Nanoparticles Reinforced Aluminum Composites – A Review

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Abstract- *In recent times efforts are taken to enhance the mechanical properties of composite. This paper deals with changes in microstructure in Aluminium by addition of various nanomaterials on its matix using various techniques, these changes had resulted in increase of Thickness, Wear resistance, Corrosion resistance, Tensile strength etc. some of the nanoparticles majorly used were titanium oxide, carbon nanotubes, aluminium oxides. The usage of nanoparticles can sometimes lead to agglomeration. In this paper, an attempt has been made to present the reviews of different research paper*

I. INTRODUCTION

During the last few decades, the interest in nano phase materials has been steadily increasing. One of them is nano crystalline powders, which, enhances the property when compared with micron-sized particles or larger [1].Metals are often coated with organic films for various applications in packing, transport and construction, and others. Native oxide plays a vital rolein terms of compatibility between the organic medium and metal substrate and is crucial and required for durable properties [2]. Conversion coatings are applied to aluminium and its alloy to provide corrosion protection as a standalone coating, or as an intermediate layer for painting. Chromate based coatings have been used since many years[4]. The composite coating is a layer deposited on the surface, in which one or more types of solid particles are uniformly distributed into a metallic or non-metalic matrix. Therefore the performance of the coating can take advantages from both the base material and composites [12]. Aluminium matrix composites reinforced with ceramic particles have been extensively used in the Aircraft, Aerospace and automotive industries because of their high stiffness, strength to weight ratio, low co-efficient of thermal expansion and good wear resistance [5]. TiAl alloys are widely used in high temperature structural application because of the low density, high melting temperature and good high temperature strength. However, they suffer from poor oxidation resistance at high temperature [6]. In gas sensor technology the base material used, the type and amount of additive and micro structure of material play a significant role in deciding sensor performance. The extensive research has been going in order to detect and monitor harmful gases and more importantly understanding the sensor properties [14]. The combustion of aluminium particles in water is of relevance to many propulsion and energy conversion application. In metalized composite solid propellants, aluminium particles typically react with the combustion products of the polymeric binder and ammonium perchlorate, of which water vapour and carbon di oxide are the two major species [7]. Metals such as aluminium have higher combustion energies and have been employed as energetic additives in propellants and

explosives. Recent advances in nano science and nanotechnology enable production, control, and characterization of nano scale energetic materials, which have shown tremendous advantages over micron sized materials [3]. Although the main research thrust over the past decade has focused on using carbon nanotubes (CNTs) to reinforce polymer and ceramic matrices, a few groups have investigated metallic matrices with the core interest being pure aluminium. In fact the interest in CNT reinforced aluminium composites has been growing considerably. The shared aim of the various groups is to produce composites with enhanced mechanical properties. Such composites would make attractive novel materials with potential applications in the aerospace, automotive and sports industries where light weight combined with high stiffness and strength is desired [1]. Sol-gel process is considered Tas an effective technique to realize various protective coatings and functional ones to improve or modify the properties of the substrate. A well known technique is dip coating which permits to cover and protect a substrate by a nano structured layer by a wet route, in opposite to the ones obtained by dry processing and is highly used for a broad range of applications. Even though coatings achieved by dip coating method are well adapted to control deposits on planar substrates, this method falls short to realize homogeneous deposit on 3D shaped substrates areas with a greater and thinner thickness are often found on this type of piece [3]. Recently, the principle of electrochemical deposition of hard, wear resistant and soft, self-lubricating inclusions in composite metal coating I well established. Lee investigated the co-deposition behavior of diamond particles and nickel onto steel in nickel sulphate baths. The objective of this research is to gain better fundamental understanding of the compatibility and the interactions between inherently very different material phases at their connecting interfaces, which will lead to a better understanding of their combined properties. As a first result, a direct effect was observed on the barrier properties of the coatings, which increased with the incorporation of agglomeration-free nanoparticles.

Table 1.

