Optical and Electrical Properties of Vacuum Thermally Deposited Aluminum Zinc Nano Thin Film.

O.R. Adetunji[*1] and O.J. Alamu[2]

[1]Mechanical Engineering Department, Federal University of Agriculture, PMB 2240, Abeokuta, Nigeria.
[2]Mechanical Engineering Department, Osun State University, Oshogbo, Osun State, Nigeria.

E-mail: adetunjior@unaab.edu.ng[*]

ABSTRACT

Vacuum thermal evaporation technique was employed in depositing thin film of aluminum, mixture of aluminum and zinc, on microscopic glass and steel substrates using Edwaed 090-10-895 B Auto 306 vacuum coating system.

Characterization of aluminum zinc nano thin films produced were done using Dektak Stylus Profilers, Four-Point Probe Resistivity Measurement, and UV-Vis Spectrometer, Scanning Electron Microscope (SEM), and Energy Dispersive X-ray (EDAX). The reflectance of nano thin films of Aluminum and Zinc produced increased with increases in wavelength. The transmittance of 100% aluminum thin films on glass substrate was low within wavelength of 350 and 500 nm. The absorbance of 100% aluminum, 100% zinc and 50% aluminum and zinc are satisfactory within wavelength of 350 to 500 nm. The reflectance of nano thin films of aluminum and zinc produced increased with increase in wavelength. The electrical characteristics of aluminum film can facilitate its use as do pant in some solar cell's film for better performance and enhanced conversion efficiency.

(Keywords: aluminum, Al, Zinc, Zn, thin films, electrical, characteristics)

INTRODUCTION

Nano materials have a characteristic length scale of less than about a hundred nanometers. The length scale could be a particle diameter, grain size, layer thickness, or width of a conducting line on an electronic chip (Amusan, et al., 2010). These nano materials have technological applications in catalysts and pigments. The large surface area to volume ratio increases the chemical activity (Yang and Luzzi, 2009). Cost advantages in fabricating catalysts from nano materials properties improve through preparing them as nanostructures (Zebaze Kana, 2006). For example, sintering temperature can be decreased and plasticity increased of single-phase structural ceramics by reducing the grain size to several nanometers (Okoli, et al., 2010; Yang and Luzzi, 2009).

Aluminum which is one of the elements of Group IIIA has been increasingly used to dope materials for effective conductivity. At temperature of 1472 K, typical value for the average grain size of face centered cubic metal like aluminum is 22 nm (Koch, 1993; Munday et al., 1993).

Aluminum is being employed in doping thin films so as to achieve highly conductive thin films and other associated improved electrical properties of the films. Thin film is a layer of material deposition whose thickness is of the order of a given wavelength of electromagnetic radiation. In making zinc nano particles, oxygen had the tendency of causing the particles to clump and form agglomerates approximately 0.5 μm in size (Eversole and Broida, 1974).

The main objective of this research work is to examine electrical and optical properties of zinc aluminum nano thin films.

MATERIALS AND METHODS

Laboratory grade of aluminum wire and zinc flakes were used. Aluminum deposition was carried out. Zinc deposition was also carried out by weighing small pieces on a Mettler weighing balance. Proportions of both aluminum and zinc were also done in the same method.

The process began by switching on a recirculating water chiller attached to the evaporator. The coater (Figure 6) is switched on and the process of creating vacuum in the backing line was initiated. Once the desired vacuum was achieved in the backing line, the deposition chamber was vented. The chamber is opened and the substrate is mounted. The evaporant (aluminum, zinc and mixture) is put in the crucible. The deposition chamber is closed and rough vacuum is done.

The fine vacuum is started and about 1.5 liters of liquid nitrogen is poured. Once the required vacuum is achieved (better than 10^{-6} Torr), the evaporation power supply is switched on gradually. The power was increased until the desired evaporation rate was achieved. The shutter was then opened. Once the desired thickness (from Monitor) is achieved, the shutter is closed and evaporator power switched off. The system is vented and the sample is removed.

The steps are repeated for the next deposition otherwise the vacuum is created in the system, the system is sealed, and shut down. Once the system is in standby mode, it is switched off from the control panel and the main utility line is turned off.

Optical Characterization on UV-Vis Spectrometer

The thin films coated on glass substrates were characterized on ultra violet spectrometer for reflectance and transmittance. Eight samples of thin films of aluminum, zinc, and different proportion of both aluminum and zinc were analyzed. The results obtained are contained in Tables 1-8 and Figures 1-5.

The sixteen thin films produced (glass slides and steel substrates) were tested for electrical resistivity. The results obtained were contained in tables in section four.

