

Nanoscale Deposition and Characterization of a Titanium Based Aluminium layer in the Fabrication of Triboelectric Nanogenerator

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ABSTRACT: In the past few decades most of the focus is on the self powered nanosystems and nanodevices which have become one of the most desired parameters for the protection of environment as these devices limits the use of batteries for energy storing purposes. Therefore, in this research paper designing of titanium based aluminium layer which basically forms a part of the triboelectric nanogenerator (TENG) is proposed. The deposition of the layers in the nanoscale is done on an ITO coated glass substrate with the thermal vapour deposition process in a clean room environment. The pressure of PR1 and PR2 is fixed to 1.5×10^{-2} mbars, where as the pressure of Penning gauge is fixed to 9.9×10^{-6} mbars respectively in order to maintain the desired vacuum in the vacuum chamber of the deposition unit. The deposition rate for the deposition of Titanium is of the order of 5-8 A/sec and that of aluminium is of the order of 10-14A/sec. The value of LT secondary current for titanium and aluminium reaches up to 70 amperes and 32 amperes respectively depending upon the melting points of both the metals. After the deposition process is over, optical characterization of the deposited layer is done on UV-VIS-IR Spectrophotometer to calculate various parameters viz. absorbance, transmittance, reflection and energy. Very good results are obtained in the characterization process as the material is performing very well in the visible range (400-700nm) of the electromagnetic energy spectrum as aluminium is absorbing good amount of energy in the above mentioned energy spectrum range.

KEYWORDS: TENG (Triboelectric nanogenerators), ITO (Indium tin oxide), PR1&PR2 (Pressure of Pirani gauge), VIS-UV-IR (Visible-ultraviolet-Infrared) Spectrophotometer

I. INTRODUCTION

Demonstration of Various nanosensors and nanosystems has been done in the recent years as self powered energy sources for parameters like temperature^[2], pH^[1], biomolecules^[3,4], mechanical vibrations, toxic pollutants^[5,6], heat and light energy^[7,8] etc. Self power devices have the advantage of being small in size and also limiting the use of environmental unfriendly materials that are present in the storage batteries. ^[9-12] In the day to day life consumption of energy is phenomenon that is going on continuously since the beginning of the civilization of mankind. Huge advancements have been made in the field of industrialization but all at the cost of depletion of environment and various natural resources, thus a big replacement to this was required. TENG (Triboelectric nanogenerators) are the devices that will be contributing in the capturing of energy from the surroundings in the form of heat, light, mechanical vibrations etc and thus converting it into the form of electrical energy output without affecting nature as well as environment, thereby replacing the commercial batteries as the main storage units for storing electrical energy. In this research paper emphasis have been given to the use of aluminium as main material in one of the layer to be used in the fabrication of TENG and various physical characterizations which includes FEGSEM, EDS, & XRD have been done. Also optical characterization of the sample is being performed on the UV-VIS-IR spectrophotometer so as to achieve the results from various parameters like absorbance, transmittance, reflection and energy. Aluminium has shown tremendous scope in absorbing light energy from the surroundings in the visible wavelength range (400-700 nm) and

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also as far as its cost; availability is concerned it is easily available and is very cost effective as compared with other materials.

