Influence of the thickness on 1/f noise and morphological properties of Titanium based thin films deposited by e-beam evaporation method

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Abstract : The noble metal Titanium has many attractive properties. The thin film devices of Titanium are specially used in aerospace technology and also in microelectronics. In this paper, we discuss 1/f noise and nonlinear effects in titanium thin films for different current densities of varying thickness of the film at room temperature. Particularly the dependence of the 1/f noise on different thickness of the Titanium film and the effect of current densities has been investigated. The plots are dawn for 1/f noise of Titanium coated thin films deposited on glass substrate using electron beam evaporation, ranging from 180 nm to 270 nm and the slopes are estimated. It is found that at thickness of 250 nm the noise pattern of the thin film shows a decrement. With regard to Structural properties of AFM, the film surface roughness decreases with increases in thickness.

Keywords: Titanium Thin Film, 1/*f* Noise, Structural properties of AFM, E-beam evaporation system, different thicknesses.

1. INTRODUCTION

Titanium material has been used in numerous applications such as micro electronics, aerospace, motor service, chemical engineering, and sensing electrodes as well as designed thin films. These thin films have been proven with better advantages like thermal stability, electrical conductivity, chemical resistivity and mechanical properties of high specific strength, low resistivity, and high melting point. These films are being fabricated using different deposition methods, such as Magnetron sputtering, electron beam evaporation and chemical vapor deposition.

It has been recognized that electron beam evaporation is the easiest technique for deposition of high quality Titanium thin film. Electron beam evaporation technique is measured as clean environmental method and totally performed in closed arrangement system. The titanium thin film is used in optoelectronic devices as it attractive properties such as good conduction and transmission coefficient in visible region. In this present work the titanium thin films are coated using electron beam evaporation with different thickness and their dependence of 1/f noise is studied.1/f noise plays significant role in choosing frequency band in which the device can effectively use. Acoording to Musha et al. [1] investigated the quantum 1/f theory in explaining electronic 1/f noise in most high tech devices and its advanced applications. Using this technique the 1/f noise in thin films and other physical systems can be accounted in different areas of physics and technology. There is high demand for thin films of different material as it has applications such as manufacturing communication layers contracts for integrated micro circuits in modern microelectronics [2]. It is observed that, for a given film, the 'γ' values decrease and appear to tend to bellow one for diminishing currents or current densities [3].

The 1/f noise like spectrum limits the sensitivity and stability of the devices due to the fluctuations at the microscopic level. This fluctuation which reflects the different processes at the atomic levels, and makes 1/f noise the promising informative parameters wares in evaluating the reliability of the devices in modern [4] optoelectronic physics.

In this film synthesis the electron beam evaporation is used to grow Titanium thin film as it requires lower processing temperature. The deposition parameters such as substrate temperature [5], the electrical power, and thickness of the specimen can be controlled at a non-flow rate of the gas [6]. Researchers recently developed a measuring system so that results with coincide the theoretical values.

2. EXPERIMENTAL DETAILS

Titanium film is deposited on cleaned glass substrate by using electron beam evaporation equipment. The surface area of glass is 50 mm x 25 mm thickness and purity of titanium target is 99%. The glass substrate is rinsed with diluted water in ultrasonicator. It is then cleaned with the mixture of HF and diluted with water in the ratio of (2:20) and followed by acetone for 5minutes.Then they are dried up in the presence of N_2 gas of 99.9% purity keeping the substrate in the cavity of furnace, for adsorbing contaminants from the substrate, maintaining the device at constant temperature of 250 ^{0}C and a pressure of $2x10^{-5}$ mille-bar. The deposition is made on glass substrate with varying thicknesses like 150 nm, 180 nm, 220 nm, 250 nm and 270 nm. These films are protected in specificators and are used for the studies of 1/f noise of the thin film.

Contacts are made on these films using adhesive silver paste which will be dealt as device under test abbreviated as (DUT).The raw noise records for different thin films under the present study are shown in fig.1 and fig.2. These graphs seem to be the same for different specimens. But each device under selected bias condition has a record of digital data. Under selected biased condition the record of each device is saved in the form of digital data files. These data files are used as inputs to the MATLAB program, and spectral power density records are obtained, which have unique signature of the noise produced by the device. These observations are of prime significance which provides information regarding the electrical behaviour of the devices, analyzed using the MATLAB program.

In this paper the results of investigations are made on Titanium thin films. The 1/f noise characterization on film thickness [7] varying the current density is made on the films of thicknesses of 150 nm, 180 nm, 220 nm, 250 nm 270 nm.

