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EVALUATION OF MECHANICAL ANDMORPHOLOGICAL PROPERTIES OF COATINGS PRODUCED BY DC MAGNETRON SPUTTERING

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ABSTRACT

In the present study, mechanical and morphological properties of coatings were analysed. The coatings tested in the present study were deposited on to aborofloat glass substrate and inconel 713C nickel based super alloy (30 x 30mm).Surface roughness of the glass (1nm) and inconel (0.008-0.012 µm) were maintained and confirmed by Atomic Force Microscope(AFM).SPUTTER 100 machine was used for deposition ofNiCrAlY thin film.H values of as-deposited and thermal cycled samples are 4 GPa and 4.5 GPa The surface roughness of the coating in as-prepared and after thermal cycling was found to be 24.09 nm, 33.00 nm respectively. The SEM micrographs confirmed that the increase in substrate temperature resulted in marginal grain growth and also evidenced that the film consisted of a number of polycrystallites.

Keywords: Aborofloat Glass, AFM, Nicraly, Inconel 713C, Sputtering,

I. INTRODUCTION

The increasing trend towards high temperature, fuel efficient jet engines has led to the development of complex cooling schemes for the turbine blades. During operation, the hot section components (mainly vanes, transition pieces and combustor) of gas turbine engine should withstand high thermal loading, mechanical loading and also chemical attack due to oxidation, which was found to increase significantly with temperature[1,2]. Thin film thermocouples and strain sensors have been developed for the measurement of surface temperature and thermal stresses on gas turbine engine for more effective health monitoring and thus extending the life of system. The multilayered thin film sensor system fabricated on these hot section components of gas turbine engine comprises of various layers of complex compositions, which should be specifically tailored for better durability, functionality and reliability. In the case of usage of nickel or cobalt-based superalloys as blade materials which are conducting in nature, an electrically-insulating layer (such as Al_2O_3, SiO_2etc.) is required between the substrate and the sensing layer[3,4].Thus MCrAlY (M stands for cobalt, nickel, iron or combination of both Ni and Co) bond coat layer is required between substrate and the succeeding layers in the sensor system to form stable and adherent system. Hence the present work is to investigate the effects of as-deposited and thermally cycled NiCrAlY thin film applied on inconel 713C substrates.Research shows that currently available commercial resistance static strain gauge has effect on gas flow patterns. Bulkiness of the

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tail gauges can drastically affect the aerodynamic behavior of the turbine or compressor, affecting the stress/temperature distribution and vibration mode. This seriously hampers the accuracy and meaningfulness of the measurements. Conventional bonding techniques can't ensure the integrity of bond under high temperatures and centrifugal loads. As the thickness of thin film sensors ranges in few micrometers meters, not much interfere with gas flow patterns [5]. The vibrational effect of rotating parts is another issue, which is not concerned with thin films as masses of sensor are on the order of micrograms. The main advantage of thin films in sensors application is its faster signal response time [6-10]. Thin films sensors are directly deposited onto the surface of stationary and rotating components without the necessity for high temperature adhesives, hence it is possible to have more precise surface measurements. For this reason, there is a motivation toward the development of non-intrusive, reliable, durable, multifunctional smart sensors that provide a wealth of information for complete engine diagnostics, prognostics and active control.

II. EXPERIMENTAL DETAILS

The Magnetron sputtering is very sensitive technique in which minute changes in the deposition parameters can result in drastic change in the properties of the films. The deposition and analysis using the conventional approach involves, experiment trials where one variable was varied at a time would have been very expensive. Thus deposition parameters were sorted based on previous research work and also conducting some initial experimental trials.For four parameters at two levels provides 16 numbers of experiment according to full factorial method. The cost and time of conducting more number of experiments was eliminated by performing fractional factorial method, i.e. conducting 8 numbers of trials instead of 16, with a very little loss in parametric effect.