II. RELATED WORK

In this research paper emphasis is mainly given on the nanoscale deposition of titanium based aluminium layer on a properly cleaned ITO coated glass acting as a substrate by using thermal vapour deposition unit. Aluminium is used as a main material for deposition process and the thickness of aluminium layer is 120nm where as titanium is used as a best binder for providing binding energy in the deposition of aluminium on the surface of glass substrate. Various parameters like pirani gauge pressures PR1 & PR2 are fixed at 1.4×10^{-2} mbars and 1.5×10^{-2} mbars respectively. The penning gauge pressure then allowed reaching at a value of 9.9×10^{-6} mbars after a time period of 3-4 hours maintaining the pressure of the vacuum chamber so that proper deposition of the material on the glass substrate can be carried out with accuracy. For the deposition of titanium layer (100nm) on the surface of ITO coated glass the average deposition rate is fixed at a value ranging from 7-8 A/sec and the value of LT secondary current is maintained at the highest value of 70 amperes where as for the deposition of aluminium the average deposition rate is of the order of 11-14 A/sec and the value of LT secondary current reaches a highest value of 32 amperes. The pressure of the water chillers unit is maintained at 25 bars and a temperature of 26°C is achieved during the deposition process. After the deposition process is over various characterization analysis of the layer so deposited is done which includes the physical characterization like FEGSEM, EDS with high and low magnification, XRD where as optical characterization is done by using UV-VIS-IR Spectrophotometer in which various parameters like Absorbance, transmittance, reflection and energy is studied in detail. The result so obtained justifies the fact that aluminium is having the properties of being utilized as optical/light energy storing material in the visible spectrum region (400- 700 nm).

III. THERMAL VAPOUR DEPOSITION

Smart coat 3.0 Thermal coating systems are constructed for the deposition of high quality coating on substrates. The Smart coat 3.0 systems chamber and source configuration is optimized for efficient deposition with controlled rated. The system is configured for deposition of material on a substrate while maintaining the vacuum conditions throughout the process. Chamber is of easy front loading type so that substrate can be easily loaded on to the substrate holder through front door opening. A view port is made on the chamber door for viewing the deposition process. The process chamber is pumped with combination of rotary pump and diffusion pump to achieve the high pumping speed. A 3KW Electron beam source is fixed on the base plate in process chamber and associated with power supply mounted on control console. Shutter source is provided to cover/uncover the deposition of material during process. For substrate holding, rotation and heating during the deposition process a substrate holder platform is designed to accommodate maximum of 6 inches diameter or multiple number of smaller substrate of minimum working area of 4 inches diameter. This work holder has heating facility for substrate, heater is provided for fast cycle substrate heating from room temperature to 300°C . This substrate holder rotation is adjustable up to 20 rpm. For accurate measurement of thin film coating single crystal head is mounted on the base plate. User friendly control system utilizes a control process and is populated with hardware modules with connectors to interface to all aspects of the system.

Features of Smart coat 3.0 Thermal coating system:-

- Easy to use.
- Excellent performance.
- Short cycle time due to high pumping speed.
- Ultimate vacuum better than 5×10^{-7} mbar.
- Easy manual deposition process operation.
- Easy front loading facility.

IV. EXPERIMENTAL RESULTS

PHYSICAL CHARACTERIZATION

Figures show the results of various physical characterizations like FEGSEM, EDS, XRD. Figures 1, 2, (a) shows the FEGSEM image at 1.00 μm scale and 500nm scales respectively. (b) are the images obtained by using image-j software showing the surface plot depicting that the surface of the deposited aluminium is smooth and don't have any roughness.

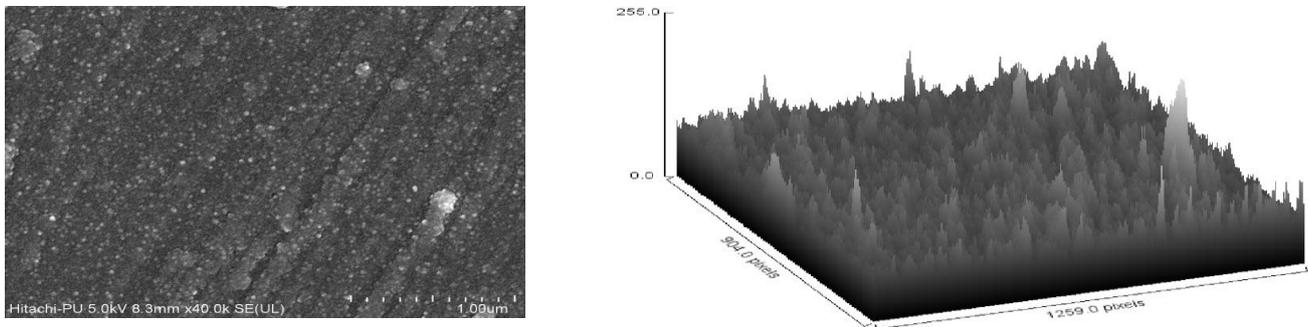


Fig. 1. FEGSEM analysis images of the sample prepared (a) Original image at 1 micrometre scale (b) Surface plot using image-j software

