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A Review for Microtechnology on Electrodeposited Metal Matrix Composite Coatings

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Abstract

Micro technological applications gain increased importance in industry and require the increase of new functional materials improving the technological properties of micro devices at reduced costs. The codeposition of micro particles within an electroplating process is a capable method to produce such improved materials. The particles are used to perform specific mechanical, electrical, piezoelectric or magnetic properties in thin coatings. The aim of giving a coating to a substrate is to improve some of its properties of the substrate or to obtain an entirely new property. The composite coating technology is used many manufacturing areas. Composites are multifunctional materials having unprecedented mechanical and physical properties that can be customized to meet the necessities of a particular application. Modern technology aims for systems performing satisfactorily under extreme operating conditions .In recent years, electroplating has emerged as a technically and economically viable synthesis route to produce nanostructured metals, alloys and composite materials both in bulk form and as coating of various thicknesses. An electrodeposited composite coating consists of a metal or alloy matrix containing a dispersion of second phase particles. These particles may be carbide particles or hard oxides, such as SiC, TiO2, WC, SiO2 Al2O3 or diamond, or even liquid containing microcapsules to develop wear resistance properties and / or to reduce friction. The aim of this paper is to review the literature relevant to the electrocodeposition of MMC coatings and its characterization form micro technological applications.

Key words: Futuristic materials, Metal matrix, composite coatings, Material properties, Electrodeposition, Co-deposition, Micro technology

1. INTRODUCTION

Modern technology calls for systems performing satisfactorily under extreme operating conditions. The composite coating method is used extensively in many manufacturing areas.Electrodeposited composite coatings are of interest primarily for wear or high thermal applications and are better than flame deposited coatings. The development of metal matrix composites has attracted a substantial amount of attention in now a days because of the requirements of high strength, lightweight and high stiffness materials. The reason for using coatings is dominated by economic or technological considerations, that is, it is either cheaper to use a coating instead of bulk material or the desired properties can only achieved by only coating. The applications of composite coatings are found in many areas in mechanical system.

In this article, the literature related to the electrodeposited composite coatings and its structure, properties of various electrodeposited coatings, applications of electrodeposited coatings has been reviewed. Division 2 describe the information about electrodeposited composite coatings. Division 3 reviews the complete literature of articles determined to be related to electrodeposited composite coatings.

2. COMPOSITE COATINGS

2.1 Electrodeposited composite coatings

Electrodeposited composite coatings consist of a metal matrix with either a ceramic or cermet particle addition which represents the new development in the field of coating processes. Electro-composite coating is a co-deposition of a homogeneously dispersed second phase material on the surface of the substance material with the form of a particulate material, whisker, and fibre in a metal matrix with enhanced or new engineering properties. Inert particles such as diamond, powdered ceramics (for example aluminum oxide, silicon nitride and silicon carbide) or polytetrafluoroethylene (PTFE or Teflon) can be deposited on the nickel matrix, forming a composite

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coating with improved self lubrication and wear resistance properties.

2.2 Formation of Electro -deposited composite coatings

In general deposition of a metal occurs on a substrate surface by the reduction of metal ions in solution. If the reduction is brought out by electrical energy than the process is called Electroplating. In conventional electroplating, insoluble suspended impurity particles present in electrolyte has been entrapped / co deposited with the metal deposition on the substrate. This resulted in greater outcome on the end property of the deposition.

In formation of electrodeposited composite coatings, the similar method of mechanical entrapment of suspended insoluble particles is used but under strictly controlled conditions. In formation of electrodeposited composite coating, the insoluble particles are dispersed in a conventional electroplating bath. The dispersed particles can be metallic or ceramic. During the electrolysis, the insoluble particles are trapped by the metal ion during its reduction from the cathode and a composite deposit is formed. The particles are held in suspension by mechanical agitation.

Electroplating process which are readily amenable to composite electrodeposition are those which operate at high cathode efficiency. The main two factors governing the particle entry into the metal matrix are the presence of a gas stream and the particle size.

