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Characterization Study of Copper Thin Film Coated on Steel Substrateby Thermal Evaporation Technique

SuganthiJ[a] Johnsonjeyakumar[b]SudhaJ[a]

[a]*Department of Physics, Sri ChandrasekharendraSaraswathiViswaMahavidyalaya University, Enathur, Kanchipuram-631561, TamilNadu, India, E-mail: sugimaya2@gmail.com*

[b]*Department of Physics,Trenquebar Bishop Manikkam Lutheran Arts and Science College, Porayar – 609307, TamilNadu, India*

Abstract

In this present study, Copper thin film deposition on steel substrates by thermal evaporation method at room temperatureis prepared. The sequential structure and morphology of copper thin film after coating is analyzed by X-ray diffraction and Atomic Force Microscopy. In X-ray diffraction, the pattern shows the presence of well defined and intense peaks. The presence of these diffraction peaks indicates the crystalline nature of films. The Atomic Microscope shows three dimensional morphology of copper thin film before and after corrosion test through salt immersion method.

Keywords*:* Atomic Force Microscopy, Copper, Corrosion, physical vapour deposition, Thermal evaporation, Thin film, X-ray diffraction etc.

INTRODUCTION:

Thin film technology is innovative and versatile modern technology, its prime objective is minimizing the size, reducing the cost and increasing the efficiency of material. Copper has attractive properties like good corrosion resistance, attractive color, excellent workability and also good mechanical properties.Corrosion is degradation of materials properties due to interactions with their environments and corrosion of most metals is inevitable.Physical vapor depositionis a variety of vacuum deposition methods used to deposit thin films by the condensation of a vaporized form of the desired film material onto various work piece surfaces.Thermal evaporation deals with the evaporation of the source materials in a vacuum chamber and condensing the evaporated particles on a substrate. This process is conventionally called vacuum deposition.

MATERIALS AND METHODS:

In this present study copper thin films were deposited on steel substrates by physical vapor deposition (Thermal Evaporation) method. The purity of copper is 99.99%.Copper thin films were deposited on steel substrate by physical vapour deposition (Thermal Evaporation) method.. Copper is replacing aluminium in microelectronic inter connections because copper circuits are faster and last longer.This study proposes a technique to deposit high strength and high conductivity copper thin films on steel substrates at room temperatureThermal evaporation is one of the oldest techniques for thin film deposition. The material to be deposited is heated until evaporation. Copper and copper alloys are widely used in a variety of products that enable and enhance our everyday lives. In the present study the copper thin films were prepared at room temperature by vacuum coating unit 12A4D. Copper was evaporated from a molybdenum boat at a pressure of $5x10^{-5}$ m bar.

The copper thin film has been subjected to salt immersion (corrosion) tests. The structural and morphological properties were studied with **XRD** and **AFM** analysis and the results are presented in the following section. Using the AFM images, the dimension of the assembly of nanostructures in the thin films has been estimated. The effects of substrates, substrate temperature and surface morphology have been discussed.

RESULTS AND DISCUSSIONS:

The copper thin films were prepared by thermal evaporation method. In the present study, copper thin films deposited on a steel substrate by using vacuum coater (Model 12A4D).The photograph of coppercoated thin film is shown in figure (1).

Figure (1): Photograph of CopperThin Film

In this present study, artificially rust or stain were made on the sample by salt immersion test. The immersed test samples were maintained at room temperature and examined every 24 hours time intervals after that the weight losses are recorded. Then the time intervals was maintained and lengthened up to the first appearance of rust or a stain. The same procedure is repeated for 4 days and fifth day the coating (which is immersed in 1% of $H_2SO_{4)}$ is disappeared. The observed readings were tabulated in the following table1.

