinforcing particles & matrices and agglomeration are the troubles experienced while processing of composites. Uniform appropriation of reinforced particles brings about better mechanical properties for MMCs [3].

Metal matrix composites (MMCs) need lightweight parameters of high resistance. Managing the microstructure, mechanical properties, and expense of the product by optimizing the chemical com-

position, manufacturing system and heat treatment is the main challenge in the development and processing of advanced materials [4]. The most advanced models routinely operate on spacecraft under challenging conditions. There are two types of constituent materials: matrix and reinforcement. The matrix layer covers and protects the materials for the reinforcement by maintaining their relative positions. The reinforcements impart their unique mechanical and physical properties to improve matrix properties [5].

A synergism produces material properties that are inaccessible from the individual constituent materials; while the wide variety of matrix and reinforcement materials enables the product or structure designer to choose an ideal combination of engineered composite materials to form [6]. The matrix material can be placed into the reinforcement before or after the reinforcing material is put into the mould cavity. Metal matrix composites consist of an element or alloy matrix where a second phase is added and distributed in order to achieve some enhancement of the properties. They have excellent advantages because of the combined metallic and non-metallic elements, thus having stronger physical and chemical elements. Particulate reinforced composites are among

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Studies on Dry Sliding Wear Characteristics of Cermet WC-Co Particulate Reinforced Al7075 Metal Matrix Composite

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Abstract

In the present work, an attempt is made to synthesize cermet (WC-Co) reinforced Al7075 metal matrix composite by liquid metallurgy route. The dry sliding wear behavior of these prepared composites was studied with varying sliding speed, load and sliding distance. Cermet in an amount of 6 wt% is used as reinforcement in Al7075 matrix. Microstructural characterization of the prepared composites is carried out using SEM/EDX and XRD studies. X-ray diffraction studies have revealed the peaks corresponding to α -Al, WC, Co and minor Al₃W phases. SEM/EDX characterization revealed the uniform distribution of cermets in Al matrix. Dry sliding wear characteristics of the prepared composites were studied using a pin-on-disc testing machine. The wear rate for alloy and composites decreased with increase in sliding speed and increased with increase in applied load and increasing sliding displacement. The worn surfaces of the composites were investigated using optical microscope.

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1. Introduction

Metal matrix composites (MMCs) provide improved properties over other monolithic materials, like high strength to weight ratio, high temperature working temperature, wear and corrosion resistance [1]. AMMCs are gaining importance due to light weight and good formability. Al7075 is the type of Al alloy containing Zn and Mg as major alloying elements commonly used for automobile, aerospace and gas cylinders. Al7075 is heat treatable, can be easily welded and good finishing characteristics. Al7075 has high strength among aluminium series and highly corrosive than other aluminium alloy [2]. Particulate composites are widely used due to their low cost and manufacturing ease. Ceramics are commonly used as reinforcements. The reason of metal reinforced with hard ceramic particles provides high strength, wear resistance, stiffness etc [3]. Fabrication of composites is commonly done by stir casting route due to simple, economical and fabrication ease [4, 5]. Eunji Hong *et al.* [6] studied the wear property of copper alloy reinforced with WC. They carried macro and micro level pin-on-disc wear testing analysis.

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Effect of Mix waste cooking-oil biodiesel on performance and exhaust emissions of a CRDI engine

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Abstract: In fast-moving world, energy crisis and waste disposal are increasing day by day. To overcome the energy crisis, it is crucial that we consume less energy. The world contains potential resources to meet the demand of energy apart from electricity, highest demand among all sources. Hence to gear up the use of alternative methods from the wastes into an alternate fuel. The transportation is playing a major role in economic growth and globalization, but cause air pollution in all medium. In regard to crisis, biodiesel production from locally available mix waste cooking oil, which can be an major alternative to production of biodiesel apart from food resources. The aim of this paper is to extract the biodiesel from mix waste cooking oil using conventional methods and study the performance of B20 biodiesel blends with respect to best fuel injection time (IT), Injection opening pressure (IOP) and number opening holes in injector using common rail direct injection engine (CRDI). The experimental studies showed that waste cooking oil methyl ester (WCOME) at 27 deg before top dead centre and IOP 240 bar, B20 blend gives better results and 5 holes 0.3 mm injector nozzle give 31.7% Brake thermal efficiency, 37 HSU smoke, 37 ppm Hydrocarbon, 0.115% carbon monoxide of volume and reduce in 2% of nitrogen dioxide without any modification of engine.

1.0 Introduction

India's primary energy consumption is increased by 7.9% in recent year and it is highest growth rate per annum reached from since past 10 years. The emission of carbon is also increased by 7% [1]. However convectional or fossil fuels resources are limited and polluting, therefore, need to use sagacious methods. The alternative methods for non polluting, indigenous and virtually inexhaustible resources is Non convectional resources. India is the fourth largest generator of renewable energy ie., grew up to 27% from last 11 years [1]. The biofuels as renewable source is more demanding fuel in the society due to climate change and increase energy independence to many nations in the world. Biofuels are envisaged as an effective way of reducing the emissions of the greenhouse gases and an alternate to fossils fuels that are very limited in availability. The developing countries like India, which imports 75% of its crude oil and petroleum products, is highly influencing to global warming and high variation in oil prices in international market[2]. For serenity, it is challenging to generation biofuels for development of nations to solve the problem of global warming and engender new opportunities to remove unemployment and demand of fossil fuels[3]. Biofuels are environment friendly fuels and their utilization in support of fossil fuels would reduce global concerns about containment of carbon emissions. Urbanization and industrialization demands of alternative to fossil fuels, which is leading to deforestation, global warming[4]. Bio fuel will account 4 to 7 % of the total energy consumption in the world by 2030[5][6].