3. RESULTS AND DISCUSSIONS

3.1 1/f noise and Non-linear properties of Titanium Thin film

The noise patterns are similar to those shown in figure1represent 8bit pulse code amplitude for Titanium film thickness 250 nm. The observations are of prime significance, containing crucial information regarding the electrical behaviour associated with DUT analyzed using the software. By using the FFT [8] transformation of the noise input simply translating the noise data into spectral power density. The noise patterns shown in fig.2 represent the variation of magnitude of FFT with the frequency for different current densities. According to Resnik [9], the prepared Ti/Ni/Ag thin film on n-Si was give high tensile residual stress; mainly in sputtered Ni layer (1.4-2 GPa) reduce the metal stack adhesion, it will effects on film properties.

The resulted graphs convey better information when they are compared for different films of different conditions for the same DUT which plotting the same graphical presentation compares two or more plots. This is equivalent to superimposing multiple graphs presented on similar scales to be visualizing the frequency difference these are shown using different colors, a legend to each graph is added for easy explanation. In the present work, 1/f noise plots are carefully compared to achieve the objectivity of 1/f noise studies.

All graphs are plotted in the standard format of log f Vs log spectral power density, after passing the data through the elliptical filter. The elliptical filters are found to be quite suitable for measurement that is recorded randomly. Notch filters were also used in the software to eliminate the stray ac interference.

Fig1. Is a plot Titanium film thickness180 nm for five current densities. While the observed values of ‘γ’ are 7697.50, 6777.48, 8270.75, 7801.28, and 7499.99, at current densities they are (A/cm^2) 11.11, 22.22, 33.33, 44.44 and 55.55 respectively. The observed values of ‘γ’ are constant for these current densities. On increasing the current density [10], the power ‘γ’ tends to increase for devices and thin films.

1/f noise in titanium thin films of 150 nm, 180 nm 220 nm, 250 nm, and 270 nm thickness is presented in figs 3 to 7. The average γ values obtained from the study are 8693.01, 7435.43, 9051.02, and 9142.82. The final results are discussed based on the investigation that is made using a number of samples of same thickness under same environment.

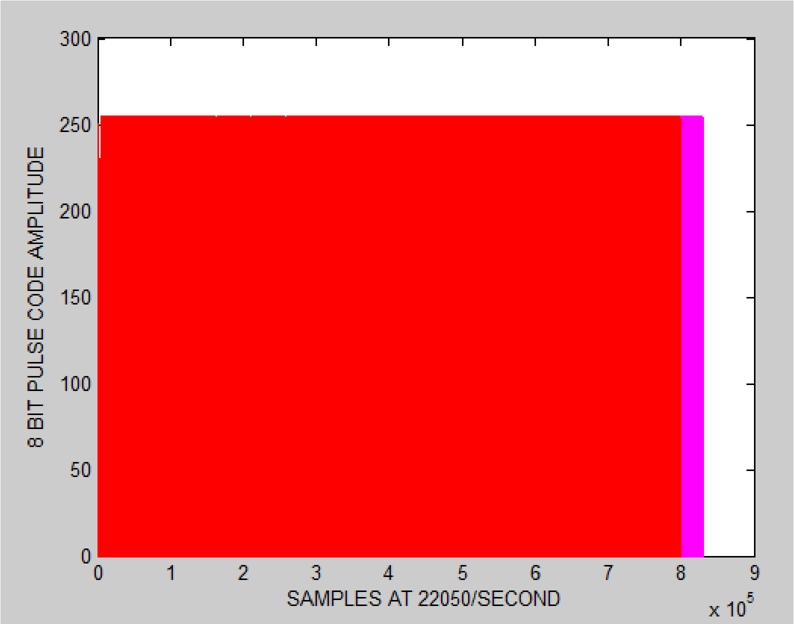


Fig 1. Pulse Amplitude of 8-Bit Titanium thin film 250 nm Thickness for different current densities.

