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DESIGN AND DEPOSITION OF HARD THIN COAT INGS ON SOFT SUBSTRATES – A REVIEW

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ABSTRACT

In this paper, the significance of the coatings and its technological development in the field of manufacturing is attempted. Currently all the auto motive, mechanical, electronics and other industries are looking to improve the performance of the materials. It has proven great potential for the development of novel thin film materials with tailored properties. Concepts for the design of such advanced multifunctional materials can be systematically evolved and verified by means of various deposition techniques. The classical multilayer coating concept today is well established and widely used for the design of protective thin films for wear and tribological applications. Recently ternary nitride based coatings are investigated and they exhibit improved tribological, mechanical and thermal properties compared to other coatings.This paper reviews the latest developments in hard, wear-resistant thin films based on the multilayer coating concept and an attempt is made to study the design and deposition of hard coated thin films on soft substrates.

Keywords: *Coatings, Thin Films, Mechanical Properties and Deposition Techniques.*

1. Introduction

Deposition of hard thin films with few microns in thickness is a new technology to improve the performance of tools, dies, and moulds for many applications. Several key processing steps are required to produce the optimized coatings. In addition to the processing steps it is very important to understand how to design the better coatings for the better applications. Now a day's surface coatings have been attracted by the industries during the last two decades and the use of coatings has increased on mechanical components in engines and transmissions, on tools in the production industry, on disc drives in the computer industry, on precision instruments and on human replacement organs. The advanced deposition techniques like physical vapour deposition (PVD) and chemical vapour deposition (CVD) techniques offer a wide variety of possibilities to tailor surfaces with many different materials and substrates [5,6,12]. Based on the requirement a wide range of materials are used to coatings include metal, metal alloys, oxides ,non oxides, ceramics, plastics, composites, and other elements are used for coatings[23]. Now in industries various number of coating methods are available but it is very critical to select the proper coating method for the application, each has its own significance, after completing the research on different materials with different methods the respectable values are provided for future reference with respect of rate of deposition and film thickness. Experiments are carried out on various methods the better deposition rates are obtained on the order of 1 to 45 kg/h or more can be achieved, for normal practice cases it is referred as 2 to 7 Kg/h as taken. The thickness of the thin film coating is 125μm to 6.5 mm are used today (2012) [7].

In the design of the coating system, the particle mass flow rate is determined by knowing the density of the powder, the radius of the nozzle and rotational speed of the stepped motor. Then the mass quantity of delivered powder per minute is given by (zou et al, 2008);

$$m=\rho\times N\times\pi\times D\times\tfrac{1}{2}\times\pi\times r \quad (1)$$

Where: ρ = powder density (Kg/m^3)
N =Rotational speed of the pulley (rpm)
D = diameter of the pulley (m)
R = radius of the nozzle hole (m)

The microstructures of the coatings basically depending on the operating conditions of the system, to obtain the good quality coatings the operating system should be choose carefully and while designing care should be taken regarding to the hardness of the coatings. While designing the proper coating the operating system can be affected by various parameter values to produce the amount of material on the substrate. The quality of the coating can be studied by the Deposition Efficiency (DE) of the coating which can be calculated by considering the various parameter values. With knowing the surface speed, width of the plate, weight of the plate, number of strokes across the

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plate and the material feed rate the DE can be calculated.

The deposition efficiency (DE) is given by time on part can be calculated by,

T= (width of the plate × strokes)/traverse rate (2)
T= (b×strokes)/v

The amount of material sprayed on the part is given by,

m= time on part × feed rate (min ×g /min) (3)
m=T × f

DE = (final plate weight-initial plate weight)/amount of material sprayed on part.

$$\% \, DE= (w_f - w_{i})/m \qquad (4)$$

The film thickness (d) can be calculated by knowing the mass of the coating (m), density of the material (ρ) and the area (A) on which the material is deposited is given by,

$$d=m/ (A \rho) \qquad (5)$$

All coatings are in a state of more or less pronounced internal stress which is composed of two components, thermal stress σt and intrinsic stress, σi [4, 11].

$$\sigma = \sigma_t + \sigma_i \qquad (6)$$

The thermal stress σ_t is caused by different Coefficients of Thermal Expansion (CTS) of the coating and the substrate is given by,

$$\sigma_t = E_s \, (\alpha_s - \alpha_u) \, (T_B - T_M) \qquad (7)$$

Where: E_s= Elastic Modulus of the film
α_s = mean CTE of the film
α_u= mean CTE of the substrate
T_B= Substrate temperature during coating
T_M= Substrate temperature during measurement

The intrinsic stress σi depends on the deposition parameters and is caused by structural disorder within the film; these stresses can be compressive or tensile depending on the deposition parameters.

2. Materials

Traditionally, the term hard coatings refer to the property of high hardness in the mechanical sense and with good tribological properties. With the development of modern technology the term hard coatings can be defined as a system, which operates satisfactorily in a given environment, can be said to be hard with respect to that environment [3].

