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Characterization of magnetron sputtered Si_3N_4 thin films deposited on Aluminum alloy substrates

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Abstract

Aluminium alloys, due to its versatile nature used in making auto mobile components. In this study the mechanical properties such as decreased coefficient of friction and roughness are attained using silicon nitride (Si_3N_4) thin film deposition. The depositions were carried out using the reactive radio frequency (RF) magnetron sputtering in surface treated and untreated samples with RF sputtering power of 70 W. The deposited films show polycrystalline nature with a preferential orientation plane (1112). The crystallite size and the lattice strain were calculated for the films deposited over the surface treated and untreated substrates. Surface morphology of the films deposited on surface treated and untreated substrates were studied using field-emission scanning electron microscopy (FE-SEM) analysis. From sessile drop technique decrease in the angle from 96 to 72˚ was observed for the film deposited over the surface treated substrate which provides low coefficient of friction.

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*Keywords:*Silicon Nitride (Si_3N_4); XRD; FE-SEM; Contact angle measurement; Microhardness.

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1. Introduction

Aluminium (Al) alloys has wide range of applications in automotive and industrial applications. Their versatile nature include low density, high tensile strength, corrosion resistance, less weight, non-magnetic, ductile and its high heat dissipation property stands for making pistons, cylinder blocks and many other engine components [1]. Also has its uniqueness in household and electrical applications. Si_3N_4 is well known for its high melting point, thermal shock resistance, chemical inertness, high wear resistance and it is one of the highly thermodynamically stable materials [2]. Hence it has been used as the thin film coating material. Currently Si_3N_4 is used in aerospace applications like in turbine blades, rocket engines and moreover in mechanical industries used as a hard coating in cutting tools to increase the lifetime of the components. There are various methods to deposit Si_3N_4 such as reactive sputtering, chemical vapour deposition techniques, reactive evaporation etc [1]. In this work, Si_3N_4 films of different thicknesses values were coated over surface treated and untreated Al alloy by RF magnetron sputtering technique and their structural and mechanical properties were studied.

2. Experimental Details

Surface treatment of Al alloy was done by polishing the alloy for 15 min in circular disc polisher with alumina solution as the abrasive. And the substrates were well cleaned with distilled water and acetone in an ultrasonic bath and the substrates were dried in an oven. Using reactive RF magnetron sputtering technique, Si_3N_4 films were deposited over the surface treated and untreated Al alloy substrates. Silicon (Si) with purity of 99.99 % was used as a sputtering target (2 inch dia; 3.2 mm thickness) material. Argon and nitrogen gases of purity 99.99 % were used as the sputtering and the reactive gases respectively. The substrate to target distance was maintained as 5 cm. Initially the deposition chamber was evacuated to a base pressure of 3.1×10^{-5} mbar with the combination of oil diffusion pump and rotary mechanical pump. The sputtering target was pre-sputtered for 15 min in order to remove the impurities on the target surface. The RF sputtering power, substrate temperature and the substrate bias were maintained as 70 W, room temperature and floating potential respectively. The depositions were carried out for different time periods, in order to obtain films of different thickness values. The deposited films were characterized using X-ray diffractometer (Ultima III. Rigaku) operated using CuK_α radiation with a step increment of 0.02°, FE-SEM (JSM 670 1F, JEOL) operated with the accelerating voltage of 3 kV and at an operating distance of ~8 mm, contact angle measurement (250 F1, Ramming Hart) and micro hardness tester (Shimadzu) to study the structural, morphological, hydrophobic/hydrophilic and the mechanical properties respectively.

Table. 1.Deposition Parameters

Parameter	Values
Target	Silicon (99.999% pure)
Substrate	Al alloy
Base pressure	3.6×10^{-5} mbar
Ar:N_2	1:3
Working pressure	6×10^{-3} mbar
Substrate to target distance	5 cm
RF Power	70 W
Temperature	Room temperature

3. Results and Discussions

Fig. 1. shows the XRD patterns of the deposited Si_3N_4 films which shows peak in the 2θ angles of 28.6, 38.6, 44.5, 47.3, 65.1 and 78.24° corresponding to the planes (203), (214), (1112), (402), (412), (519) respectively (JCPDS card no. 01-083-1287). The films were polycrystalline in nature with hexagonal structure. As the deposition time increases the preferred orientation peak of the (1112) was increased in the surface untreated sample where the peak intensity of (1112) plane was less in surface treated sample. The crystallinity of the film will be affected by the substrate surface and the reason was given as follows: untreated substrate has a rough surface which has a large