Scanning Electron Microscopy (SEM) for Thin Films

The samples were prepared for SEM analysis by cutting into 10mmx10mm. Each of the glass slide samples were mounted on the machine. They were scanned and the best resolution taken on the monitor.

Energy Dispersive X ray (EDX) for Thin Films on Glass Slides

The prepared samples for SEM analysis were also run for EDX analysis to confirm the elements in the thin films. The sixteen thin films produced (glass slides and steel substrates) were tested for electrical resistivity. The results obtained were contained in tables in section four.

RESULTS AND DISCUSSION

Optical Properties of Aluminum and Zinc Nano Thin Films

The results of reflectance and transmittance data measured with spectrometer serial number: 0708067S1.

Table 1: Reflectance and Transmittance of Al-Zn Nano Thin Film (Al-50%).

S/N	Wave (nm)	Reflectance (%)	Transmittance (%)
1	350	12.35	12.46
2	400	16.12	11.89
3	500	25.23	10.70
4	600	30.91	9.93
5	700	24.67	9.52
6	800	37.88	9.69
7	900	41.54	10.50
8	1000	47.32	10.31
9	1100	70.60	8.54

The reflectance and transmittance obtained for the Al-Zn (50%) film on glass slide was 12.35% and 12.46%, respectively, at wavelength of 350 nm. As the wavelength increased to 600 nm, the reflectance increased to 30.91% while reflectance decreasedto 9.93%.

Transparency depends on amount of light absorbed and backscattered light is collected as reflected light by the integrating sphere. A can be simply be computed as A=1- T-R. The highest value of relectance got was 70.60% with corresponding lowest of 8.54 %.

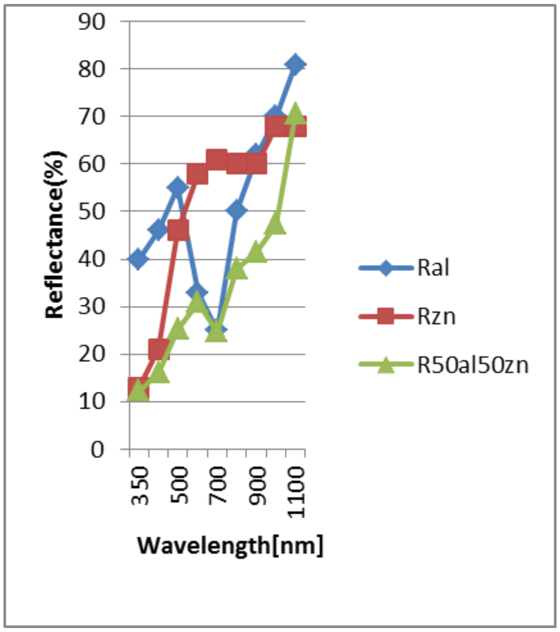

Figure 1: Reflectance of Nano Thin Films against Wavelength.

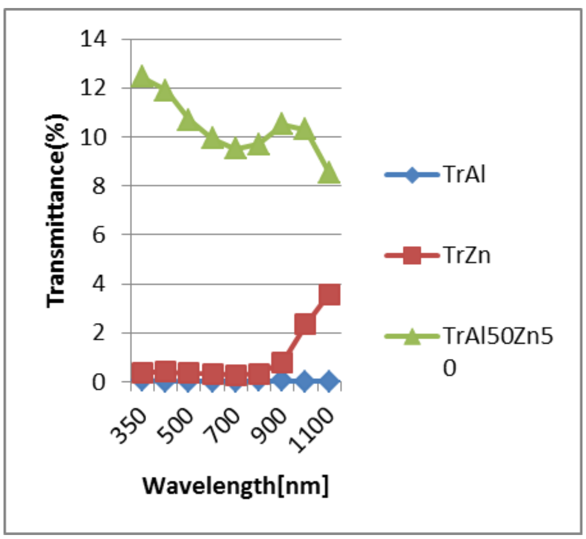

Figure 2: Transmittance of Nano Thin Films against Wavelength.

The reflectance of pure aluminium thin film on glass ranged from 40% to 81% while the transmittance values were low.

The reflectance of zinc thin film on glass slide ranged from 13% to 68% within a wavelength of 350 nm to 1100 nm while the transmittance were very low from 0.37% to 3.56%.

Table 2: Reflectance and Transmittance of Al-Zn Nano Thin Film (Al-100%).