Simulation and analysis of P(VDF-TrFE) cantilever-beams for low frequency applications

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ABSTRACT

The work presented here describes a structural design of piezoelectric co-polymer P(VDF-TrFE) cantilever-beams for very low frequency applications; the design is based on silicon bulk-micromachining and micro-electromechanical systems technology. COMSOL simulation software has been used to study the mechanical and electrical behavior of cantilever-beams. The dimensions of the beams designed are: $3\text{mm} \times 0.6\text{mm} \times 5\mu\text{m}$, $5\text{mm} \times 1\text{mm} \times 5\mu\text{m}$ and $10\text{mm} \times 3\text{mm} \times 5\mu\text{m}$. The configuration of the cantilever-beam comprises of an active layer of piezoelectric P(VDF-TrFE) with chrome-gold interdigitated electrodes for electrical signal output generated due to vibration of piezoelectric beams. Simulation results show that the cantilever-beam of dimension $10\text{mm} \times 3\text{mm} \times 5\mu\text{m}$ has a resonant frequency of 42.68 Hz, indicating that P(VDF-TrFE) is a favorable piezoelectric material for low and very low frequency applications.

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1. Introduction

During the past few decades, piezoelectric materials obtained significant attention due to their wide range of applications in many devices like energy harvesters, actuators, vibration sensors and other low frequency devices [1–5]. For the development of piezoelectric based micro-devices, the advancement of micro-electromechanical systems (MEMS) process technologies is very important [6–8]. As piezoelectric thin films can be easily incorporated into MEMS based structures and their piezoelectric energy conversion does not drop significantly in the micro-scale, piezoelectric based devices are extremely suitable for miniaturization [9].

Inorganic ceramics such as lead zirconium titanate (PZT), zinc oxide (ZnO), aluminum nitride (AlN), etc. [10] and organic

polymers like Polyvinylidene fluoride (PVDF) along with its co-polymers are most commonly used piezoelectric materials [10]. Piezoelectric ceramics have high spring constant and hence, use of these materials for designing low/very low frequency devices is challenging even though they have significant uses in micro-electromechanical systems (MEMS) based devices [11,12]. Hence, polymers and their co-polymers with piezoelectric properties find applications in low/very low frequency devices due to their soft and flexible nature and these properties result in lower resonant frequencies. In addition to these there are other advantages such as weak dielectric constant, strong piezoelectric properties and low electromechanical coupling factors [13]. Polymers with piezoelectric properties are therefore, favorable materials for low/very low frequency MEMS based devices, such as vibration sensors [14,15].

The most commonly used polymer for various piezoelectric based devices is PVDF and its co-polymers [16–19]. The advantages of PVDF are low cost, chemical inertness and comparatively

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Study on thermal resistance of brass with and without coating of metallic surface

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ABSTRACT

The thermal interface material (TIM) is basically one of the best selections to solve the thermal issues in electronic packaging applications. The basic functions of TIM are to fill micro or nano sized rough surfaces (viz., valleys, gaps etc) between two conducting materials and to improve the thermal conduction and reducing the thermal contact resistance between them. In the present study, brass substrate with and without coating of metallic substrate is considered as TIM material and thermal contact resistance of the same is assessed. Tin (Sn) is considered as a metallic coat on brass substrate. The contact pressure at the interface was varied with and without application of load (kg) to investigate the thermal contact resistance. Results indicated that Sn coated brass interface material exhibited better thermal performance than bare brass substrate.

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1. Introduction

With increased performance requirements for smaller, more competent and more effective electronic systems, thermal challenges have turned out to be critical issues in electronic packaging design. Developments are needed in advanced cooling solutions and realistic design at chip, board, and system package levels. In response to these critical requirements, advanced materials and their process enhancements in packaging and cooling technologies are required in terms of high thermal transfer efficiency, environmental compatibility, low weight, acceptable material and fabrication cost. As a result, electronic devices and their applications have been among the fastest advancing fields, in micro and nano scale industries. Today, many modern electronic devices operate with critical dimensions in the tens of nano meters. At present, minimum feature sizes of 14 nm and below are being targeted for next-generation technology nodes [1,2].

With these advances, thermal management of the package becomes more challenging. The life span of an electronic component is profoundly dependent on the operating temperature; therefore, the enhancement of the heat diffusion rate for maintain-

ing required device operating temperature is increasing interest [3]. One of the thermal management areas in electronics involves reducing the thermal resistance between the microprocessor chip and heat sink using a thermal interface material (TIM). TIMs are crucial part of thermal management in electronics cooling and often account for a significant portion of the overall thermal economical. Thermal interface material can be defined as any material that is applied between the interfaces of two components to enhance the thermal coupling between these devices. Usually, TIM is used between heat generating devices (e.g. microprocessor, photonic integrated circuits, etc.) and a heat dissipating device (e.g. heat sink) to remove the heat from the component [4]. TIMs are a critical solution for minimizing the contact resistance between the power electronics module and the cold plate assembly. It is difficult to assess the thermal performance and reliability of TIMs in their final packaged configuration, therefore several test standards and modeling approaches have been created to quantify their bulk and contact thermal resistances [5]. An ideal TIM should possess high thermal conductivity, low thermal resistance at a thin bond line thickness (BLT), conformability at low to moderate pressure, good wetting properties, ease of manufacturing, and low cost while also being environment and health friendly. Also an ideal TIM would fill all the microscopic irregularities that exist at the interface. However, an actual TIM will leave few air gaps at the interface depending on the conformability of the TIM.