Figure 1 showing the clear FEGSEM image of the deposited aluminium layer by using thermal vapour deposition technique with the use of Smart coat 3.0 Thermal coating system, at 1 micrometre scale and the surface plot has been obtained from image-j software which is showing the evenly distribution of the aluminium metal onto the surface of the ITO coated glass substrate.

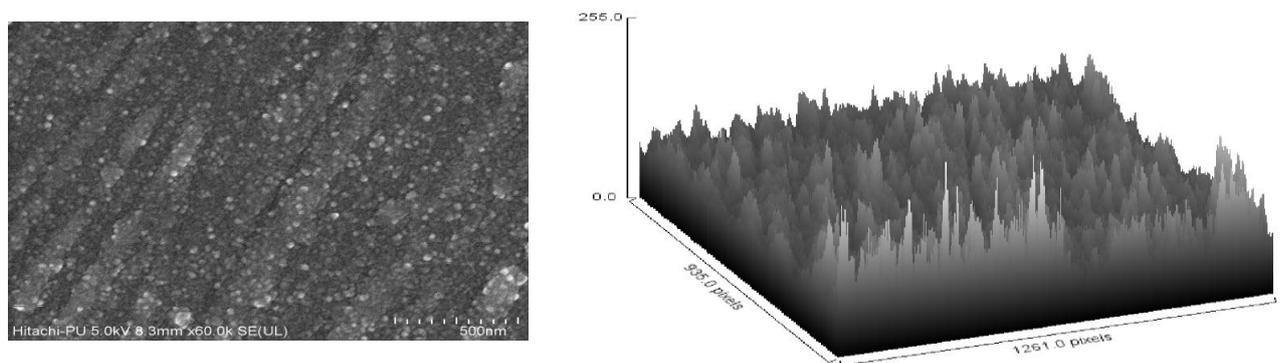


Fig. 2 FEGSEM analysis images of the sample prepared (a) Original image at 500 nanometre scale (b) Surface plot using image-j software

Figure 2 showing the FEGSEM image at 500 nanometre scale and its corresponding surface plot which depicts the deposition of aluminium metal by just providing the surface view of the metallic layer so deposited through vapour deposition technique.