MATERIAL	NANO PARTICLES	TECHNIQUES	PROPERTIES CHANGE	REF NO
ALUMINIUM COMPOSITES	CARBON NANOTUBE	BALL MILLING	TENSILE STRENGTH,STIFFNESS	1
ALUMINIUM	NANO-DISPERSED CeO_2 PARTICLE	DIPCOATING	IMPROVE BARRIER PROPERTIES	2
ALUMINIUM 2024	SOL-GEL BOEHMITE	ELECTROPHORETIC DEPOSITION	THICKNESS INCREASED	3
ALUMINIUM ALLOY	TiO_2	STEAM TREATMENT, NEUTRAL SALT SPRAY	REDUCED ANODIC ACTIVITY	4
ALUMINIUM MATRIX COMPOSITES	In-Situ ALB_2 PARTICLE	SCRATCH TEST, HOT ROLLED AND HEAT TREATED	HARDNESS AND WEAR PROPERTIES	5
TiAL-BASED ALLOY	Au NANOPARTICLES DOPED Al_2O_3	ELECTRO DEPOSITION	IMPROVE HIGH TEMPERATURE CYCLIC OXIDATION RESISTANCE	6
LIQUID WATER	NANO ALUMINIUM PARTICLE	BURNING NANOALUMINIUM-WATER STANDS IN ACONSTANT VESSEL	THE FLAME THICKNESS INCREASE IN CUMBUSTION	7
ALUMINIUM	N-P-NANO SiO_2 COMPOSITE	POLARIZATION	IMPROVE CORROSION RESISTENCE	8
ALUMINIUM IN SEA WATER	NANO TiO_2	VACCUM DIP COATING ANODIZATION	STRUCTURE STABILITY &CORROSION RESISTANCE IMPROVE	9
ALUMINIUM ALLOY	EARTH/NANO TiO_2	BRUSH PLATE METHOD	HIGHER BARRIER ABILITY&INCREASE CORROSION RESISTANCE	10
SAPER HYDROPHORIC ALUMINIUM SUBSTRATE	NANO SILICA &FLUORO SILANE	HEAT TREATMENT	ELECTRO CHEMICAL & MECHANICAL PROPERTIES	11

COPPER	NI-NANO-Al_2O_3	ELECTRO PHORETIC-ELECTROCHEMICAL DEPOSITION	LOW FRICTION AND ANTI WEAR BEHAVIOUR	12
ALUMINIUM MATRIX	CARBON NANO TUBE	CONSOLIDATION OF NANOPOWDER	THERMAL STABILITY	13
ZiNC OXIDE THIN FLAME	ALUMINIUM	SPRAY PYROLYSIS	GAS SENSING PROPERTIES	14
ALUMINIUM BASED COMPOSITES	DIAMOND NANO PARTICLES	TRANSMISSION ELECTRON MICROSCOPY& RAMAN SPECTRO SCOPY	INERFACIAL PROPERTIES&THERMAL PROPERTIES	15
CAST-Al-SI PISTON ALLOY	NI& NANO Al_2O_3	UNIVERSAL TENSILE TESTING MACHINE	ULTIMATE TENSILE STRENGTH &GOOD DUCTILITY	16
A356 ALUMINUM ALLOY	NANO-SIZE ALLUMINIUM OXIDE	STIR CASTING METHOD	WEAR RESISTANCE,COMPRESSIVE STRENGTH	17
MICRO SIZED ALUMINIUM	POROUS SILICON	CONSTANT VOLUME PRESSURE VESSEL EXPERIMENTS	IGNITION &CUMBUSTION PROPERTIES	18
2024-T_3 ALUMINIUM ALLOY	CARBON NANO TUBES	CVP METHOD WITH Fe-Co CATALYSTS	FATIGUE STRENTH,FATIGUE LIFE TIME	19
SINGLE CRYSTAL ALUMINIUM SUBSTRATE	NANO ABRASIVE PARTICLE	QUASICONTINUUM INVESTIGATION METHOD	FRICTION BEHAVIOUR	20
ALUMINIUM MATRIX COMPOSITES	GRAPHANE ENCAPSULATED SiC NANO PARTICLE	UNIVERSAL TESTING MACHINE	YIELD STRENGTH AND TENSILE DUCTILITY	21

II. TESTS AND DISCUSSION

BALL MILLING

A ball milling method is a type of grinder used to grind and blend materials for use in mineral dressing process. A ball milling works on the principle of impact and attrition Size reduction was done by impact, as the balls drop from the top of the shell. It was done by adding the carbon nanotubes in the aluminium composites [1], which improved mechanical properties of aluminium composites like tensile strength and stiffness.

ELECTROPHORETIC DEPOSITION

A characteristic feature of this process is that colloidal particle suspended in a liquid medium migrate under the influence of an electric field and are deposited onto an electrode All colloidal particles that can be used to form stable suspensions and that can carry a charge can be used in electrophoretic deposition . It was done by adding the sol-gel boehmite in the aluminium2024, which improved the thickness of composites[3] and it was done by adding the Au nano particles doped with Al_2O_3 in the Ti-Al based alloy, which improve the hight temperature cyclic oxidation resistance [6].