In this study after consider the many of the reviews, the aluminium as taken as the base element (or) substrate. Because all industries are interesting about the light weight materials for their applications and recent reviews tells aluminium is the good competitor in engineering applications by the end of 19th century. The main properties that make aluminium a valuable material because of its low density, high strength, corrosion resistance, durability, ductility, formability, conductivity and possibility to be 100% recycled. Due to this unique combination of properties and the variety of applications the demand for aluminium is increases in worldwide which shown in (fig 1) .Today aluminium is widely used in cars, trucks, buses, coaches, trains, metros, ships, aircraft and bicycles [6, 16, 22].

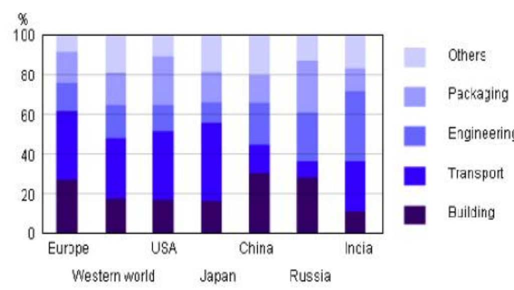

Fig. 1 Different sectors of aluminium applications

Many of the research papers are present the better results with the deposition of hard coatings like Titanium, Vanadium, Chromium and other elements are used for the coatings [24], based on availability of the literature the application of Niobium is limited and it also exhibit the same properties of above materials. Now Niobium is being viewed, accepted and used as a material for the prevention of corrosion that offers in weight savings, replacement costs and life cycle cost benefits.

3. Deposition Technique

The structure of thin films is mainly responsible for their mechanical properties, therefore at first the connection between the film growth, structure and morphology of the film can be taken in to account. Physically vapour deposition (PVD) and chemically vapour deposition (CVD) techniques were first introduced a few decades ago in the field of the machine tools and dies. Many industries such as aerospace and automotives shows the good interest about these methods because of good tribological and anti-corrosion performances are achievable with these deposits, which have been highlighted by several research studies[12]. Three major steps that constitute a typical thin film deposition process are, (i) production of the appropriate atomic, molecular, or ionic species, (ii) transport of these species to the substrate through a medium and (iii) condensation on the substrate to form a solid deposit [7].

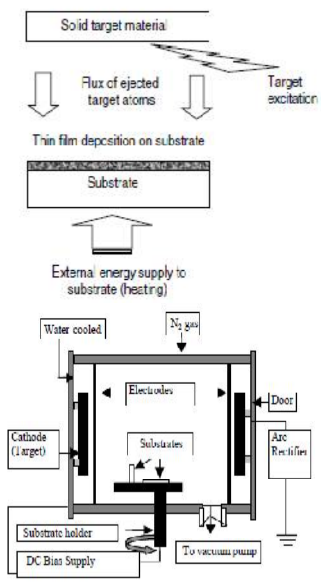

Fig. 2 PVD Working principle

The ambient pressure p determines how many particles of the residual gas impinge on the surface area of $1cm^2$ per second is given by the relation,

$$P = 2\, m(v) \times Z. \qquad (8)$$

Where m is the mass of the gas molecules, (v) is the average thermal velocity and Z is the impinging rate.

When a coating is used for material protection the coating efficiency depends strongly on its adhesion to the substrate, and the chemical inertness of the coating material and for the protection in wear and corrosion the hardness and toughness of the coatings are also important.

In recent studies of PVD hard coating with some modified deposition techniques for cutting tools have attracted a lot of research interest because of their wide range of applications both in industry and in research. The flexibility of coating processes especially of the PVD method well supported by the superior and controllable properties of modern coatings exclusively world wide applications of coated tools. The superior machining performance of coated parts is determined by an ability to maintain high hardness and resistance to oxidation at elevated temperatures [15].

Micro structural design has attracted increasing interest in modern development of hard coatings for wear-resistant applications. The tribological contact with two surfaces loaded against each other in relative motion is a very complex system and the system becomes even more complex when coatings are introduced on the surfaces. Regarding the future applications of the Niobium and ternary coatings on aluminum substrates, a very important advantage would be the possible substitution of certain parts (those that the mechanical solicitation would allow for) of the airplanes that are made of expensive titanium alloys (Ti6Al4V for example), and other products of the transport industry like ships or green cars. This last approach would significantly decrease the cost and the fuel consumption, since it would replace an alloy of approximately 4.43 g/cm3 that costs 24000 US$/ton [5] for one of 2.81 g/cm3 that costs 1290 US$/ton [6].

4. Conclusion

The current literature reveals that hard thin films have great importance and having a great significance for a large variety of industrial applications and the technology for tribological applications capable of producing verity of super hard and tough coatings which includes self- lubrication. So many Researchers develops the different kinds of deposition techniques and hence the PVD method is proving that it produces high quality films compared to others methods. From this work comparing with the other films better hard coatings are produced by Niobium and Ternary coatings on soft substrates like Al, Cu, etc.

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