Various types of wear resistant electro-composite coating are,

- Ni-SiC Electro-Composite Coating
- Ni-diamond Electro-Composite Coating
- Ni – Al2O3Electro-Composite Coating etc.,

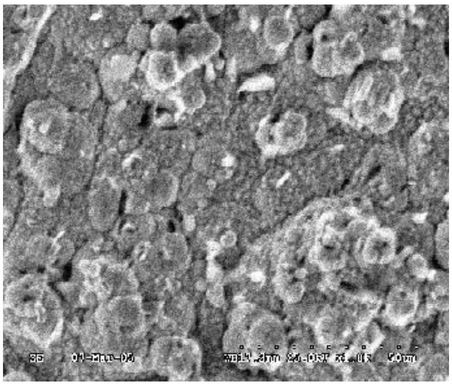

Figure.1 Electrodeposited Ni- SiC composite coatings

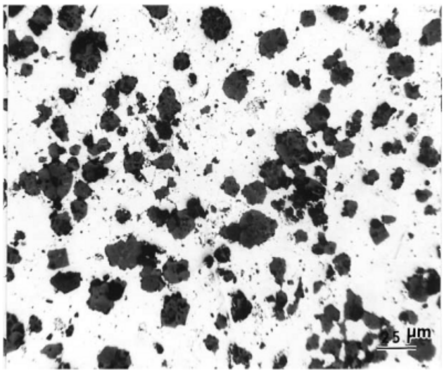

Fig.2 Electrodeposited Ni- Al2O3 composite coatings

3. Literature Survey

Clint and Michael have reported that surface coatings have gained great reputation over the past several years and are prevalent in a more number of industries which include aerospace, automobile, computer, machining and precision manufacturing industries [1].

Hagedorn and Weinert mentioned that metal matrix composites (MMCs) are very commonly used to combine low structural weight with high wear resistances in the component development of automobiles. As a matrix work piece material as aluminium or magnesium is used because of their low density,reasonable mechanical strength and super hard fibers or particles made of silicium carbide ,aluminium oxide or titanium dibroide[2].

Kılıc kap et al has found that aluminium, titanium and magnesium alloy can be used as metal matrix element and the accepted reinforcements are silicon carbide (SiC) and alumina (Al_2O_3). Aluminium-based SiC particle reinforced MMC materials are used for many Engineering applications because of their properties such as less weight, heat-resistant, wear-resistant and low cost [3].

Hui et al explained that a brush plated alloy Ni–Fe–W–S coating having a corrosion resistance is greater than that of electrodeposited chromium and a superior wear resistance than that of electrodeposited chromium at high speed and heavy load under normal conditions where lubricant was applied between the contact surfaces. [4].

Hou et al determined from the experimental results that the amount of micron-sizeed SiC particles in the deposition layer increased with the increasing concentration of both the SiC and the surfactant Cetyl terimethyl ammonium bromide (CTAB) in the electrolyte. The wear resistance of deposit layer increases with increasing Silicon carbide(SiC) volume percentage on the deposit layer. The

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surfactant CTAB cannot only considerably homogeneously dissolve the SiC particles in the electrolyte but also shows positive contribution to enhance the embedded SiC volume percentage in the deposition layer [5].

Medeliene found that non-metallic inclusions in the metal may change its electron structure and fragment the crystal lattice, follow-on in changes in the properties of the electrodeposits. [6].

Hongzhi et al suggested that the composite electroplating technique is most advanced production routes of functionally graded materials (FGM). The advantages of this method is simplicity to control, possibility to process complicated parts, and the low initial capital investment.

Hongzhi et al concluded that the method of rising SiC concentration steadily and controlling the deposition conditions, the Ni/SiC gradient deposit with constant distribution of the SiC content 0 to 30 volume percentage can be prepared. The hardness of the gradient electro deposit increases steadily in the direction of the growth of the deposit. The top layer hardness is high up to 688 Vicker hardness (HV). The Ni/SiC gradient deposit has good malleability and wear resistance performance [7].

Kezheng and Zhihao Jin said that oxide formation on nickel alloy surface may provide a lubricating function. Another research for SiC–TiC/SiC–TiC and $SiC–TiB_2/SiC–TiB_2$ shows that oxide of titanium has been formed on friction surface, but friction coefficient is always high except that of SiC–TiC/SiC–TiC at room temperature. The formation SiO_2 on the surface of SiC might reduce friction coefficient. It is clearly proved that further research on the effects of oxides during friction process is needed for ceramics [8].

Grosjean et al have found from the experimental results that the hardness of nickel increases with increasing the rate of incorporation of articles until a maximal value. In addition found that hardness increases with increasing SiC particle size. Regardless of the rate of inclusion of particles, the friction coefficients of co-deposits were always higher compared with that obtained for nickel deposits[9].