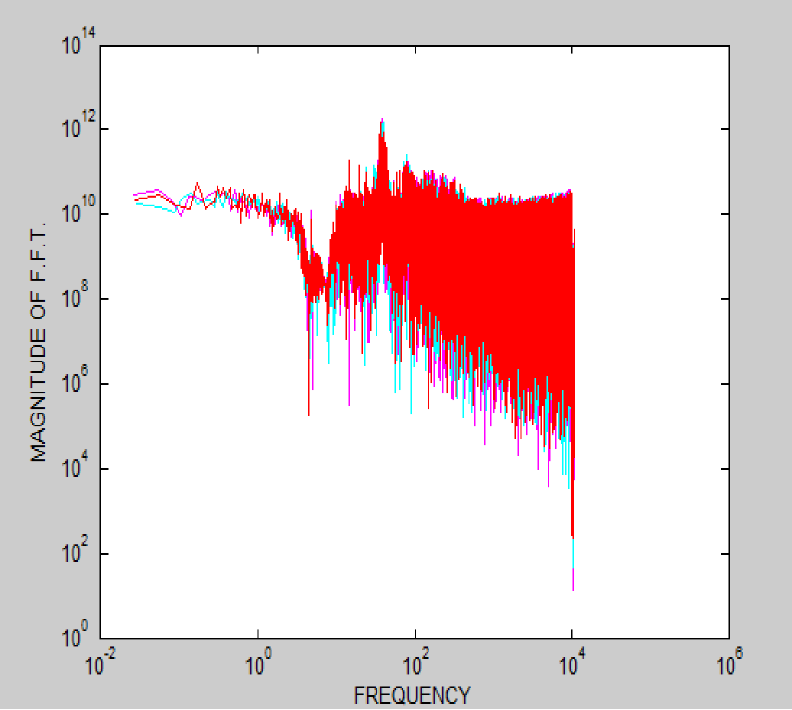


Fig 2. Amplitude of Titanium thin film 250 nm thickness for different current densities.

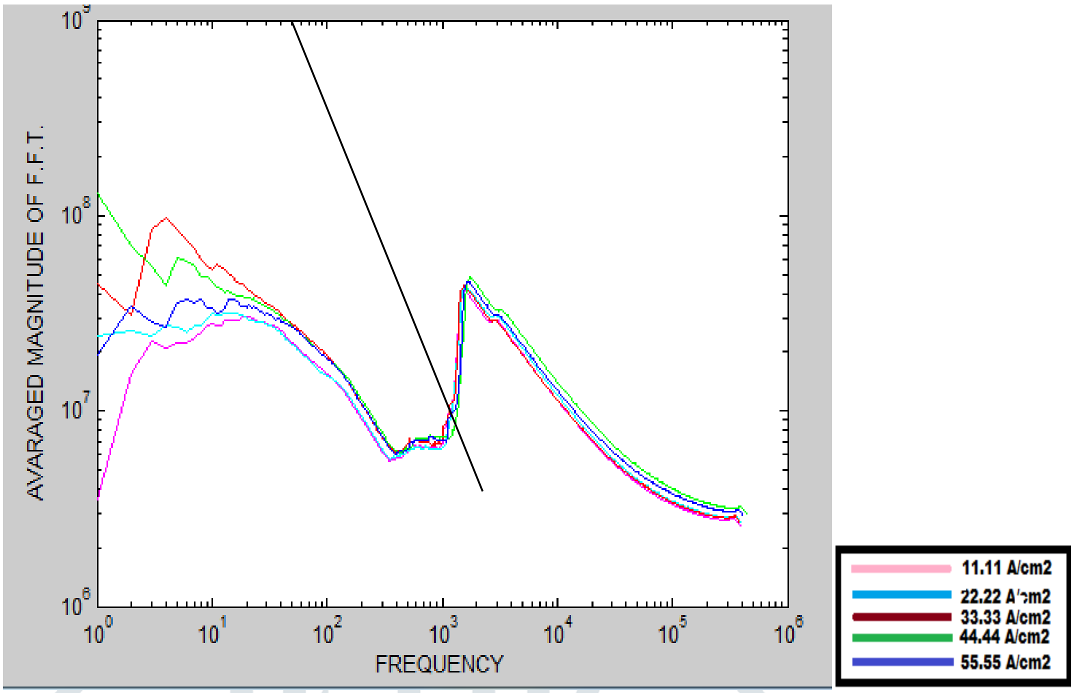


Fig 3. FFT amplitude of Titanium thickness 150 nm for different current densities.

Table 1. Average slope γ- values derived from the figure for various frequency ranges in 150 nm of Titanium thin film.

Current Density For 150 nm	Frequency Below1KHz	Frequency Range 1KHz To 10KHz	Average slope γ
11.11 A/cm^2	5494.317	9900.692	7697.50
22.22 A/cm^2	5191.981	8362.985	6777.48
33.33 A/cm^2	6374.519	10167.202	8270.75
44.44 A/cm^2	6278.825	9323.739	7801.28
55.55 A/cm^2	5637.038	9362.954	7499.99