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A review on effect of alloying elements and heat treatment on properties of Al – Sn alloy

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ABSTRACT

Aluminum (Al) –Tin (Sn) alloys are potential lead free bearing materials, widely used in automobile and marine applications. These alloys possess good fatigue strength, seizure resistance, corrosion resistance and embedability properties. However, properties of Al – Sn alloy have to be modified to suit for engineering applications. In this paper we present a review on characterization of mechanical and tribological properties of Al – Sn alloys subjected to heat treatment (Annealing) and also effect of addition of alloying elements such as Bi, Mg, Pb, Nano Si and Nano Gr. The review suggests that heat treated alloys exhibited better mechanical properties whereas ternary alloyed samples showed improved tribological properties. © 2020 Elsevier Ltd. All rights reserved.

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1. Introduction

Self – lubricating bearing materials are widely used in various applications such as machine tools, small motors, home appliances, construction equipment and aerospace industries [1,2]. Aluminum (Al) –Tin (Sn) alloys are known as anti-frictional materials due to their self – lubricating property and they are regarded as lead free bearing materials [3,4]. Al–Sn is a binary alloy with a solid solubility of Sn in Al below 0.09 wt% at room temperature. Due to the immiscibility of Al–Sn system and big density difference between Al (2.7 g/cm³) and Sn(7.2 g/cm³), there is very strong sedimentary tendency in the casting of Al–Sn alloy [5,6]. During solidification soft tin which forms a dendritic structure distributes evenly on the grain boundaries of Al matrix, Sn imparts seizure resistance property to the alloy while aluminum matrix supports the load bearing property. However, it is difficult to achieve uniform distribution of Sn within aluminum matrix due to strong sedimentary properties [7]. Various techniques such as physical vapour deposition, stir casting, rapid solidification and cold rolling have been

used in manufacturing of Al – Sn alloys [4,8]. Al – Sn alloys possess good tribological and mechanical properties and are widely used in the manufacture of engine bearing and cylinder liners. However, recent trend in automobile industries demand more efficient engine to support higher loads; hence, it is necessary to improve the properties of the alloys [9]. Various investigators have worked on enhancing the properties of the alloy [10–13]. In this short review characterization techniques used by some of the researchers to study the effect of alloying element and heat treatment on mechanical and tribological properties are presented.

2. Effect of alloying elements

2.1. Effect of Si addition

Si added Al – Sn alloys were prepared by cladding process. The prepared alloys were tested for mechanical and tribological properties. The addition of Si increased the hardness and tensile value when compared to Al–Sn alloys without Si. Further, there is a greater enhancement in the wear resistance properties due to the presence of hard Si particles surrounded by soft Sn phase [14]. The properties are presented in Table 1 and Table 2.

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Effect of surface treatment on wetting behavior of copper

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ABSTRACT

Super-hydrophobic surfaces are very useful in cleaning activities. Surfaces with water contact angles above 150° are regarded as superhydrophobic surfaces. In the present study an attempt has been made to achieve superhydrophobicity on copper substrate by electrochemical etching and electro-deposition of Co-Ni alloy and Co-Ni-Graphene composite. A contact angle of about 105° was obtained on Cu surface with electro-deposited Co-Ni alloy and on electro-deposited Co-Ni-G alloy contact angle was found to be 106°. The contact angle was significantly higher at about 142° with electro etched surface. Corrosion test was carried out with electrochemically etched Cu. Electrochemical etching time was varied from 30 to 240 min. The electro-etched Cu substrate etched for 60 min. showed better corrosion resistance with a corrosion rate of 0.197 mm/year. The surface topography of both etched and electrodeposited samples was studied by atomic force microscopy (AFM) and the results were correlated with the wettability data. © 2020 Elsevier Ltd. All rights reserved.

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1. Introduction

Wetting is one of the most important properties of liquids to spread over a solid substrate. Wetting of a solid by liquid is of great technological importance. Some applications require a good wetting between liquid and substrate surface such as soldering and printing whereas some others demand poor wetting (repellence) such as painted surface and solar panels. Contact angle is a measure of the degree of wetting or wettability of a surface by a liquid [1].

Wettability is an important characteristic of solid surfaces, and is usually measured by the contact angle between water and the surface. If the contact angle is less than 90°, the surface is hydrophilic; if it is greater than 90°, the surface is hydrophobic and if it is greater than 150°, the surface is superhydrophobic [2]. A super-hydrophobic surface is the one that repels water to such an extent that contact angles obtained are extremely high; they are generally defined as surfaces with water contact angles above

150° but it has also been less commonly adopted as 140° [3]. The microscopic geometric structure of the surface is one parameter which determines wettability; Free energy is another parameter- higher the free energy, higher is the wettability, and vice-versa. In general, a solid surface becomes hydrophobic when treated to give micro- or nano-roughness structures and low surface energy. Many kinds of surface treatment techniques, including optical micro-lithography, dry and wet etching, surface coating and precision diamond dicing processes were reported [4-7]. To reduce the production costs and increase the processing speeds, laser machining processes techniques such as laser ablation, laser milling, and laser deposition have been employed [8-10]. These techniques have been effectively used to manufacture components with enhanced hydrophobic properties.