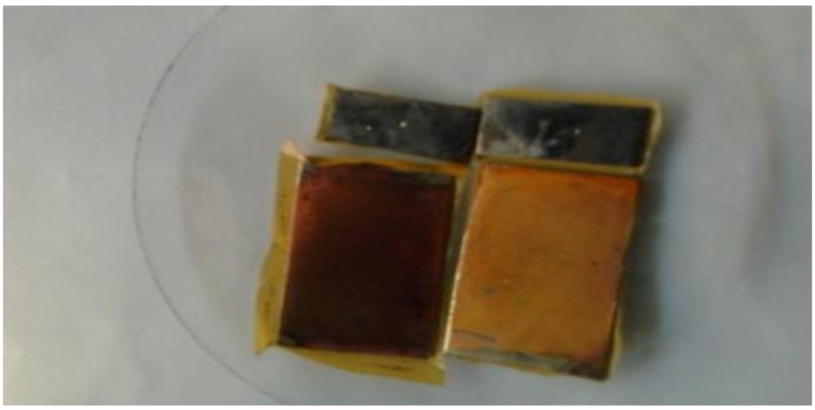

Figure (2): Photograph of Corroded Samples

Sample	**Weight loss (gm)**				
	Day 1	**Day 2**	**Day 3**	**Day 4**	**Day 5**
Copper Coated sample (NaCl)	11.175	11.168	11.159	11.143	11.138
Copper Coated sample(H_2SO_4)	10.926	10.888	10.879	10.871	10.764
Steel sample (NaCl)	3.194	3.187	3.178	3.172	3.164
Steel sample (H_2SO_4)	3.269	3.264	3.257	3.249	3.239

From the above table the weight losses shows the signs of rust formed on the sample in fast manner.

Atomic force microscopy is an excellent tool to study morphology and texture of diverse surfaces. The versatility of this technique allows meticulous observations and evaluations of the textural and morphological characteristics of the films, showing better facilities than other microscopic methods.

The topography and morphology were identified by using AFM technique for both coated and corroded samples. These were shown in figure(3).The following figure shows that the 3D morphology images of the copper thin film. The scan is measured in between 1 x 25μm.

Finally, the surface morphology of copper thin film is uniformed one in fig (a) and it differs in fig(b), which clearly shows corrosion of the sample.

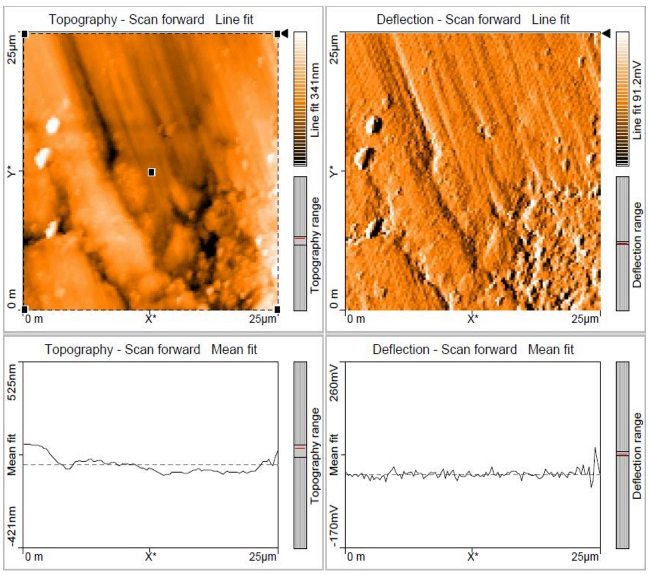

Fig. (b)

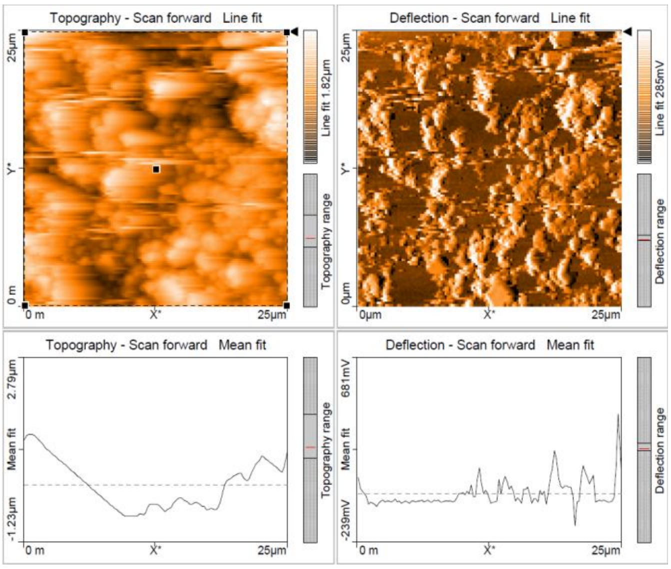

Fig.(b)