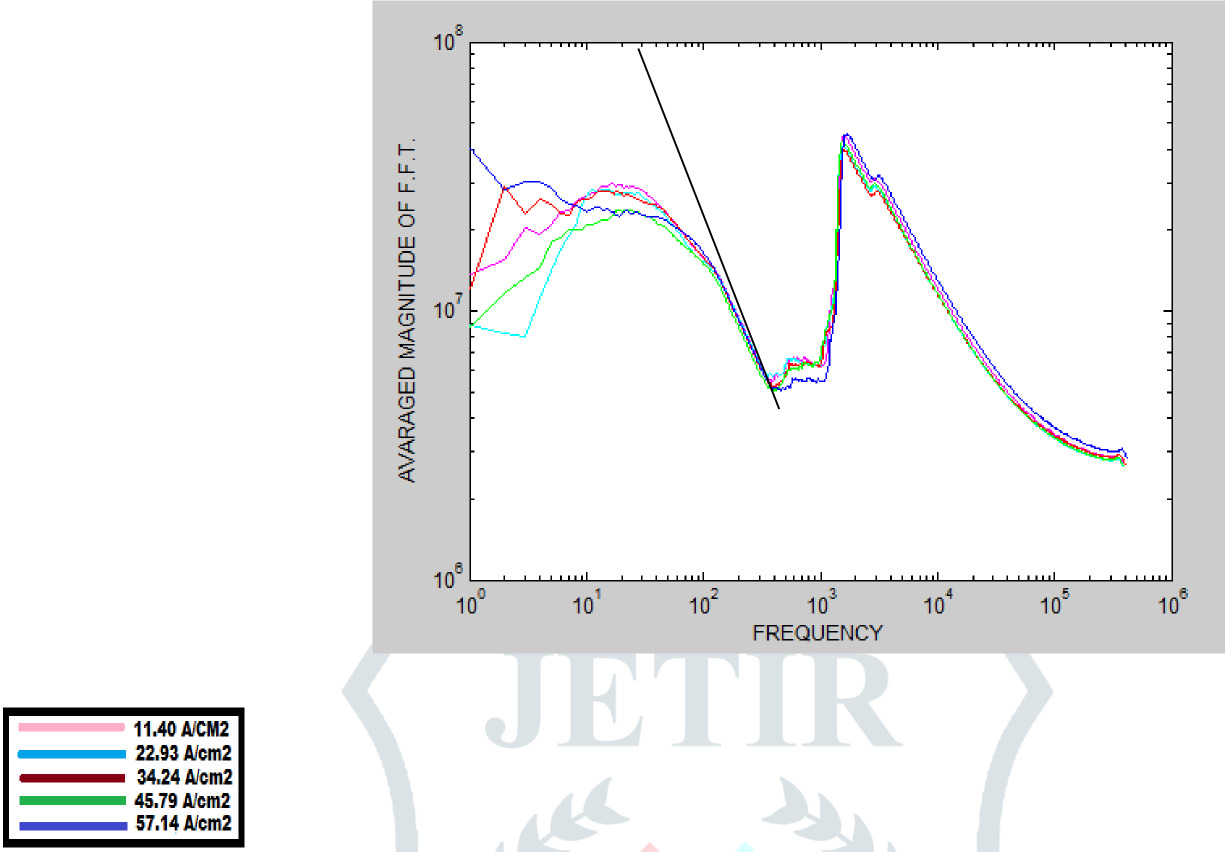


Fig 4. FFT amplitude of Titanium thickness 180 nm for different current densities.

Table 2. Average slope γ- values derived from the figure for various frequency ranges in 180 nm of Titanium thin film.

Current Density For 180 nm	Frequency Below1KHz	Frequency Range 1KHz To 10KHz	Average slope γ
11.4 A/cm^2	7199.014	10187.009	8693.01
22.93 A/cm^2	6473.024	11868.655	9080.84
34.24 A/cm^2	6382.824	8752.204	7567.51
45.79 A/cm^2	6729.933	10848.056	8788.88
57.14 A/cm^2	5267.305	6990.708	6129.00