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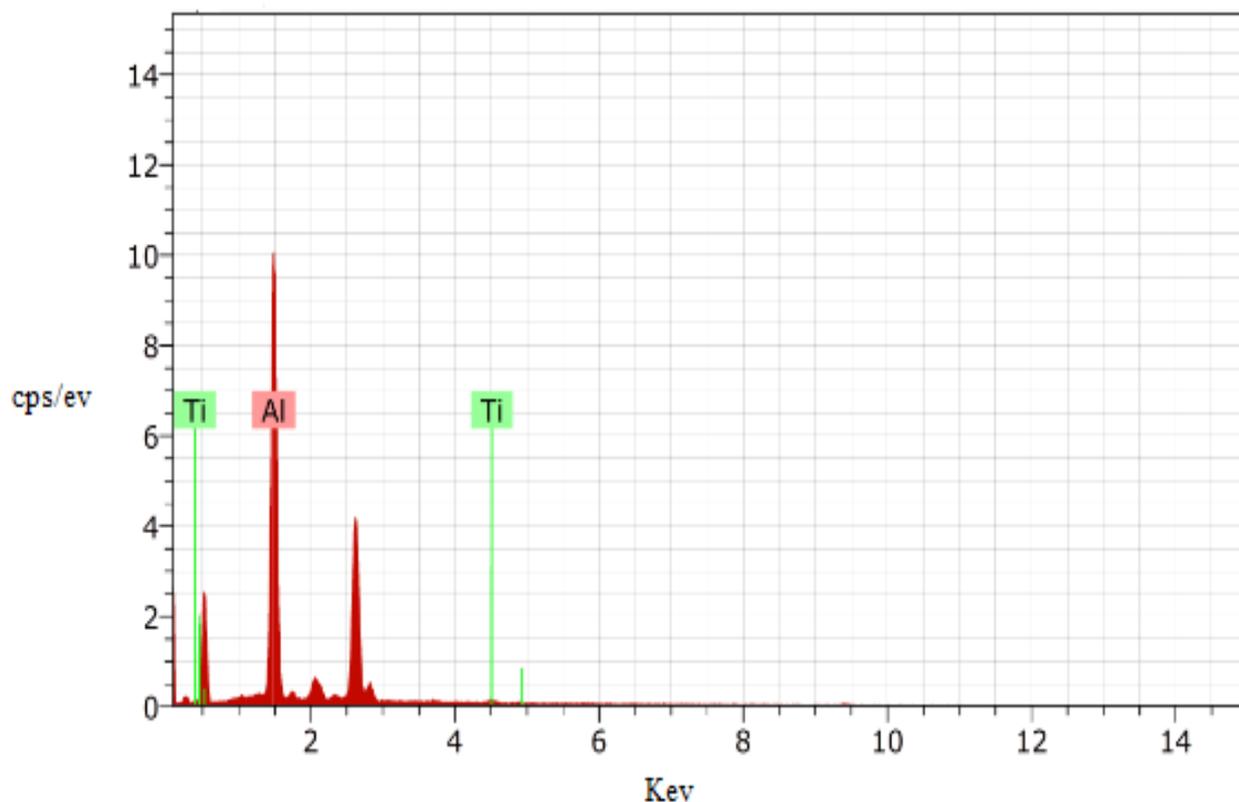


Fig. 3 EDS with low and high magnification (a) image showing deposition of aluminium and titanium metal on the surface of the substrate

Figures 3 showing the EDS with low and high magnification from which it has been analysed that the peaks corresponds to aluminium metal as well as titanium with major portion of aluminium and small fraction of titanium which was actually desired during the deposition process. Thus expected results were obtained from the EDS characterization.

Element	Series	Unn. C (wt. %)	Norm. C (wt. %)	Atom. C (at. %)
Aluminium	K-Series	18.90	96.67	98.10
Titanium	K-Series	0.65	3.33	1.90
Total		19.55	100.00	100.00

Table 1 showing the %age of aluminium and titanium deposited on the ITO coated glass substrate using thermal vapour deposition technique

Table 1 showing that the percentage weight of aluminium metal so deposited is 96.67% where as the weight of the titanium metal is 3.33% clearly depicting the fact that the main layer in the deposition process is of aluminium metal where as titanium is just acting as a binder for binding aluminium to the glass substrate.