Figure (4): AFM images for (a) Copper Thin Film (b) Corroded sample

XRD Analysis:

The XRD pattern of copper thin film was studied by X-ray powder diffraction method. The XRD pattern of copper thin film shows in figure (5).The XRD pattern indicates that the resultant particles are (FCC) structure of copper material. The particle size calculation was performed by using Scherer formula. Table (2) shows that particle size is less than 97 nm.

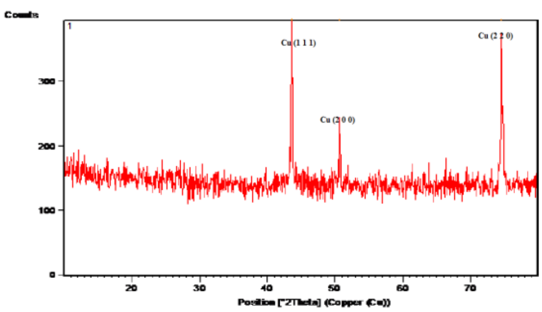

Fig5 : XRD Image of Copper Thin Film

Table (1): Details of the information obtained from the XRD patterns of sample:

Position (2θ) (Deg)	**Height (cts)**	**FWHM(2θ) (deg)**	**d-Spacing (A°)**	**Relative Intensities (%)**
43.605(7)	210(59)	0.11(2)	2.07398	100.00
50.73(1)	80(32)	0.09(2)	1.79830	38.19
74.530(8)	180(67)	0.15(3)	1.27216	85.44

Table.2: Simple Peak Indexing:

Peak Position(2θ) (deg)	**1000 x $\sin^2\theta$ (deg)**	**1000 x $\sin^2\theta$/46 (deg)**	**Reflection (hkl)**	**Remarks**
43.605	137.94	2.9	(1 1 1)	$1^2 + 1^2 + 1^2 = 3$
53.73	183.51	3.9	(2 0 0)	$2^2 + 0^2 + 0^2 = 4$
74.530	366.72	7.9	(2 2 0)	$2^2 + 2^{2+} 0^2 = 8$

Table.3: Peak indexing from d – spacing:

Peak Position(2θ) (deg)	**d-Spacing (A°)**	**1000/d^2**	**(1000/d^2)/77.32**	**hkl**
43.605	2.07398	232.48	3.006	(1 1 1)
53.73	1.79830	309.22	3.999	(2 0 0)
74.530	1.27216	617.89	7.991	(2 2 0)

Table (4): Calculated Values of Particle Size

2θ of The Intense peak (deg)	**h kl**	**θ of The Intense peak (deg)**	**FWHM Of Intense Peak (β) (radians)**	**Size of The Particle (D) Nm**	**d-Spacing nm**

43.605	(1 1 1)	21.80	0.0019	78.56	0.2073
53.73	(2 0 0)	25.36	0.0015	97.94	0.1797
74.530	(2 2 0)	37.26	0.0026	66.72	0.1271

From the above table the grain size of copper were calculated with corresponding values of FWHM of intense peak values. Finally XRD pattern confirms that the structure of copper is face centre cubic structure (FCC).

CONCLUSION:

Copper thin films thus deposited on a steel substrate was observed to be good in appearance and hence the analysis with the XRD spectra is found that if the deposition is a gradual uniformity attained. The immersion test shows the weight losses. From this corrosion testing analysis the copper thin films were dissolved in acids. The AFM analysis for the two samples (before and after corrosion) was carried out and the thin film morphology was compared between the samples. Analyzing the AFM image of corroded sample, it is found that there is no continuous and smooth film is attained.

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