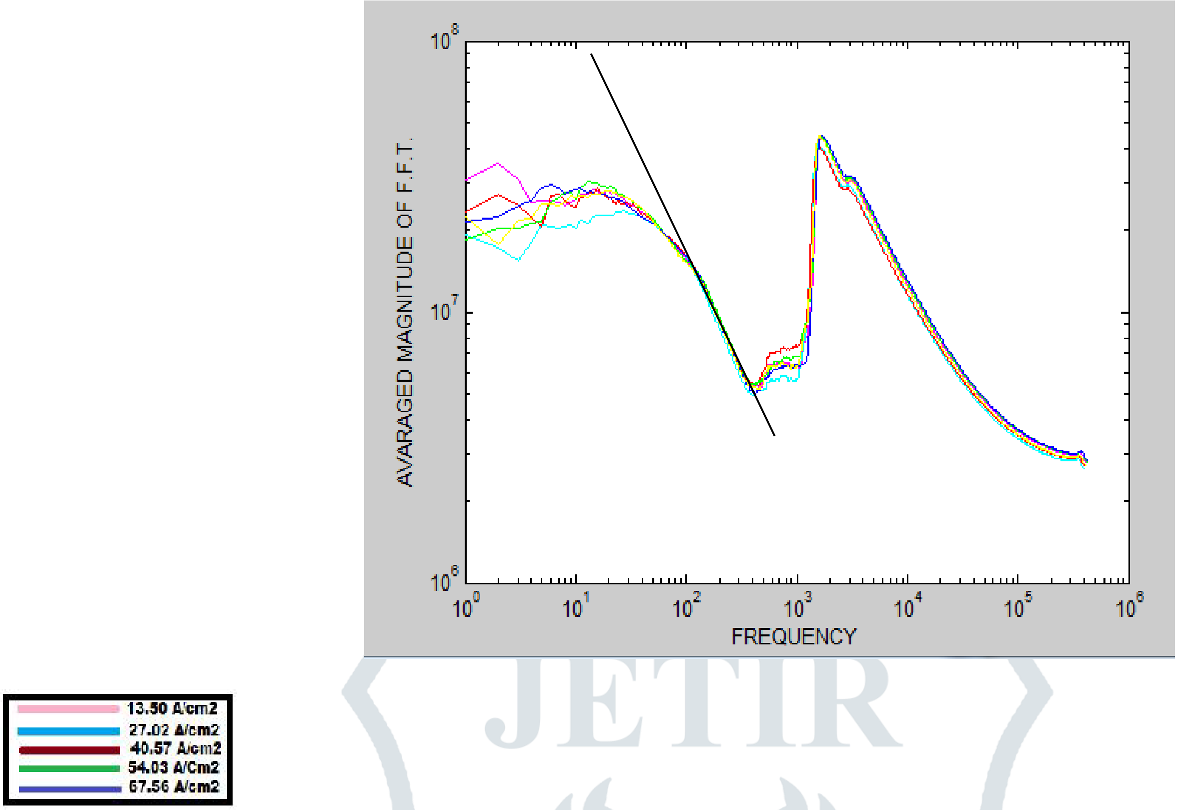


Fig 5. FFT amplitude of Titanium thickness 220 nm for different current densities.

Table 3. Average slope γ- values derived from the figure for various frequency ranges in 220 nm of Titanium thin film.

Current Density For 220 nm	Frequency Below1KHz	Frequency Range 1KHz To 10KHz	Average slope γ
13.05 A/cm^2	6036.701	8834.176	7435.43
27.02 A/cm^2	5958.086	8715.789	7336.93
40.57 A/cm^2	6386.965	11362.852	8874.90
54.03 A/cm^2	6862.195	10776.039	8819.11
67.56 A/cm^2	6924.996	11794.665	9359.83