There is little research is carried out on the developing a simple technique of fabricating super-hydrophobic surfaces on various substrates. Realization of super-hydrophobic surfaces via simple coating methods to design a solid surface with appropriate surface roughness and low surface energy are rarely attempted [11].

Different topography can be achieved by creating rough surface either by etching or by coating the surface. Wenzel regime

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Compression and water absorption behaviour of banana and sisal hybrid fiber polymer composites

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ABSTRACT

Advancement in science and technology with Environmental awareness have made us to find suitable materials which are light, high strength, biodegradable and can sustain harsh environmental conditions for various applications. Among various materials, both synthetic [wool, nylon and terylene] and natural [sisal, banana, jute, etc.] fibers, extracted from plants and animals, are of special interest. Natural fibers are available in nature abundantly at very low cost. Composite materials are heterogeneous in nature made from two or more constituent materials with significantly different physical and chemical properties. Hybridization of natural fibres affects the mechanical properties of composites and interfacial adhesion between fiber and matrix. In this work sisal and banana fibers are used as reinforcement which is treated with NaOH solution to improve the bonding between fiber and resin by removing moisture. The different compositions of treated and untreated hybrid mixture composites were prepared. Experimental study on compression and water absorption shows that with increasing sisal fiber percentage improves the property of the composite material.

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1. Introduction

Natural fibers are available plenty in nature and can be grown very easily. The researchers and many industries are working to replace synthetic fibers with natural fibers because of growing environmental pollution. The composite materials are a mixture of two or more materials that are stronger than individual materials to obtain good properties. The effect of natural fiber composites is controlled by nature of fiber-matrix interface, weight fraction and orientation. The various bio-fiber reinforced epoxy hybrid composites studied using compression moulding technique with various weight ratios of fiber and resin showed that during testing the flax/kenaf/epoxy hybrid composite produced better result [1]. The sisal fibers were treated with NaOH solution with different percentages, specimens were prepared with ASTM standard and both treated and untreated for tensile test and it was found that 3% NaOH treated fibers shows a better result compared to untreated fibers [2]. Banana fiber and polyester were used as

matrix, and specimens were prepared by varying weight percentage of different fiber lengths under different chemical treatment and results were checked with ANSYS software [3]. Further, the short randomly oriented banana/jute hybrid composites with different percentage of fibers with volume fraction of both fibers 1:1 and with hot compression moulding at 85 deg C, it was found that their strength increases up to 25% [4]. The different fibers such as sisal fiber, kenaf fiber, banana fiber and rice husk hybrids are separately used with thermosetting polymer by compression moulding method [5]. The hybrid composites of sisal/coir, sisal/hemp and sisal/flax fibers reinforced with epoxy hybrid composites using hand layup method followed by NaOH treatment of fibers, showed that sisal/hemp exhibit good properties [6]. The randomly oriented short sisal fiber reinforced with epoxy composite using hand layup method for different fiber lengths of NaOH treatment showed good result and SEM showed good adhesion between fibre/epoxy [7]. In addition, different chemical compositions of NaOH treated fiber surfaces and the effect of these concentrations on the mechanical and visco-elastic behaviour of the composites has been studied and it was found that 1% NaOH treated fiber-reinforced composites behave better than other treated fibers [8].

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A study on thermal conductivity enhancement of silicon carbide filler glass fiber epoxy resin hybrid composites

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ABSTRACT

The silicon carbide filler glass fiber reinforced polymer composites have been prepared by using hand-lay-up technique compression molding machine. Thermal conductivity of silicon carbide filler glass fiber reinforced polymer composites at different volume fractions of glass fiber and silicon carbide is determined using Lee's apparatus experimentally. The experimental results show that the thermal conductivity of the hybrid polymer composite increases with increase in silicon carbide percentage. Experimental results are compared with mathematical models Hashin formula, Maxwell model and Rule of mixture model to find the variation of the thermal conductivity with volume fraction of silicon carbide. All three mathematical models exhibited results close to each other at low percentage silicon content. From mathematical models and experimental results the difference between the two has been found to be small for 20% SiC content; for example, Maxwell model showed a difference 10.40%, Rule of mixtures 16.12% and Hashin formula 3.62% for 20% SiC content.

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1. Introduction

Hybrid polymer composites are the new kind of materials whose properties can be tailored during manufacture for different applications. Mechanical, physical and thermal properties can be improved by adding fillers in glass fiber (GF) epoxy resin (ER) polymer composites which make the material known as hybrid polymer composites (HPC). Hybrid polymer composite materials give much better thermal properties without affecting the physical properties. HPC materials are used in military, automotive, civil infrastructure, aerospace, marine and medical instruments due to better mechanical, thermal and electrical properties, low density, high strength and low cost compared to regular conventional materials. Currently the requirement of HPC materials has increased in the fields of communication, electronics, satellites and aircraft applications where light weight thermal resisting materials are needed [1]. While designing the hybrid composite

material systems for different applications, a study of their thermal properties is essential. Further, it is difficult to predict the temperature behavior of HPC materials without knowing their thermal conductivity. However, measurement of thermal conductivity of HPC materials is a complex task [2]. Adding SiC to epoxy resin composites gradually increases the thermal conductivity; 20 percent silicon carbide epoxy resin and 30 percent silicon carbide epoxy resin have 0.41 W/mK and 0.51 W/mK thermal conductivity values respectively. SiC-Epoxy Resin composites have lower thermal conductivity even though the thermal conductivity of SiC (280 W/mK) is higher compared to other hybrid composites due to smaller filler particle size (6–12 μm). However, they are not useful in producing conductive paths [3]. Hence, most electronic devices fail due to inadequate cooling. To increase the life and consistent performance of electronic components it is necessary to maintain operating temperature of an electronic device within the specified limits. The exact thermal management is a key point for packaging of high performance semiconductors [4].