S/N	Wave (nm)	Reflectance (%)	Transmittance (%)
1	350	40	0.059
2	400	46	0.000
3	500	55	0.007
4	600	33	0.023
5	700	25	0.015
6	800	50	0.051
7	900	62	0.047
8	1000	70	0.000
9	1100	81	0.000

Table 3: Reflectance and Transmittance of Al-Zn Nano Thin Film(Zn-100%).

S/N	Wave (nm)	Reflectance (%)	Transmittance (%)
1	350	13	0.37
2	400	21	0.41
3	500	46	0.36
4	600	58	0.32
5	700	61	0.28
6	800	60	0.33
7	900	60	0.80
8	1000	68	2.35
9	1100	68	3.56

Table 4: Reflectance and Transmittance of Al-Zn Nano Thin Film (Al-30%).

S/N	Wave (nm)	Reflectance (%)	Transmittance (%)
1	350	12	0
2	400	19	0
3	500	42	0.041
4	600	59	0.129
5	700	76	0.117
6	800	89	0.161
7	900	96	0.705
8	1000	102	0.709
9	1100	106	0.00

The reflectance of 30% aluminium and 70% zinc improved from 12% to 106% at higher wavelength of 1100 nm but the transmittance was very low.

Table 5: Reflectance and Transmittance of Al-Zn Nano Thin Film (Al-70%).

S/N	Wave (nm)	Reflectance (%)	Transmittance (%)
1	350	25	11
2	400	32	12
3	500	50	13
4	600	58	15
5	700	60	16
6	800	66	17
7	900	64	19
8	1000	69	20
9	1100	56	22

The reflectance of 70% aluminium and 30% zinc thin film on glass slide rose from 25% to 56% while the transmittance rose from 11% to 22% as wavetength increased from 350 nm to 1100 nm.

Table 6: Reflectance and Transmittance of Al-Zn Nano Thin Film (Al-36%).

S/N	Wave (nm)	Reflectance (%)	Transmittance (%)
1	350	25	11
2	400	32	12
3	500	50	13
4	600	58	13
5	700	60	16
6	800	66	17
7	900	64	19
8	1000	59	20
9	1100	55	22

The reflectance of 36% aluminium and 64% zinc rose from 25% to 55% while transmittance increased from 11% to 22%. As wavelrngth increased from 350 nm to 1100 nm.

The reflectance of 64% aluminium and 36% zinc thin film on glass slide increased from 12% to 106% while transmittance rose from 14% to 19% as wavelength moved from 350 nm to 1100 nm.

Table 7: Reflectance and Transmittance of Al-Zn Nano Thin Film (Al-64%).

S/N	Wave (nm)	Reflectance (%)	Transmittance (%)
1	350	12	14
2	400	19	13
3	500	42	12.5
4	600	59	14
5	700	76	16
6	800	89	16.8
7	900	96	17.6
8	1000	102	18
9	1100	106	19

Table 8: Reflectance and Transmittance of Al-Zn Nano Thin Film (Al-45%).

S/N	Wave (nm)	Reflectance (%)	Transmittance (%)
1	350	63	25
2	400	67	32
3	500	75	50
4	600	81	58
5	700	86	60
6	800	88	66
7	900	90	64
8	1000	92	69
9	1100	98	56

Both reflectance and transmittance improved considerably with 45% aluminium and 55% zinc thin film on glass slide when subjected to optical analysis. This is a good sample where both properties are desirable.

Reflectance and Transmittance of Al-Zn Nano Thin Film

The reflectance of 100% aluminum thin film on glass substrate increased from 40% to 55% between a wavelength of 350 and 500 nm. This is later decreased to 25% at wavelength of 700 nm. As wavelength increased further the reflectance increased from 25% to 81% at wavelength of 1100 nm. However, the transmittance remained very low for this consideration. For the 100% zinc thin film, the reflectance is slightly lower within same wavelengths considered, transmittance is also low.

The absorbance of the thin film which is given by 1-R-T is okay for 100% aluminum, 100% zinc, and 50% aluminum and zinc within wavelength of 350 to 500 nm.

Electrical Properties of AL-Zn Nano Thin Films

The resistance of the thin films as measured by four point probe revealed low resistivities for 100% aluminum thin film with corresponding high conductivities. Conductivities of 9.283 E9/Ωm of 100% Al, 4.295 E8/ Ώm for 100% Zn, and 2.078 E 7/ Ώm for 50% Al, 50% Zn. The conductivity for 100% Al on Steel substrate got was -8.82 E12/ Ώm. The advantage of this conductivity value can be utilized to facilitate the conductivity of the doped materials for enhanced performance and improved conversion efficiency. Some earlier reporters like Amusan et al. (2010) agreed on these findings.