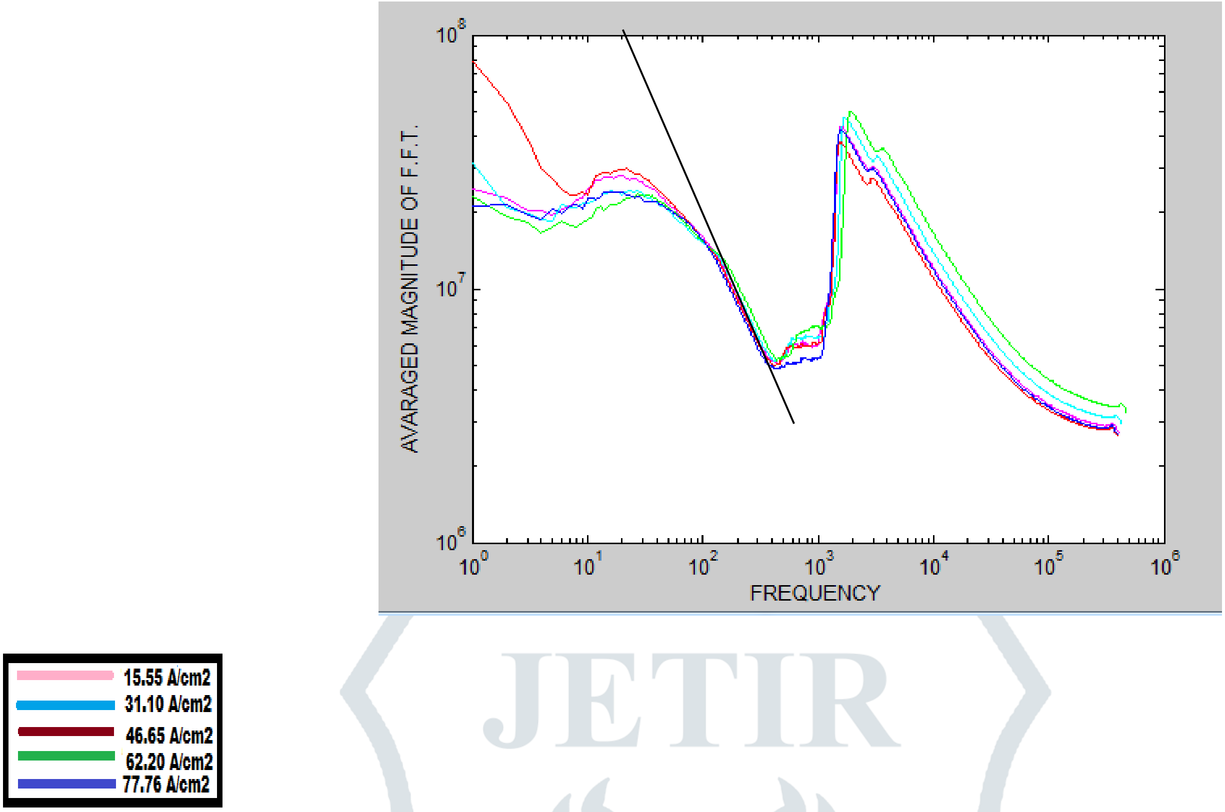


Fig 6. FFT amplitude of Titanium thickness 250 nm for different current densities.

Table 4. Average slope γ- values derived from the figure for various frequency ranges in 250 nm of Titanium thin film.

Current Density For 250 nm	Frequency Below1KHz	Frequency Range 1KHz To 10KHz	Average slope γ
15.55 A/cm^2	6221.967	11880.081	9051.02
31.10 A/cm^2	5421.857	12153.413	8788.99
46.65 A/cm^2	6203.600	13507.472	9855.53
62.20 A/cm^2	6370.852	11295.216	8333.03
77.76 A/cm^2	5806.169	11028.662	8417.41

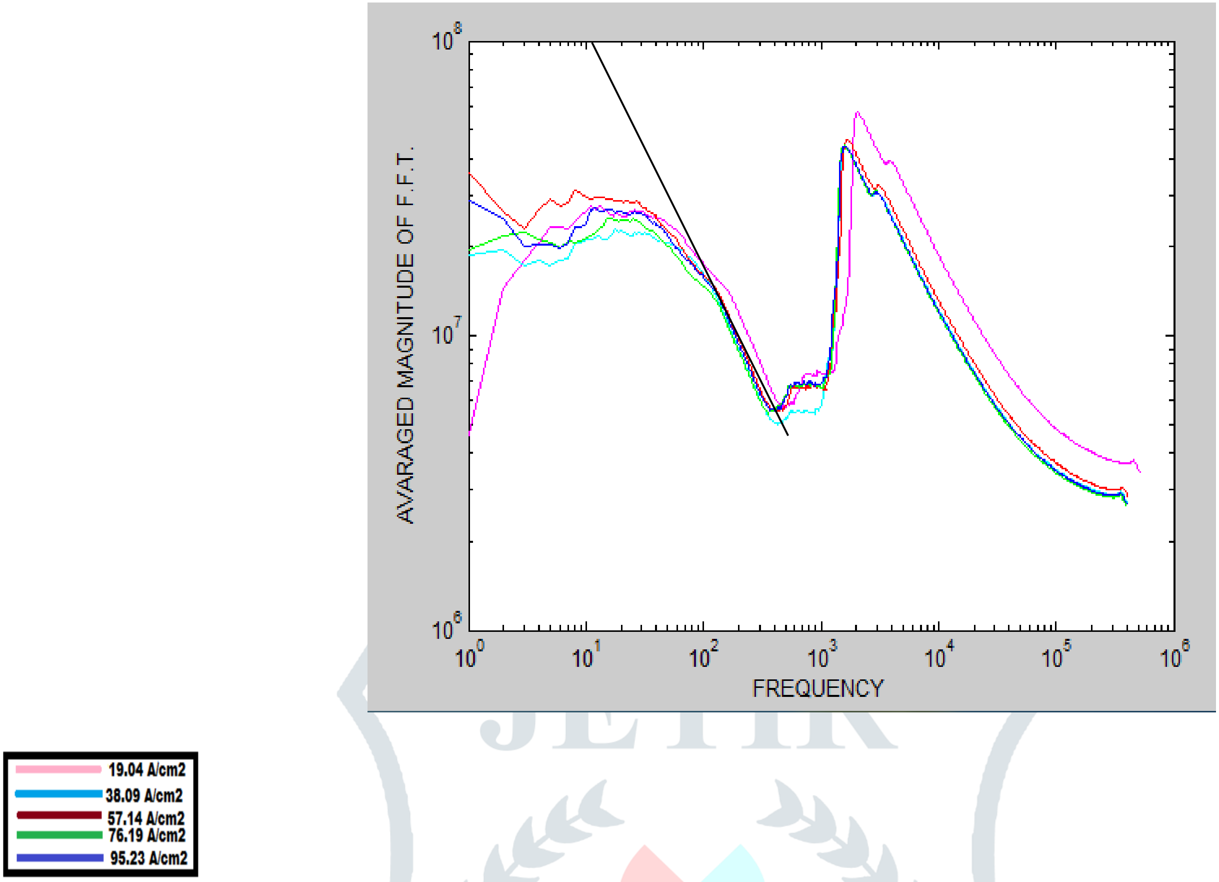


Fig 7. FFT amplitude of Titanium thickness 270 nm for different current densities.