The advantage of using HPCs depends upon the filler materials which give highest thermal conductivity. Hybrid nano-filler modi-

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Thermal property characterization for enhancement of thermal conductivity of hybrid polymer composites

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ABSTRACT

Hybrid Polymer Composites (HPC) are the novel answer for high thermal resistivity and stability of composites under variable thermal conditions. In this work the effort has been made a study of thermal properties of silicon, copper inserted HPC (Glass - FCS). The HPC's made by hand layup with compression machine moulding by non-heating moulding method at room temperature. Thermal properties of HPC's Thermal Conductivity (K), Coefficient of Thermal Expansion (CTE) and Thermal Gravimetric Analysis (TGA) are found by experiment. Experiments conducted at different heat inputs to find K of each material, by the experimental readings, the results designates K of silicon inserted hybrid composite material increases as percentage of silicon increases in HPC's. The value of coefficient thermal expansion decreases with increase in percentage of silicon and in TGA the failure of HPC material occurs at 285 °C and time of 25 min, very small amount of decline in mass of silicon filler HPC's in TGA test. In comparison with copper hybrid polymer composites silicon hybrid polymer composites gives better and higher thermal conductivity results.

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1. Introduction

Composites are made of two or more components. The composites are custom-made to get better properties than individual constituents. Polymer composites reinforced with fibre identified as Fibre Reinforced Polymers (FRP) composites. A composite which consists two or more constituent phases, matrix acts as a continuous phase and fibres are reinforcing phase. Fibres increases the strength, stiffness, thermal and fatigue properties, better dimensional stability and electrical resistivity. The function of resin is to transfer load uniformly, to hold fibres, protects fibres from environment and mechanical abrasion. Matrix sustain transverse loads and interlaminar shear stresses. Polymer Composites are high strength to weight ratio, non-corrosiveness, maintenance less, high electrical resistance etc. Composites manufactured in many ways depending upon matrix, reinforcement and application. Different methods are Hand-layup, Compression moulding, Resin Transfer Moulding, Pultrusion, Autoclave and Filament moulding etc. [8].

Study of filler materials essential without effecting the mechanical properties of composites [2]. Polymers are lower K value due to lower atomic density, complex crystal structure, chemical bonding [4] and enharmonic in molecular vibrant shaking [3]. Heat transfer in polymers occurs by lattice vibrant shakes causing thermal resistance [7]. Improvisation of thermal conductivity made by minimizing the thermal resistivity of that material. A suitable adhesive material used by modifying the filler material decreases thermal resistance [10]. If the K of the filler is more than hundred times the thermal conductivity of the polymer matrix, cause no much significant enhance in K of the polymer composites [7]. To restrain this, the percentage ratio of the filler material is varied to generate conductive paths [9,5]. The conductive paths are developed by increasing the weight fraction of fillers, and use of hybrid fillers [6]. Hence, the current work suggests into the modification of polymer composites, by combination of particulates of Cu, Si at various % weight proportions to enhance thermal conductivity. Si micro filler is a right material for high temperature and high power applications, as it has low thermal expansion coefficient and high thermal conductivity [1].

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An experimental study of process parameters on material removal rate in ECDM process

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ABSTRACT

This article highlights on Electro Chemical Discharge Machining (ECDM) process which is an unconventional machining process used to cut several conductive and non-conductive materials. Electro-chemical machining (ECM) and electro-discharge machining (EDM) processes are already developed and are available in market. Presently the emphasis is on developing hybrid machining process to utilize the benefits of both processes. ECDM is a process that combines the features of ECM and EDM processes to machine non-conductive materials like borosilicate glass, soda lime glass, silicon wafers etc. Present work addresses the machining of non-conductive material by drilling hole in Borosilicate glass through the use of stainless steel as tool material and sodium hydroxide (NaOH) as electrolyte. Experiments were conducted as per Taguchi method by selecting different parameters like electrolyte concentration, applied voltage and machining time with three different levels. Material removal rate (MRR) was calculated for all the experiments. In this paper the effect of total machining time on MRR had been studied. From the results it is observed that MRR directly depends on machining parameters; further, the significance of input parameters were analyzed by analysis of variance.

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1. Introduction

The non-traditional machining processes utilize several forms of energies like mechanical, chemical, thermal etc., to carryout machining. Some of the mechanical machining processes are Ultra Sound Machining (USM), Abrasive Jet Machining (AJM), Water Jet Machining (WJM) and Abrasive Water Jet Machining (AWJM) etc.; chemical machining processes are Electro-Chemical Grinding (ECG), Electro-Chemical Machining (ECM) etc.; and thermal machining processes are Electro-Discharge Machining (EDM), Ion Beam Machining (IBM), Laser Beam Machining (LBM), Plasma Arc Machining (PAM) etc. Out of these non-conventional machining processes, an ECDM process is a hybrid machining process which conglomerates the principles of ECM and EDM processes. ECM is process of removing material by electro chemical reactions and it is mainly used for heavy production and for working on hard materials. Its application is restricted to electrically conductive