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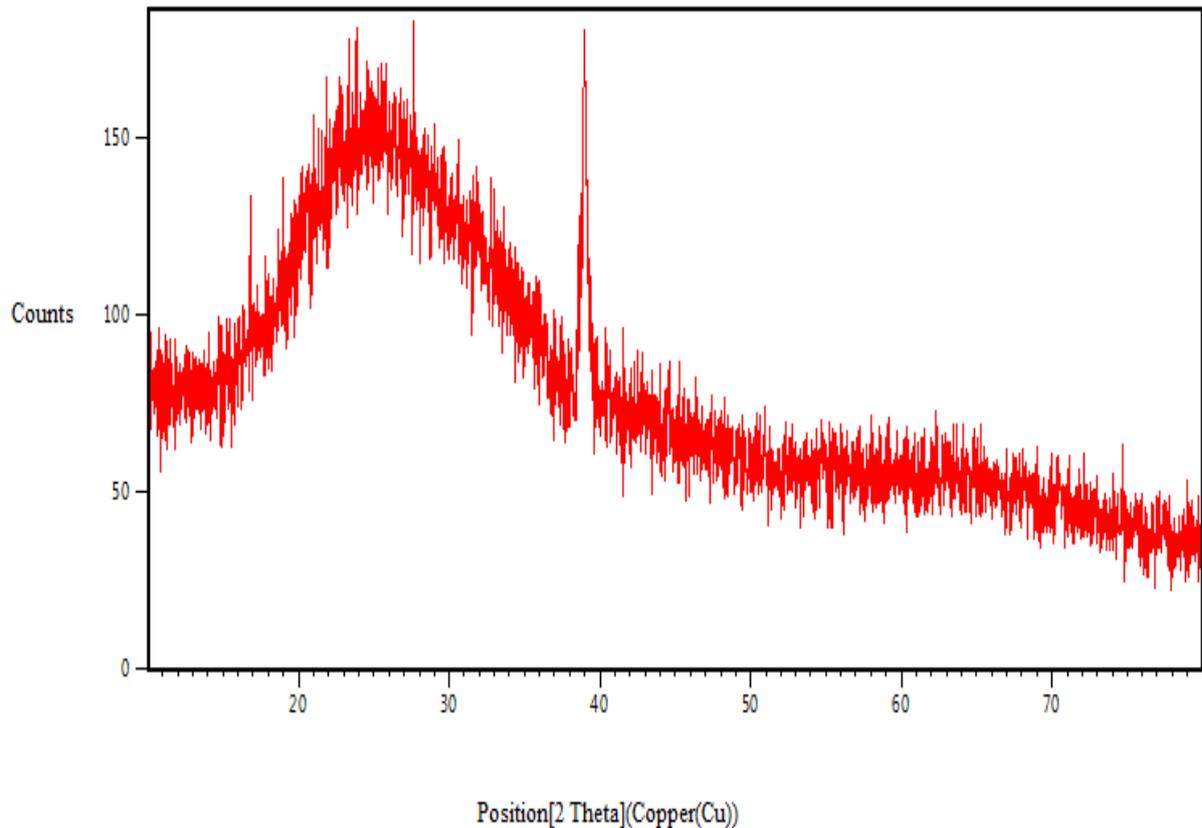


Fig. 4 XRD analysis (a) image showing peak corresponding to aluminium metal

Figure 4 showing the XRD results in which a peak correspond to 38.9519° is obtained which upon comparing with the ICDD clearly stating that the peak corresponds to aluminium metal thereby authenticating the deposition of aluminium onto the surface of ITO coated glass substrate which was our first and the main requirement. The data so obtained from the XRD analysis is compared with the data obtained from ICDD (international centre for diffraction data) and the results clearly depicted that the peak so obtained is none other than that of the aluminium metal which was the first and the far most requirement of the whole fabrication process.

Pos. $^{\circ}2\theta$	FWHM Total $^{\circ}2\theta$	d-Spacing $^{\circ}A$	Rel. Int.[%]	Area[cts. $^{\circ}2\theta$]
38.9519	0.4001	2.31036	100.00	26.55

Table 2 showing the angle at which the peak corresponds to aluminium metal is obtained along with other parameters

Table 2 showing the various results of XRD analysis which includes the angle corresponding to the peak of the aluminium metal as well as the values of various other parameters which includes FWHM, d- spacing, relative intensity and area that are matching with the data obtained from ICDD (International centre for diffraction data) site. The position of the peak so obtained corresponds to angle 38.9519° which belongs to aluminium metal conforming the deposition of proper material (aluminium).