Begona Ferrari et al reported that ceramic coatings are mostly used to enhance the surface behavior of substance, though allow to used in high temperature applications, such as thermal barrier coatings etc., One of the most commonly studied metal – ceramic systems is the Ni – Al_2O_3, because of the high refractoriness and stability of nickel [10].

Clark et al have found that many technique used to make nanostructured powder,thin films or bulk materials operate at conditions which are conducive to the formation of non- equilibrium structures. Electrodeposition is identified to be a technologically suitable for many applications, economically better technique for the production of nanocrystalline materials. basically, electrodeposition may produce nanostructures when the deposition parameters (e.g. plating bath composition, pH, temperature, current density, etc.) are chosen such that electro crystallization results in huge nucleation and reduced grain growth. Clark have suggested that the initial capital investment of electrodeposition plating is low and often requiring only minor modifications to existing conventional plating lines. Continuous foil and sheet production is feasible for bulk production and net shape forming. The costs for nanostructure plating are comparable to those of conventional electroplating processes as the bath constituents are essentially the same [11].

However, the reduction of particle size will decrease the codeposition content of the particles. SiC particles, the amount incorporated during rotating disc experiments in a nickel sulfate solution never exceeded 0.7 weight percentage. Similar results reported by Ming-Der Ger that the highest volume fraction of codeposited SiC have been achieved with 5 μm particles, rather than with 0.7 or 0.3 μm particles. In addition, for a $Ni–Al_2O_3$ composite, the amount of codeposited Al_2O_3 of 10 μm particle size found as four times larger than that of Al_2O_3 of 0.3 μm in the composite coating [12].

Garciaa and J.-P. Celis investigated that the sliding wear behavior of Ni–SiC composite coatings containing different amounts of articles was the same for uni and bi-directional sliding. The best sliding wear resistance against corundum balls indenter was obtained for Ni– SiC coatings containing 4–5 vol.% of 0.3- and 0.7-mm SiC particles. Higher volume percent or number density of codeposited particles lowers the wear resistance. By reducing the particle size affects the wear resistance in a positive manner [13].

Pei-Huan Hsieh, Ming-Chang Yang found that the volume percentage of alumina incorporated into the nickel matrix is affected by temperature. The quantity of alumina in the nickel matrix increased with current density, and reached a maximum about 10% in the current density of 10~20mA/cm2 for temperature range of 30~50^{o}C. The current density to reach the maximum amount of alumina in the matrix increased temperature [14].

Discontinuously reinforced metal-matrix composites are attractive for high elastic modulus and strength, good wear resistance, and good dimensional stability.There are no reports found for superplasticity of composites produced by electrodeposition. By varying the deposition parameters, electrocodeposition can produce composites of a high density, that are free of porosity and that have different microstructures. [15].

Electroless nickel (EN) coatings are suitable process for wear and corrosion resistance. Codeposition of hard particles into the EN to form a composite coating can further improve the tribological behavior of the coating and also add on additional functions. Hard silicon carbide is widely used as codepositing particles for wear resistant composites. On the other hand, polyviniledene tetra fluroethylene (PTFE) has been used for lubricant particles to improve wear resistance and antisticking performance in many areas. A multi component EN-PTFE-SiC composite coating has been developed which demonstrated a promising combination of mechanical and tribological properties as well as low surface energy [16]

Junhong Jia et al found that Ni-based composites can be designed with capability self-lubricating property in a maximum temperature range.[17].

Electrodeposited composites are gaining importance for their advantages including low cost, ease and simplicity of operation to tailor made coatings for tribological applications. Generally, ceramics like Al_2O_3, SiC etc., are preferred for high wearresistance, increasedhardness, improved corrosion resistance, and high temperature oxidation resistance as compared to alloy and pure metal electroplating [18]

4. Conclusions

Surface Engineering is the modification of surfaces for a variety of reasons such as to enhance the corrosion resistance, decrease wear or to provide electrical or thermal insulation. Improvement in material properties is inevitable in order to meet the advanced engineering applications. Electrodeposition of composite coatings plays a remarkable role to obtain desired physical properties in the metal matrix composites. This article deals with some work of the earlier investigators on electrodeposited composite coatings has been reviewed, that can be used for characterization of coatings for micro technology applications. Details about these, and indeed about all the information's presented in this article, are available in the literature. It is nevertheless hoped that this article serves as a preliminary introduction for electrodeposited composite coatings.

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