materials. EDM is a unconventional machining process that specifically works on conductive materials and the main principle of this process is the capability of controlling electric sparks to erode material. The electrical discharges guarantee a sequence of micro explosions in the work surface layer, so that micro quantities of material removed from workpiece [1] as it incorporates high-temperature melting and enhanced chemical etching. The ECDM process is capable of machining very hard and non-conductive materials like ceramics, quartz, borosilicate glass etc., proficiently and economically [2]. Much of the work in ECDM had been focused on borosilicate glass which has valuable properties like chemical resistance or biocompatibility. The non-conductive materials like quartz, glass and ceramics are playing main role in aeronautics, automobiles & additional industrial applications due to their improved mechanical properties [1]. The importance of borosilicate glass is also rising in the area of Micro Electro Mechanical Systems (MEMS). Few applications of glass in the field of MEMS are micro-reactors, pharmaceuticals, micro-accelerometers and medical devices such as degradation products and flow sensors. All these applications have generated a need for effective and

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An investigation on effects of wire-EDT machining parameters on surface roughness of INCONEL 718

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ABSTRACT

This paper studied the effects of machining parameters on surface roughness of wire EDT of INCONEL 718 super alloy. The investigated machining parameters were rotational speed, pulse-on time, pulse-off time, servo voltage, wire feed rate and flushing pressure. Analysis of variance (ANOVA) technique was used to find out the most significant parameters affecting the surface roughness. Results from ANOVA show that pulse-on time is significant variables to surface roughness of wire-EDT INCONEL 718 alloy. The surface roughness of the test specimen increased as these variables increased. Lastly, regression model was developed using a regression method to formulate the machining parameters to the surface roughness. The developed model was validated with an optimal setting parameters and the maximum prediction error of the model was less than 8%.

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1. Introduction

Wire electrical discharge machining (WEDM) is a spark erosion process where wire electrode is used to produce complex shapes through electrically conductive work-pieces. WEDM is playing a vital role in the manufacturing of prototype parts, extrusion dies and stamping dies because of the desirable quality characteristics such as higher degree of accuracy and surface finish of the components. In recent years WED turning is emerging as an advanced technique in the current research scenario for machining cylindrical components of difficult to machine materials. By selecting the optimum parameter setting, exceptional improvement in productivity can be achieved. It has been extensively used in automobile, aerospace and nuclear industries to produce intricate shapes from difficult to machine materials. WEDT is performed by adding a rotary axis to WEDM. Most of the researchers have studied the effect of process parameters on responses in WEDT. Janardhan et al. [1] compared the effect of MRR of WEDM and WEDT and proved that MRR was found to be improved in the case of WEDM.

Qu et al. [2,3] compared the MRR of WEDM and WEDT by developing a mathematical model. Haddad et al. [4] investigated the influence of WEDT process on output responses such as MRR and surface roughness on AISI D3 tool steel. Mohammadi et al. [5,6] conducted a regression analysis to know the relation between the machining parameters on MRR. Janardhan and Samuel [1] examined the effect of machining process parameters on roundness error, surface roughness and MRR by using used pulse train data analysis technique. Su et al. [7] performed the optimization of EDM process parameters in finish cutting and rough cutting. Several researchers concentrated on optimizing the process parameters of WEDT process for different work material [8–11]. Few efforts have been reported to optimize the process parameters of WEDT on INCONEL 718 super alloy. It is a most widely used material in the field of wellhead components, auxiliary and down-hole tools, and sub-surface safety valves etc. because of its incredible properties such as high corrosion resistant, high-stress temperature resistant and best plasticity in the heat treatment. It is very difficult to machine Inconel 718 in conventional lathe which results in poor dimensional accuracy and surface finish. Hence there is a need to optimize the process parameters of WEDT process for INCONEL 718 super alloy. In the present research work,

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Effect of injection pressure on performance and emission of diesel engine with blends of Honge-Rice bran bio diesel

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ABSTRACT

In this study the performance and emission tests were conducted on single cylinder 4 S diesel engine using Honge biodiesel and Rice bran methyl ester (RBO) blend with diesel. Two samples of bio diesel blends 10R5H (10% RBO + 5% Honge + 85% Diesel) and 20R5H (20% RBO + 5% Honge + 75% Diesel) were prepared and tested at different injection pressures such as 180 bar, 200 bar and 220 bar at 16.5 compression ratio with varied load and the results are compared with diesel at 220 bar injection pressure. The test results showed that at full load, the brake thermal efficiency of 20R5H is 33.32% which is close to diesel i.e. 34.36%. Honge and Rice bran hybrid biodiesel blends at 220 bar injection pressure exhibited better performance and low emission than at 180 bar injection pressures except NO_x. Hence, the 20R5H optimized fuel blend can be considered for a compression ignition engine without any modification.