Table 5. Average slope γ- values derived from the figure for various frequency ranges in 270 nm of Titanium thin film.

Current Density For 270 nm	Frequency Below1KHz	Frequency Range 1KHz To 10KHz	Average slope γ
19.04 A/cm^2	6371.546	11914.094	9142.82
38.09 A/cm^2	6212.398	11434.747	8823.57
57.14 A/cm^2	5573.539	9499.325	7536.43
76.19 A/cm^2	5414.648	9494.415	6954.53
95.23 A/cm^2	5489.757	9374.037	7431.89

Average slopes of various 1/f noise graphs and Different Current densities in Titanium Thinfilm

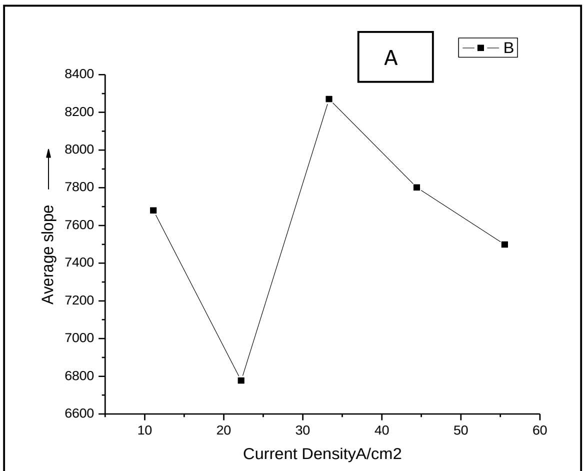


Figure-1

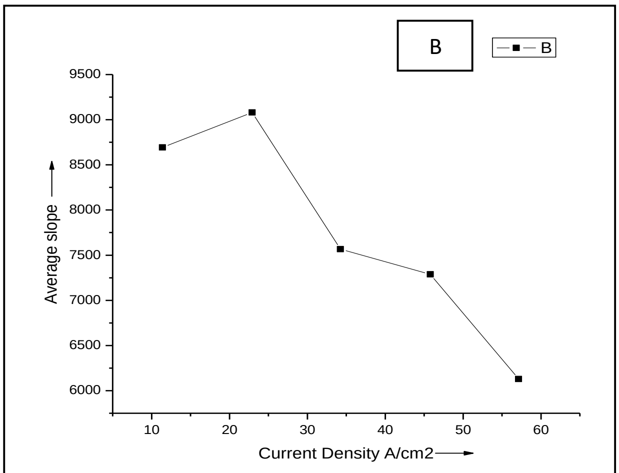


Figure-2

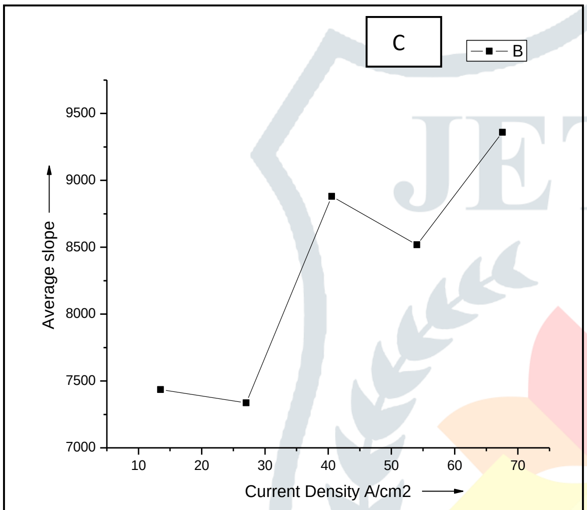


Figure-3

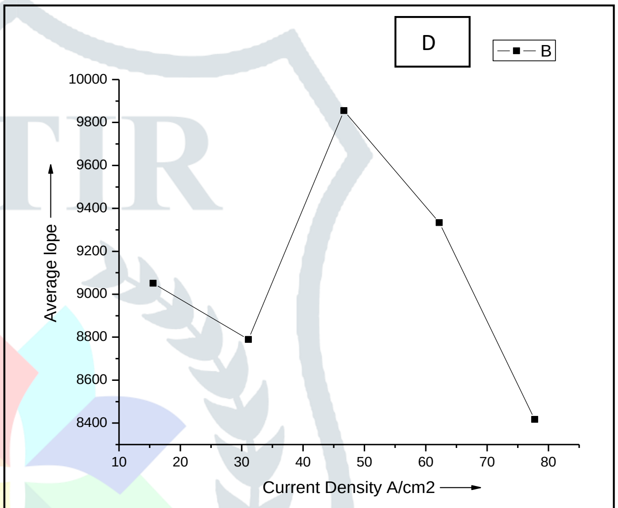
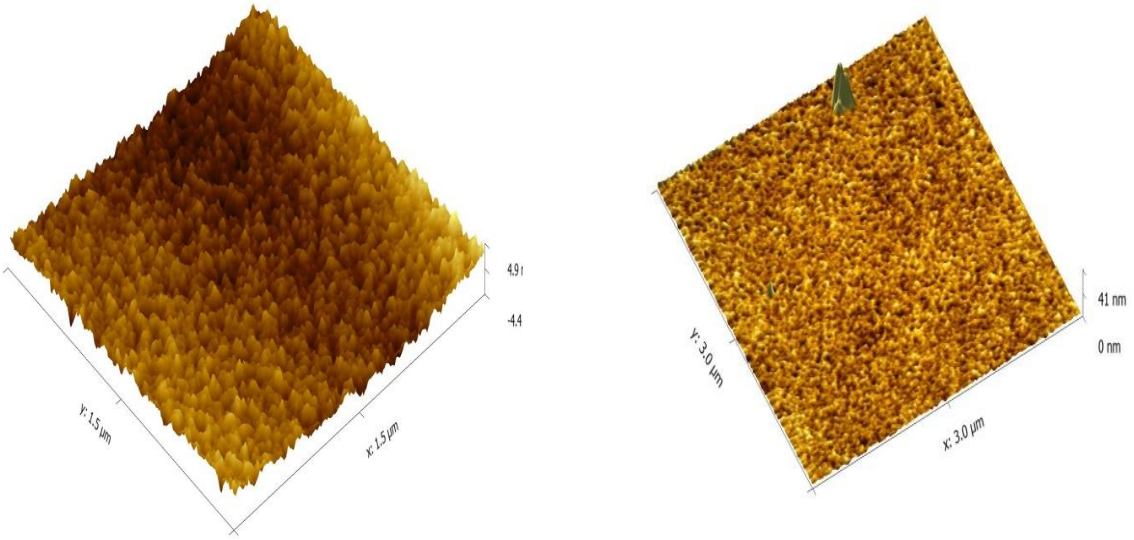


Figure-4

3.2 AFM images of Titanium film

The atomic force microscopy (AFM) measurement was employed to find the surface morphology of 500 nm, 1 µm of Titanium thin films of different thickness of glass substrate three dimensional AFM images as shown in figure 8. Which are represented that the surface morphology of the film is reasonably smooth with a root mean-square (RMS) roughness of Titanium films was ~2·3 nm is shown in figure 8 (a), and figure 8 (b) shows the RMS roughness of the Titanium film is ~4·9 nm deposited using e-beam evaporation system. The surface topography shows that the grain size on the surface roughness allows the current to be distributed uniformly into different grain domains. This indicates that the surface of the Ti film on glass substrate is resolved 1/f spectral behaviour of the thin film.



(a) (b)

Fig 8(a), (b), Shows grain size and surface roughness AFM 3D-images of 500nm, 1µm of Titanium thin films on different thickness of

