Journal of the Nigerian Association of Mathematical Physics
Volume 53 **(November** *2019 Issue***), pp201 – 204**

FABRICATION OF HIGH REFLECTOR MIRROR FOR OPTICAL APPLICATION USING MgF_2 and ZnS

A.M. Bello[1], D. Dahuwa[2] and M. Buba[3]

[1] SLT Department Federal Polytechnic Bauchi, Bauchi State Nigeria
[2]Physics Department A.S.C.O.E Azare Bauchi State, Nigeria.
[3] SLT Department Federal Polytechnic Mubi, Adamawa State, Nigeria

Abstract

Recently design and fabrication of high reflector mirror using thin film materials is one of the recent technology that can be used in most of the optical industries. Hence, the strategy for creating an artificially stacked multi-layered mirror using Radio Frequency magnetron sputtering methods and deposited it on a glass substrate. In this design zinc sulphide (ZnS) target as high refractive index (n = 2.35) layer and a magnesium fluoride (MgF2) target as the low refractive index (n = 1.38) layer. Furthermore, the microstructures and optical properties of the ZnS/MgF2 multilayer films are also investigated through UV-Vis spectrometer and FESEM imaging. The fabricated filters consist of high and low refractive 10 and 10 alternating layers, which exhibit a reflectance of 100% respectively. The obtained results suggest that these mirrors could be an exceptional choice for next-generation high-reflection mirrors, and polarized interference filters using Nano technology and the materials can also be used to different types of filter. The total thickness of about 924 nm was obtained with minimum ripple

Keywords: fabrication, mirror, refractive index, multi-layer

1.0 INTRODUCTION

In optical thin film coating technology design with the same wavelength thin film can be thick or thin depending on the illumination and the detection condition, and it can only be distinguished by names and function [1]. This optical coating is used to improved transmission, reflection or polarization of an optical element at a definite angle of incident and both in S polarization (perpendicular to the plane) and P polarization (parallel to the plane), or random polarization [2].

In multilayer high reflection quarter-wave mirror edge filter design and fabrication, many methods have been used by different authors such as spray pyrolysis [3], radio frequency (R.F) magnetron sputtering method [4], sol-gel method [5].

In this present study Radio frequency (RF) magnetron sputtering is used for simulation of thin film deposition on a glass substrate. The same thickness can also be used for fabrication in an R.F magnetron sputtering and this filters characterization are done by Field Emission Scanning Electron Microscope (FESEM) and ultraviolet-visible near-infrared spectroscopy (UV-VIS) and the material used for this design were magnesium fluoride/zinc sulphide (MgF_2/ZnS) due to excellent sensitivity, hardness in nature, stability, chemically inert and high-temperature resistance. The precursor gas can be used during the fabrication process are Argon for deposition and Nitrogen for breaking the vacuum at the end process. This method of fabrication has various advantages over other methods such as uniform coating thickness, high purity film, extremely high adhesion of the film, ease of automation, and ease of sputtering any metal alloy or compound and it can be used for a wide range of inorganic materials.

Dielectric mirror

Dielectric mirror is also called a Bragg mirror and it composed of multiple thin layer dielectric materials that are mainly deposited on a glass substrate or other materials. It is possible to choose an optical coating with a targeted

Corresponding Author**:** Dahuwa D., Email: dahuwadahiru5@gmail.com, Tel: +2348141125149

reflectivity at a various wavelength of light by increases the number of layers' pairs. Moreover, it can also apply to produce ultra-high reflectivity mirror for a spectral range of a few hundred nanometres with a longer lifetime [6].

For a given wavelength, the reflectivity in the air for this stack of the layer is given by equation.

$$R = \left(\frac{1 - \left(\frac{n_H}{n_L}\right)^{2X} \left(\frac{n_H}{n_s}\right)}{1 + \left(\frac{n_H}{n_L}\right)^{2X} \left(\frac{n_H}{n_s}\right)} \right)^2 \quad (1.0)$$

Where
R = reflectivity
X = integer
n_H = high refractive index

n_L = low refractive index.

n_s = The refractive index of the substrate e.g. glass

Product Features

Thereare some features that are very essential in thin film production, for example, Anti-reflective, reflective, and transparent feature in optical coating application and Semi conductive, dielectric mirror, high reflection mirror, conductive feature in telecommunication, electronics, microelectronics, and solar cell application.