OPTICAL CHARACTERIZATION

The optical characterization of the deposited layer of aluminium is done using UV-VIS-IR spectrophotometer with a measuring wavelength range from 200nm to 1200 nm, sampling mode of 2.0, time constant of 0.1 second, detector change wavelength of 830 nm, grating change wavelength of 720 nm. Various parameters like absorbance, transmittance, reflection and energy graphs vs wavelength are obtained as shown in the figures 5 (a), (b), (c) & (d) respectively. From figures 5 (b) & (c) the graphs of transmittance and reflectance solidifying the fact that no transmission and reflection takes place in the visible spectrum region which is again going in favour of aluminium as a supporting proof indicating regarding the fact that aluminium can be used as one of the best materials for the absorption of energy and hence be used for energy harvesting applications. Figure 5 (d) showing the graph of energy vs wavelength predicting that maximum absorption of energy takes place at 500nm and at 700nm with a value of 0.003 units.

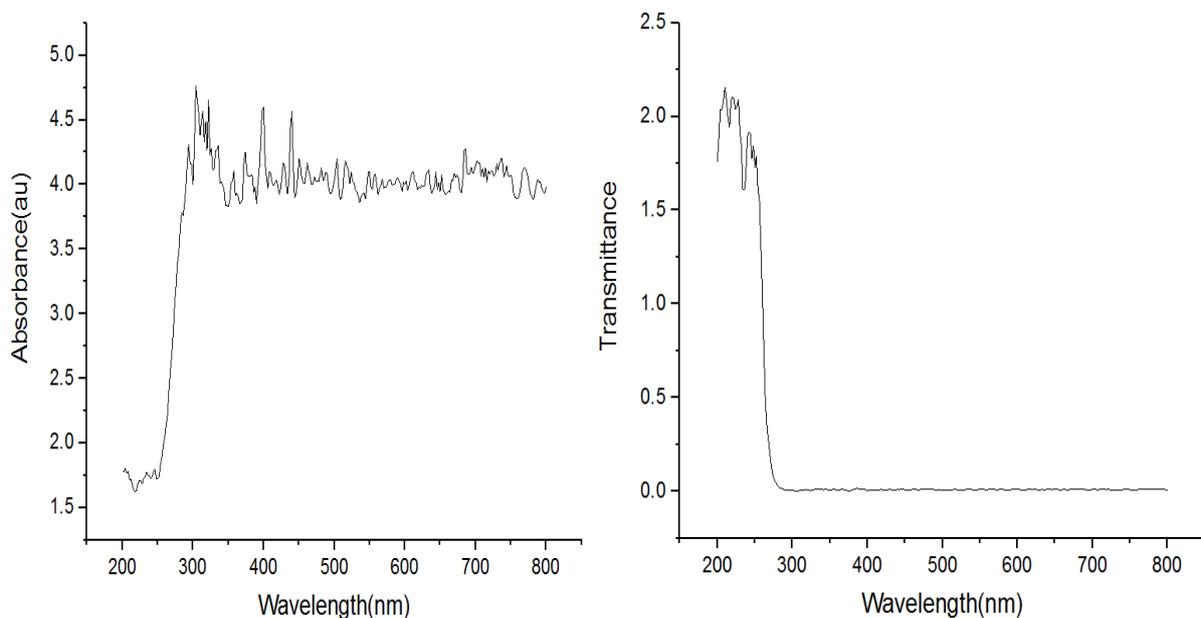


Fig.5 Results of UV-VIS-IR spectrophotometer (a) absorbance vs wavelength (b) Transmittance vs wavelength

From figure 5(a) it is quite clear that the maximum value of absorbance is 4.5 au and the average value is 4.0 au majority of which is in the visible spectrum region with maximum absorption taking place which signifies the importance of aluminium metal as one of the best materials for the absorbing of energy. Figure 5(b) showing the variations in transmittance with respect to the wavelength and from the above graph it is very clear that in the visible spectrum region no transmission of energy takes place as most of the energy is being absorbed by the aluminium in the above mentioned visible spectrum range. Transmission of energy takes place only in the ultraviolet wavelength region and is maximum at a wavelength of 230nm.