glass substrate.

The variation of average slope, which is the value of ‘γ’ in the Titanium films as tabulated below

	Thickness 500 nm	Thickness1µm
RMS	1.217µm	1.16nm
Surface area	2.261µm	9.023µm

4. MAIN SIGNIFICANCE OF THIS WORK

1. For Titanium film of thickness 150 nm the average slope value is maximum at 33.33A/cm^2 and as the current density increases the slope goes on decrease as shown in fig.1.
2. At thickness of 180 nm the average slope value is maximum for 22.93 A/cm^2 as current density variation is not gradual but decrease in zigzag order shown in fig.2.
3. At 220 nm the average slope value is maximum at current density of 67.56 A/cm^2 the slope was increases not gradual but go on increases up to 9359.9 as shown in fig.3.
4. For 250 nm the average slope value is maximum at current density 46.65 A/cm^2 the slope increase up to 9855 and again decrease. Shown in fig.4.
5. Titanium film of thickness 270 nm the average slope value is maximum at current density 19.04 A/cm^2 as γ value decreases gradually reaches a value of 7431.89.shown in fig.5.

This shows all the titanium film fallow a typical order except the film whose thickness is 250 nm and hence Titanium film of thickness to be 250 nm gives more spectral power density of 1/f noise spectrum a be the energy gap for all optoelectronic applications may be observed in films other than the band width of 250 nm.

5. ACKNOWLEDGEMENTS

This work was supported by the Management of Madanapalle Institute of Technology and Science (MITS, Madanapalle) and DST-FIST-2015 (SR/FST/College-263) Program for providing the financial support.

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