Any material used for optical coating can also produce a thin film by either physical vapour deposition or chemical vapour deposition technique. The must possess all or at least one of these requirement [7] shown below

1. Refractive index
2. Homogeneity and packing density
3. Mechanical properties such as hardness, adhesion, and magnitude
4. Chemical properties such as solubility and resistance to attack by the atmosphere and their compatibility with other materials

Deposition of thin film on Radio frequency (R.F) magnetron sputtering.

The R.F magnetron sputtering techniques for fabrication a thin film is a physical vapor deposition (PVD) used to deposit various thin film materials on a substrate from few nanometres up to several micrometres in thickness, the deposition is taking place, whenever the chamber is in vacuum condition similar to many chemical vapour deposition (CVD) methods of deposition. The pressure of the chamber is between 10^{-3} to 10^{-4} torr, oxygen, nitrogen and water vapour can remove to avoid chemical reaction when deposition is taking place and the working pressure is achieved by inserting a gas in to the chamber for example argon gas to create plasma (8,9) .Table 1shows the parameter used for deposition thin film materials whereas figure 1shows (RF) Magnetron sputtering vacuum chamber and control panel during deposition process

Table 1 Deposition parameter during R.F magnetron Sputtering process.

Deposition perimeter for radio frequency magnetron sputtering		
1	Target materials	MgF2/ZnS
2	Electrode distance	6.5cm (maximum)
3	Temperature	Unheated
4	Working gas	Argon (50sscm)
5	Breaking vacuum gas	Nitrogen
6	Substrate rotation	3.0 rev
7	Power	100watts
8	Pressure	10^{-3} to 10^{-5} torr.
9	Deposition time	8minute (480sec)

Figure 1 R. F Magnetron sputtering vacuum chamber and control panel.

Result and Discussion

MgF_2 and ZnS materials have been deposited on a glass substrate alternating based on high and low refractive index materials for twenty (20) layers. In order to obtain very high reflection mirror, this construction design stack formula has been used for different reference wavelength are Air|10(HL)|Glass to design multilayer high reflection mirror. In this fabrication the structural and optical properties using FESEM and UV-Vis spectrometer.

Deposited Sample

Figure 2 shows the photo image of a deposited thin film sample. The dark color of the sample is due to the amount of MgF_2 and ZnS layers deposited on a glass substrate. Each layer of thin film deposited on fixed-parameter. The deposition rate for $MgF_2$and ZnS about 0.068 nm/sec and 0.67 nm/sec respectively.

Figure 2 Photo image of the deposited MTF edge filter sample

Structural Analysis of Deposited MoS_2 /Si Thin Films

In Figure 2 above sample structure was analysed, the scanning photo is obtained from FESEM as shown in Figure 3.0. therefore, From the image of the sample non-uniform layer thickness of MgF2/ZnS materials are observed. The 300 x 300 pixels area are selected and analysed using Gatan software thickness of each layers was observed as showing in Table 2.0 this obtained the total thickness of about 924 nm thickness respectively.

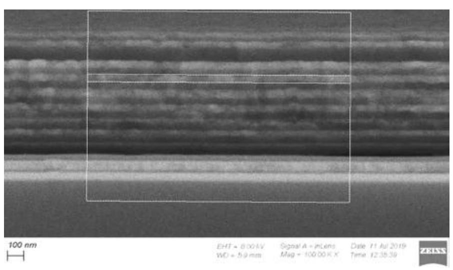

Figure 3Scanningphoto image of the sample thickness from FESEM.