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1. Introduction

In the power generation sectors the internal combustion engine plays a vital role. Power used in agriculture, transport, marine, electricity generation, transportation, military, etc. is derived mainly from internal combustion engines (IC Engines). Most of the IC engines are currently operated by fossil fuels. Fossil fuel reserves are rapidly depleting, and the combustion of fossil fuels also leads to environmental problems such as smog, acid rain, loss of ozone, global warming as per Bora et al. [1]. Biodiesel is an alternate clean burning fuel made from renewable resources such as honey, soybeans, sunflowers, waste cooking oil and animal fats. Biodiesel is prepared through a chemical process called transesterification that removes glycerine from vegetable oil or fats. The decline in world oil reserves leads to the production of biofuels, since these fuels offer alternatives to fossil fuels as per Lin et al. [2] Biodiesel is produced by trans esterification of oil by means of methanol or ethanol with NaOH or KOH as a catalyst as per Meher et al. [3]. The investigation of the pongamia pinata, mustard oil mixed with diesel at different compression ratio and Srithar

et al. [4] found that there is an improvement in physiochemical properties such as calorific values, specific gravity and viscosity of the mixtures and in slight improvement in brake... (BSFC). Mohith et al. [5] conducted an experiment with karanja biodiesel mixed with diesel up to 30% and found that B20 blend produced high thermal efficiency and low emissions of smoke compared to other blends. Shravanan et al. [6] examined the combustion properties of CI engine with crude rice bran oil methyl ester and observed that B20 blend yielded low smoke and higher NO_x. Nanthagopal et al. [7] conducted experimental investigations with varying injection pressures 200 bar, 220 bar and 240 bar with Calophyllum and inophyllum methyl ester. The experimental results revealed that brake specific fuel consumption of Calophyllum and inophyllum methyl ester was reduced to a great extent with higher injection pressure. Significant reduction in emissions of unburnt hydrocarbons, carbon monoxide and smoke opacity was observed during fuel injection of biodiesel at 220 bar compared with other injection pressures. Kapilan et al. [8] conducted an experiment on the effect of injection pressure and emission of karanja methyl ester and observed that B20 blend yielded good results at 200 bar injection pressure compared with other injection pressures. In recent years there is increasing interest in mixing biodiesel from different feedstock's to exploit the benefits of each form of biodiesels. A number of researchers followed strategy for the

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Optimum hydrogen flowrates and membrane-electrode clamping pressure in hydrogen fuel cells with dual-serpentine flow channels

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ABSTRACT

Hydrogen fuel cells have been designed and fabricated with an aim to investigate effect of cell clamping pressure and hydrogen flowrates on the performance of fuel cells. Fuel cells with active area $1.9 \text{ cm} \times 1.6 \text{ cm}$ were fabricated with aluminum anode, cathode and other accessories. Membrane Electrode Assembly (MEA) was made up of nafion 212 ($50 \mu\text{m}$) membrane sandwiched between two gas diffusion electrodes (GDE) on either side of nafion membrane. Anode and cathode GDE had carbon cloth with 0.25 mg/cm^2 and 0.50 mg/cm^2 Pt loading, respectively. Double serpentine flow channels were used for the flow of hydrogen and oxygen at anode and cathode. Hydrogen was humidified with an external humidifier. Cells were fabricated with two clamping pressures, 5 kg/cm^2 and 25 kg/cm^2 both at 80°C . Hydrogen and oxygen flowrates were varied from 10 sccm to 70 sccm . The polarization plots indicate that the cell with clamping pressure of 25 kg/cm^2 and with a flowrate 20 sccm have higher power output (350 mW/cm^2) compared to other flowrates thereby implying an optimum flowrate for a given design. © 2020 Elsevier Ltd. All rights reserved.

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1. Introduction

Fuel cell is one of the most important energy devices which can convert chemical energy of the fuel (such as methanol, hydrogen etc.) directly to electrical energy with high efficiency and, in the case of hydrogen, with zero pollution. Further, due to depleting fossil fuels, energy sustainability is a serious concern. According to the various electrolytes and fuels used, there are many different types of fuel cells, such as polymer electrolyte membrane fuel cell (PEMFC), direct methanol fuel cell (DMFC), solid oxide fuel cell (SOFC), molten carbonate fuel cell (MCFC), phosphoric acid fuel cell (PAFC), alkaline fuel cell (AFC), and alkaline anion exchange membrane fuel cell (AEMFC) [1–4]. Among all these, PEMFC with hydrogen fuel is considered as the most promising alternative energy source for variety of applications; for automotive application especially, owing to their advantage of low noise, low operating tem-

perature and high power density, hydrogen fuel cells (HFCs) have become very attractive [5]. Obviously therefore, hydrogen fuel cells have received increasing attention in recent years primarily due to increasing concerns and awareness in the use of fossil fuels which cause environmental damage and global warming. Further, due to their high conversion efficiency ($\sim 60\%$) and high energy capability HFCs are suitable for portable devices as well as residential buildings [6]. Despite the many advantages, the high cost of catalyst (Pt) and nafion membranes has hindered the rapid progress of HFCs. There are also technical challenges such as water management impacting performance enhancement and commercialization of HFCs. Water control was seen as a key issue for the realization of HFCs [7]. The membrane needs to have sufficient hydration level to transport protons efficiently. Further, operation of HFCs at low humidification or non-humidification levels may accelerate the membrane degradation process due to the radical formation [8]

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Assessment of carbon nanotubes (CNT) and fly ashes (FA) reinforced Al nanocomposites properties synthesised by powder metallurgy.

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Abstract

In this paper properties of Al metal matrix composites reinforced with carbon nanotubes (CNTs) and fly ashes (FAs) synthesized by powder metallurgy technique were investigated. Density, hardness and compression tests were carried out for the mechanical properties of the specimens. The experimental results showed that addition of FA increases hardness up to 8 wt. % and then decreases while hardness of the composite decreases with increase in CNT content. The results also showed that addition of FAs decreases density values while, addition of CNTs increases density of the composites. The compression strength properties of the composites improved over matrix material. With the aid of scanning electron microscope it was observed that CNTs and fly ashes were well dispersed and embedded in the matrix. XRD and EDS results showed no carbide formation or contamination during the processing of the composites.