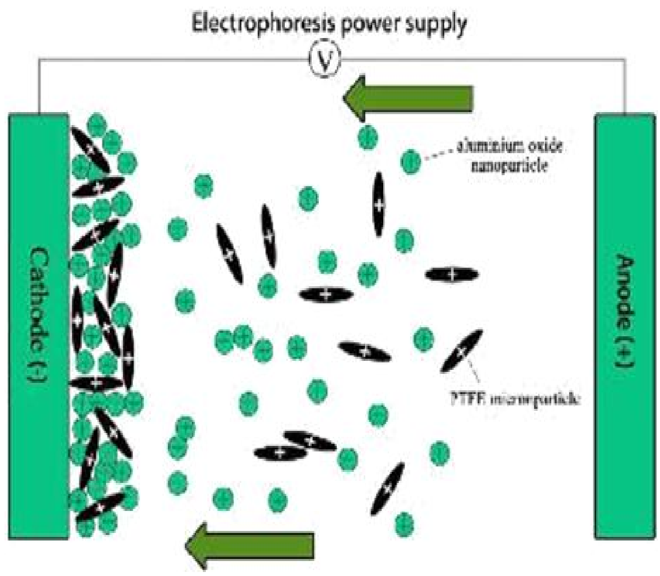

Figure 1.

STEAM TREATMENT

The spin coated samples were exposed to high temperature steam, generated from deionised water in an autoclave at 107 degree Celsius and 1.3 bar vapour pressure, for a period of 2min. After the steam treatment, the samples were rinsed with deionised water and dried in ambient air. It was done by adding the TiO2 nano particles in aluminium alloy, which improve the corrosion resistance due to the deduce the anodic activity [4].

HEAT TREATMENT

In the heat treatment process the furnace temperature is 1,8000F (9800C). Using this heat treatment the specific composition of an alloy system will usually have a great effect on the results of heat treating, the microstructure is changed. It was done by adding the In situ AlB2 particle in aluminium matrix composites, which improves the hardness and wear properties of material [5] and this test was done by adding nano silica and fluoro silane in shaper hydrophoric aluminium substrate, which improve the electro chemical and mechanical properties [11].

DIP COATING

Dip-coating is with no doubt the easiest and fast method to prepare thin films from chemical solutions with the highest degree of control, making it highly appropriate for R&D and small scale production. In specific high technology cases it is used to deposit coatings on large surfaces. The principle is as simple as dipping the substrate into the initial solution before withdrawing it at a constant speed. During which the solution naturally and homogeneously spreads out on the surface of the substrate by the combined effects of viscous drag and capillary rise. It was done by adding nano dispersed CeO2 in aluminium, which improves the barrier properties [2].

STIR CASTING METHOD

Manufacturing of aluminium alloy based casting composite materials via stir casting is one of the prominent and economical route for development and processing of metal matrix composites materials. Properties of these materials depend upon many processing parameters and selection of matrix and reinforcements. It was done by adding nano size aluminium oxide in aluminium composites, which improve wear resistance and compressive strength [17].

POLARIZATION

An external electric field that is applied to a dielectric material, causes a displacement of bound charged elements. These are elements which are bound to molecules and are not free to move around the material. Positive charged elements are dis placed in the direction of field, and negative charged elements are displaced opposite direction of the field. The molecules may remain neutral in charge, yet an electric dipole moment forms. It was done by adding N-P-nano SiO_2 in aluminium composites, which improve the corrosion resistance [8].

TENSILE TESTING

Universal tensile testing machine is used in this test. Tensile testing, is also known as tension testing. The results from the test are commonly used to select a material for an application, for quality control, and to predict how a material will react under other types of forces. The following properties are determined in this method like youngs modulus, yield strength. It was done by adding Ni& nano AL_2O_3 in cast-Al-Si piston alloy, which improve ultimate tensile strength, good ductility [16] and it was done by adding graphane encapsulated SiC nano particle in aluminium matrix composites, which improve yield strength and ductility [21].

BRUSH PLATE METHOD

The alloy samples with the size of 400 mm×200mm were abraded with AL_2O_3 based abrasive papers up to 1000#. The brush plating procedure and conditions are shown in Table 1. The solutions used are as follows:

Electro clean: Na_2CO_3 40 g/L, NaOH 25 g/L, Na_3PO_4 40 g/L and NaCl 25 g/L.
Activation: HCl 25 g/L and NaCl 140 g/L.
Brush plating: Ce(NO3)3·6H2O 20 g/L, NaF 0.1 g/L, TiO_2 2–8 g/L.

It was done by adding earth/nano TiO_2 in aluminium alloy, which creates the material like a higher barrier ability and increase the corrosion resistance[11].