Surface Texture Analysis: The results obtained from Dektak Stylus Profilers for the nano thin films showed values for R_p which is the peak values an R_v the lowest values. The Surface profiler employed for the research scans with the following parameters: Stylus Radius 12.5 µm, length of scan coverage of 1000 µm, Duration of scan is 60 sec, Resolution of 0.056 µm per sample, Force of 3.0 mg, Measurement range of 6.5 µm and the profile covering hills and valleys.

The maximum peak to valley is obtained from sum of R_p and R_v. These values are contained in table 33 as illustrated by Figures 1 to 5. R_a and R_z which measures the waviness and average height between peaks and valleys. From the results contained in Tables 1 to 8, best result was got for G3 (45%Al,55%Zn) with R_z of 960 while worse result was got for S1 (100% Al on steel substrate) due to surface roughness. The values of R_z are contained in Table 7.

Surface Morphology from Scanning Electron Microscope

Figures 3 and 4 showed the image of 100% aluminum thin film on glass substrate, the image of 100% zinc thin film on glass.

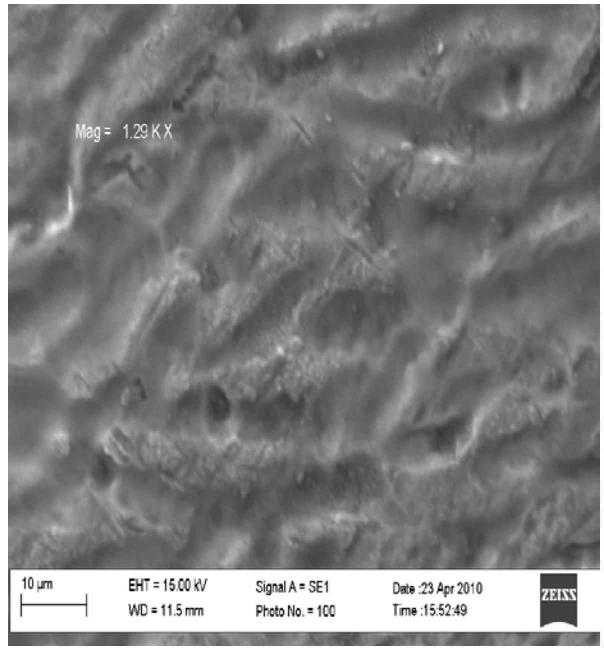

Figure 3: SEM for 100% Al Thin Film on Glass.

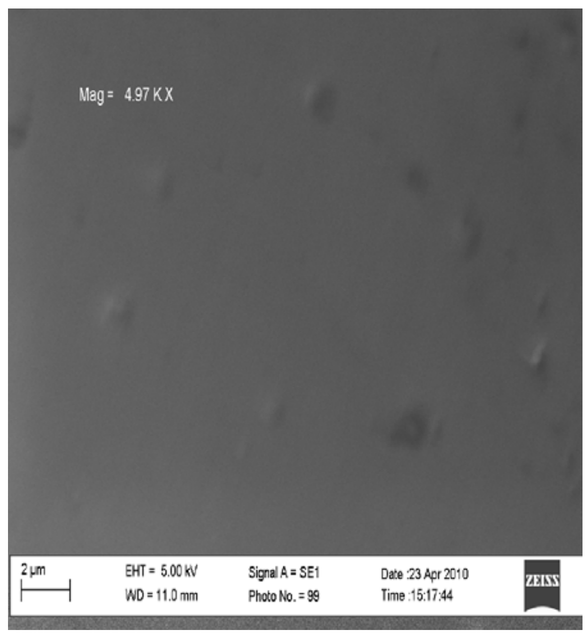

Figure 4: SEM for 100% Zn.