Table 2Shows the Thickness of each layer from the GatanSoftware

layer number	materials	thickness (nm)
1	MgF2	59
2	ZnS	34
3	MgF2	29
4	ZnS	60
5	MgF2	45
6	ZnS	90
7	MgF2	32
8	ZnS	49
9	MgF2	50
10	ZnS	61
11	MgF2	62
12	ZnS	30
13	MgF2	45
14	ZnS	17
15	MgF2	20
16	ZnS	31
17	MgF2	40
18	ZnS	50
19	MgF2	50
20	ZnS	70

Optical Properties

The optical Reflectance of the deposited multilayer thin film sample is analyzed by the used of UV-Vis spectrometer within a 400-1000 nm wavelength range. The graph of Reflectance against wavelength (nm) is plotted in Figure 4 From the graph, it is observed reflectance increases up to 100%

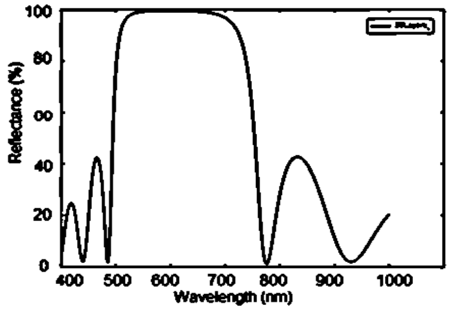

Figure 4Shows Reflectance against wavelength (nm)

Conclusion

The fabricated high reflector mirror is characterized using UV–Vis spectrometer and FESEM the optical reveals that the 100% reflectance was obtained with minimum amount of ripple respectively. The structural analysis is successfully observed using FESEM, the thickness of each alternating layers of MgF2 and ZnS are obtained. The photo image analysis using Gatan software showed that the thickness of each layers and the total thickness of about 924 nm was obtained.

REFERENCES

[1] A. Piegari and F. Flory, *Optical thin films and coatings: From materials to applications*. United kingdom: Elsevier, 2013.

[2] A. Buchberger, S. Peterka, A. M. Coclite, and A. Bergmann, "Fast Optical Humidity Sensor Based on Hydrogel Thin Film Expansion for Harsh Environment," *Sensors (Basel).*, vol. 19, no. 5, pp. 1–11, 2019.

[3] R. J. Deokate, R. S. Kalubarme, C. Park, and C. D. Lokhande, "Simple Synthesis of $NiCo_2O_4$ thin films using Spray Pyrolysis for electrochemical supercapacitor application: A Novel approach," *Electrochim. Acta*, vol. 224, pp. 378–385, Jan. 2017.

[4] D. Benetti, R.Nouar, and J.M.Macleod " Combine magnetron sputtering and pulses laser deposition of TiO2 and BFCO thin films." Sci. Rep. Vol.7 no.1, P.2503,Dec.2017.

[5] M. Kitui, M. M. Mwamburi, F. Gaitho, and C. M. Maghanga, "Optical Properties of TiO 2 Based Multilayer Thin Films : Application to Optical Filters .," *Int. J. Thin Film. Sci. Technol.*, vol. 21, no. 1, pp. 17–21, 2015.

[6] V. V Elyutin, M. A. Butt, and S. N. Khonina, "Cold mirror based on High-Low-High refractive index dielectric materials," in *3nd international conference ' 'information technology and Nanotechnology*, 2017, no. 1, pp. 5–9.

[7] M. Saliba, J.-P. Correa-Baena, M. Grätzel, A. Hagfeldt, and A. Abate, "Perovskite Solar Cells: From the Atomic Level to Film Quality and Device Performance," *Angew. Chemie Int. Ed.*, vol. 57, no. 10, pp. 2554–2569, Mar. 2018.

[8] A. R. Boyd, L. Rutledge, L. D. Randolph, and B. J. Meenan, "Strontium-substituted hydroxyapatite coatings deposited via a co-deposition sputter technique," *Mater. Sci. Eng. C*, 2015.Vol.46,PP 290 - 300

[9] G. H. Abdullah, B. R. Mhdi, and N. A.Aljaber, "Design Thin Film Narrow Band-pass Filters For Dense Wavelength Division Multiplexing," *Int. J. Adv. Appl. Sci.*, vol. 1, no. 2, p. pp 65-70, Jun. 2012.