In the present study, mechanical and morphological properties of coatings were analysed. The coatings tested in the present study were deposited on to aborofloat glass substrate and inconel 713C nickel based super alloy (30 x 30mm) a typical composition of this alloy is given in Table 1.

Table 1. Substrate (INCONEL 713C) compositions (wt %)							
Element (wt %)	Cr	Al	Mo	Nb	Ti	C	Ni
	13.5	6.04	4.65	2.3	0.95	0.1	Bal.

The specimens had NiCrAlY coating applied by DC magnetron sputtering and the compositions of the bond coat, is given in Table 2.

Table2. Bond coat (NiCrAlY) compositions (wt %)			
Ni	Cr	Al	Y
67	22	10	1

The borofloat glass substrates of size 30 x 30 mm were cut by using diamond glass cutter and inconel 713C using wire cutting machine. It was rinsed in soap water and cleaned ultrasonically in acetone **for 20 minutes**

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and isopropanol for 10minutes and **after that** blown dry in **air/**nitrogen.AFM characterisation was conducted on substrates to check there surface roughness. For sputtering process in the experiment, SPUTTER 100 machine was used for deposition of**NiCrAlY thin** film. Hind High Vacuum's Sputter 100 is configured forupward sputtering by Argon (Ar) gas for DC magnetron sputtering.The thermal cycling experiments were performed on NiCrAlY coating at 800^0c in ambient atmosphere and the Thermally cycled specimens are shown in Fig1.

Figure 1. Samples after 30 thermal cycling

III. MECHANICAL TEST AND MORPHOLOGICAL CHARACTERIZATION

AFM is a device used to view the object to the nanometer scale with the help of atomic forces. AFM is used to obtain 3D topological view of the surface. In atomic force microscopy a tip, integrated to the end of a spring cantilever, is brought within the interatomic separations of a surface, such that the atoms of the tip and the surface are influenced by interatomic potentials. Atomic force microscope testing was conducted in contact mode using APE Research (Italy) model. Several localities on the coatings were studied with the AFM tip moving along the NiCrAlY coated sample surface for both as prepared and thermal cycled samples. The captured images were processed using image-processing software supplied with the AFM system.

Nano indentation test is a helpful technique to study the mechanical properties of thin films such as and hardness (H) and Young's modulus (E).Nano indentation method was applied for NiCrAlY coated samples in as-deposited and thermal cycled condition. In the present work hardness and reduced Young's modulus were determined by using a nanoindenter (Agilent G200) with Berkovich tip (shown in Figure 5.12). For every sample 5 indentation were performed and considered the average value of elastic modulus and hardness. The parameters used in the present work are the maximum load was 100 mN. And loading rate=5 mN/s, unloading rate=5 mN/s and dwell period at maximum load=10 sec.

Microscopic evaluation was carried out for as-deposited and thermal cycled NiCrAlY thin films with scanning electron microscope (SEM). The SEM and EDS analysis was performed on a SIGMA Series ZEISS field emission scanning electron microscope (FE-SEM) which operated under low accelerating voltage conditions.

IJARSE
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IV.RESULTS AND DISCUSSIONS

The NiCrAlY coating obtained from the sputter deposition was observed to be uniform and to present a fine-grain coating microstructure, as observed from the AFM and SEM.. It was seen that the roughness Ra of the of the NiCrAlY coatings decreased with the reduction of the substrate roughness. The surface roughness of the coating in as-prepared and after thermal cycling was found to be 24.09 nm, 33.00 nm respectively.

The two important parameters for determining the mechanical properties of thin film are hardness and elastic modulus. Thehardness of sputter deposited NiCrAlY film tested by nanoindentation, in as-deposited condition and also after thermal cycling at 800 °C are 4 GPa and 4.5 GPa.). The SEM micrographs confirmed that the increase in substrate temperature resulted in marginal grain growth and also evidenced that the film consisted of a number of polycrystallites.

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