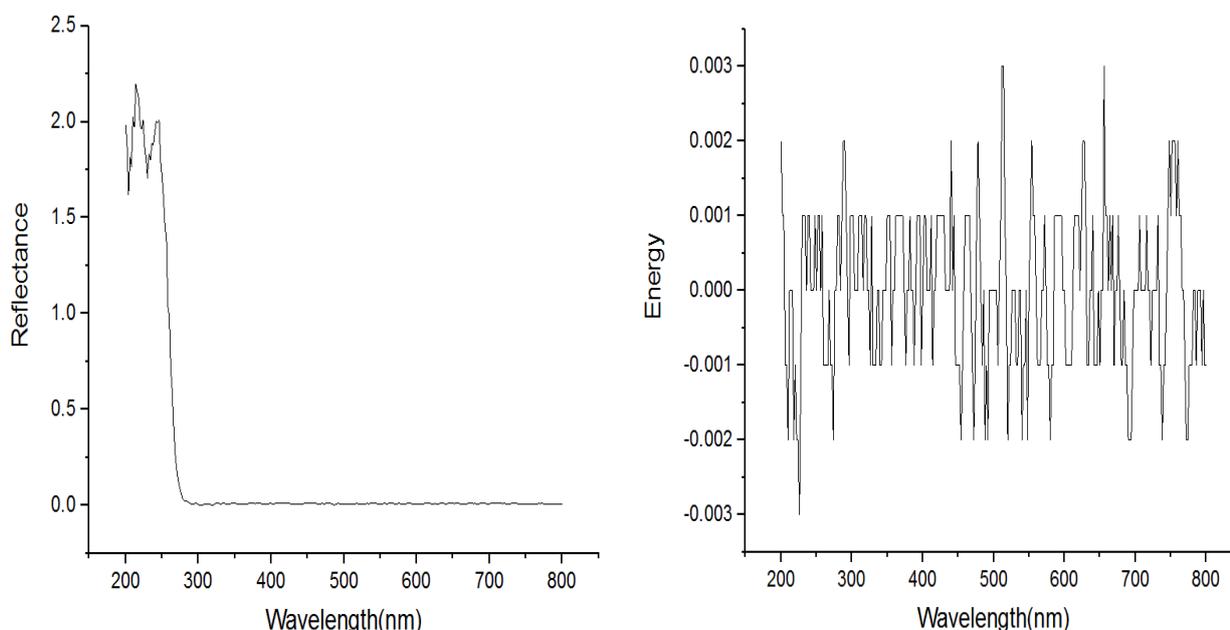


Fig.5 Results of UV-VIS-IR spectrophotometer (c) Reflectance vs wavelength (d) Energy vs wavelength

Again from the reflectance graph as shown in the fig. 5 (c) above it is very much clear that the reflection of light takes place in the ultraviolet wavelength region only and is maximum at 23nm, whereas no reflection is visible in the visible spectrum region solidifying the fact that aluminium can be used as one of the materials for the making of solar cells and its utility can be made at the commercial level also. Figure 5(d) showing the energy peaks which are also maximum in the wavelength ranging from 400 – 700 nm.

V. CONCLUSION

We have deposited a layer of aluminium on the ITO coated glass with titanium as a binder using smart coat 3.0 coating system in the nanometre range which has been successfully deposited as shown by the EDS result as well as from the peaks of the XRD analysis in which the peak so obtained corresponds to 38.9519⁰ which corresponds to aluminium metal as per ICDD available. On the other hand, the graphs of absorbance, transmittance, reflection and energy authenticating clearly that aluminium is one of the best material for absorbing optical energy in the visible wavelength region (400nm-700nm) of the electromagnetic spectrum. Thus titanium based aluminium layer can be used as an energy absorber and hence its utility can be made in the day to day applications for harvesting optical/solar energy replacing batteries as an output power source. In the present scenario of energy harvesting, aluminium can be used as one of the best materials in the fabrication of solar cells and can capture the solar market because of its low cost, easy availability and also easy fabrication process rather than going for other costly materials which makes solar panels so costly that cannot reach the masses at a reasonable & economical rates even in the 21st century.

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