CONSTANT VOLUME PRESSURE VESSEL EXPERIMENTS

The effect of adding p-Si/NaClO 4 compos- ite on the combustion behavior of m-Al/n-CuO thermite mixtures was quantified in a constant- volume pressure vessel (volume: 13.5 cm 3) filled with ambient air for which the schematic setup is shown in Fig.2 . Various control samples were first placed in a crucible and then mechanically agitated to have a uniform packing density. The thermite samples were ignited by an embedded NiCr filament at the bottom.

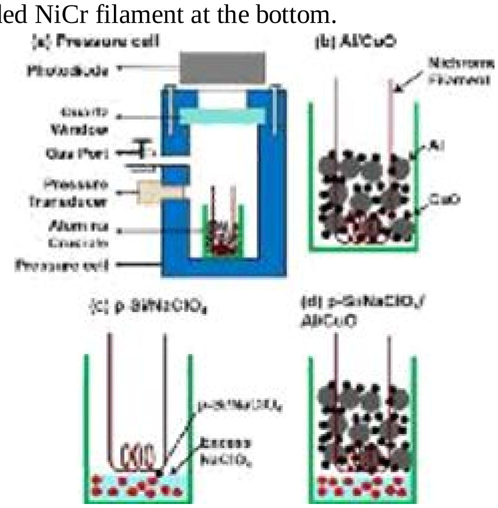

Figure 2.

This experiment was done adding porous silicon in micro sized aluminium, which improve ignition & combustion properties [18] and nano aluminium particle adding in liquid water, which improves the flame thickness of combustion [7].

III. MEASURING METHODS

Scanning electronic microscope (SEM) with energy dispersive spectroscopy (EDS) was used to observe the surface morphology and analyse the composition of the composite coating (S4700). The content of Ti in the coating was detected with EDS and the weight fraction of TiO_2 was determined according to the titanium to oxygen ratio of 1:2 in TiO_2. X-ray photoelectron spectroscopy (XPS) was analyse the surface composition of the coating. The coating structure was studied with X-ray diffraction (XRD, 2500VB2+PC). The adhesive strength of the coating to the substrate was tested with a Test Pull-Off Adhesion Tester according to GB/T 5210-2006. For each condition five parallel tests were run and the average values were obtained. The micro-hardness of the coating was measured with a Fischer HM 2000 micro-hardness tester using a load of 20 Nm. The thickness of the coating was measured with a TT230eddy current instrument, which was calibrated with the same base metal.The measurements were carried out at 6 randomly selected position the coating surface and the average thickness values were obtained. The corrosion behavior of the specimens was investigated with Potentio dynamic polarization and electrochemical impedance spectroscopy (EIS) in 1 mol/L NaCl solution. EIS measurements were performed with a PARSTAT 2273 (PAR) system, and the frequency range was from 100 kHz to 0.01 Hz at open circuit potential, with a 10 Mv potential perturbation. A three-electrode system was used, consisting of a saturated calomel electrode (SCE) as reference electrode, a platinum electrode as counter electrode, and the specimen as the working electrode. The specimens were sealed with epoxy resin, leaving an area of 1 cm2 exposed to the solution.

For micro-roughness of surfaces, a hand-held roughness tester (Model TR200, Time Group Inc., Beijing, China) with cut-off length of0.25mm to 2.5 mm was used. For this study, the portable tester was used to measure at minimum three 0.8×5 mm2 areas, from which an average Ra value was calculated. For nano-roughness of surfaces, the AFM was used to image at minimum three 10×10 μm2 areas, from which an average Ra value was calculated.

Electrochemical measurements were conducted using a conventional three-electrode system. The coated Al coupon served as the working electrode, while the counter electrode and the reference electrode used were a platinum wire mesh and a saturated calomel electrode (SCE) respectively. The corrosive solutions included 0.3 wt.% and 3 wt.% aqueous NaCl solutions. Two methods were used to assess the anticorrosion performance of the coatings: EIS and PWP. The EIS measurements were carried using a Gamry ECM8 Multiplexer. The Al coupon was polarized at ±10 mV around its open circuit potential (OCP) by an alternating current (AC) signal with its frequency ranging between 10 kHz and 10 mHz (10 points per decade). For PWP, the Al coupon was polarized at ±30 mV around its OCP by a direct current (DC) signal at a scan rate of 0.2 mV/s. Polarization resistance (RP) is defined by the slope of the potential-current density plot at the corrosion potential.

IV. CONCLUSION

Numerous techniques have been implied on aluminium matrix and their property changes are determined. The use of nano particles may sometimes lead to agglomeration, and sometimes there problems arise due to changes adhesion property, research is being made in order set them right. The application of these modified aluminium matrix are in areas regarding Aerospace, IC Engine piston.

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