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Keywords: Powder metallurgy; Aluminium; Fly ash; Multi wall carbon nanotube; metal matrix composite; Scanning electron microscope; X-Ray Diffraction; Energy dispersive spectroscopy.

1. Introduction

Carbon nano tubes have been utilised immensely in aluminum metal matrixes due to their unique chemical and physical properties [1-2]. Experimental results indicated that single-walled nanotubes (SWNTs) and multiwalled

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The Effect of Thermal Ageing on Solder/Substrate Interfacial Microstructures During Reflow of Sn–37Pb and Sn–3Ag–0.5Cu

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Abstract In the current study, the influence of thermal ageing on evolution of microstructures in the interfacial region between solders (Sn–37Pb, Sn–3.5Ag–0.5Cu) and copper substrates was investigated. Pb-containing and Pb-free solders were reflowed on Cu substrates at 230 °C for 15 min and were isothermally aged at 100 °C for 24 h. As-reflowed Sn–Pb solder/Cu substrate interfacial region exhibited continuous and layered type of IMC at the interface, and this IMC morphology changed to scallop type with isothermal ageing. SAC solder/Cu as-reflowed samples showed continuous and needle-shaped Cu_6Sn_5 and Ag_3Sn IMCs at the interface. However, in an isothermally aged condition, plate-shaped Cu_6Sn_5 and flower-shaped Ag_3Sn IMCs were found inside the solder matrix. Scanning electron microscopic (SEM) study showed that the thickness of Cu_6Sn_5 IMC was higher in reflowed Sn–Pb/Cu region than in SAC/Cu region.

Keywords Solder joint · Reflow · Microstructures · IMC layer · Isothermal ageing

1 Introduction

Soldering is defined as a process of joining metallic materials at a low temperature by using a filler material that melts below 400 °C [1]. Reflow soldering is the most widely used method of attaching surface mount components (SMCs) to printed circuit boards (PCBs). The aim of the reflow soldering is to form acceptable solder joints by first pre-heating the components/PCB/solder paste and then melting the solder without causing damage by overheating. Lead (Pb)-containing solder alloys are used commonly in electronic applications because of their distinctive combination of properties and less cost [2]. Environmental considerations, global economic pressures and legal implications have justified the elimination of Pb from solder alloys. Even though there is no drop in substitute for the Pb-containing solders. At present, Sn–Ag, Sn–Cu, Sn–Ag–Cu lead-free solders are preferred to replace Pb-containing solders due to their good wetting characteristics and mechanical properties [1–3]. Copper is extensively used as a substrate material for ball grid array (BGA) applications. During reflow when liquid (molten) solder reacts with base substrate by the dissolution of Cu into the molten solder, intermetallic compounds (IMCs) grow at the interface [4]. These IMCs provide a strong bond to the solder joints. However, in microelectronic industry, especially in flip chip packaging process, package undergoes repeated reflow process, due to which IMCs grows rapidly at the solder/substrate interface [4–7]. Like reflow, thermal ageing of solder joints under service conditions greatly varies the growth of IMCs that can strongly influence the life of the soldered joints [5]. Thus, in the present study, the effect of isothermal ageing on microstructure evolution during reflow of Sn–37Pb and Sn–3Ag–0.5Cu solders on copper substrates has been investigated.

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A Review of the Performance and Characterization of Conventional and Promising Thermal Interface Materials for Electronic Package Applications

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Thermal interface materials (TIMs) play a key role in reducing thermal resistance between jointed solid surfaces in order to increase thermal transfer efficiency. A TIM is a thermally conductive material which is applied between the interfaces of two components (such as circuit board and heat sinks) to enhance the thermal conductance between them. The present paper provides a detailed review in order to characterize conventional and advanced TIMs in terms of thermal performance. The paper also discusses the measurement of TIM performance using different techniques. It was found that greases are the most widely used TIMs and offer thermal resistance in the range of 0.1–1 cm²/C/W. However, greases are messy and difficult to apply and remove due to their high viscosity. Moreover, they have reliability issues such as pump-out, phase separation and dry-out, which limits their use as an efficient TIM. The thermal resistance of TIMs which contain carbon nanotubes (CNT) fall in the range of 0.01–0.19 cm²/C/W. However, the use of CNT as a TIM at high temperatures does not allow for uniform distribution of heat on cooling of electronic packaging systems. Although TIMs with the addition of nano-metal particles are considered promising, it is necessary to carry out extensive research on CNT as a TIM.

Key words: Thermal interface material, thermal resistance, thermal contact, thermal conductivity, low-melting alloys

INTRODUCTION

Over the past decade, as technology has advanced, materials management systems have also advanced. At present, human life is completely dependent directly or indirectly on advanced materials and their management. For advanced technology, miniaturization of equipment must be intensified. Nowadays, miniaturization in electronic industries means cooling of electronic components is also a concern to attain better efficiency. There is a limit to further power upgrades and multi-operations of electronic devices.

An increasing trend or growth of miniaturization by the addition of microelectronic (semiconductor) devices has led to increasing heat generation from the circuit board, and thus heat management has become increasingly difficult. With more components on the circuit board, consumption of power will increase. Eventually the power density of the circuit board also increases. As a result, more systematic thermal management and electronic cooling at the package level is essential, because the reliability of electronic equipment strongly decreases with increasing junction temperature. Hence, efficient management of heat generation in electronic devices has become a critical problem in the modern electronics industry. According to Moore's law, the number of transistors that can be placed inexpensively on integrated circuits doubles

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