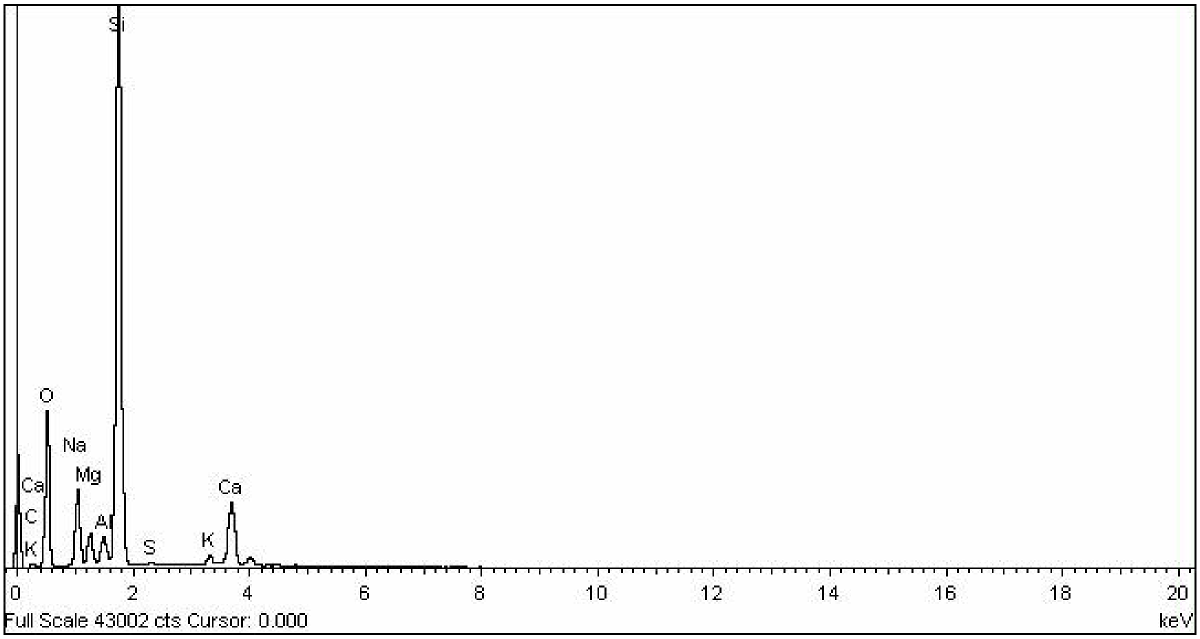

Figure 5: EDAX Plot of 100% Al Thin Film on Glass.

Energy Dispersive X ray

The principal elements in the thin film are showed by the peak of the graph (Figure 5).

CONCLUSION

The reflectance of nano thin films of aluminum and zinc produced increased with increase in wavelength.

There is specific range of length on the film which gives the uniform, uncontaminated surface film. The four point probe technique provides the resistivities at various points on thin film surface. The electrical characteristics of aluminum film can facilitate its use as do pant in some solar cell's film for better performance and enhanced conversion efficiency.

REFERENCES

1. Amusan, J.A., A.S. Olayinka, Y.P. Nwambo, S.O. Alayande, O.D. Ojuh, C.C. James, A. Ibiyemi, O.R. Adetunji, A. Fagbulu, and W.B. Ayinde. 2010. "Electrical Characterization of Vacuum Thermally Deposited Aluminium". *Thin Film Research Journal of Applied Sciences*. 5(2):96-100.

2. Bein, T. 1992. "Supramolecular Architecture; Synthetic Control in Thin Films and Solids". ACS Symposium Series 499. ACS: Washington, DC.

3. Eversole, J.D. and H.P. Broida. 1974. "Zinc Particles". *Journal of Applied Physics*.

4. Knozinger, H. 1991. *Fundamental Aspects of Heterogeneous Catalysis Studied by Particle Beams*. H.H. Brongersma and Ravansanten (eds.) Plenum: New York, NY. 7.

5. Koch, C.C. 1993. *Nanostructural Matter.*

6. Munday, J.S. and R.J. Cotton. 1990. *Chemistry and Physics of Solid Surfaces, VII ed.* Springer: New York, NY. 347.

7. Munday, J.S., R.J. Cotton, and B.B Rath. 1993. *Synthesis, Processing, and Modelling of Advanced Materials.* Brookfield: Philadelphia, PA.149.

8. Okoli, D.N., G.C. Okeke, and A.J. Ekpunobi. 2010. "Optical Properties of Chemical Bath Deposited Ag_2S Thin Films". *Pacific Journal of Science and Technology*. 11(1):411-415.

9. Yang and Luzzi. 2009. "Nanotechnology". Microsoft Encarta DVD. Microsoft Corporation: Redmond, WA.

10. Zebaze-Kana, M.G, E. Centurioni, D. Iencinella, and C. Summonte. 2006. "Influence of the Sputtering System's Vacuum Level on the

Properties of Indium Tin Oxide Films. *Elsevier Thin Solid Films*. 500:203-208.

SUGGESTED CITATION

Adetunji, O.R. and O.J. Alamu. 2012. "Optical and Electrical Properties of Vacuum Thermally Deposited Aluminum Zinc Nano Thin Films". *Pacific Journal of Science and Technology*. 13(2):64-70.

Pacific Journal of Science and Technology