IOSR Journal of Applied Physics (IOSRJAP)
ISSN – 2278-4861 Volume 1, Issue 4 (July-Aug. 2012), PP 01-03
www.iosrjournals.org

Promising Application of Neodymium Oxide Nano Films in Microelectronics

Arun Chandra Sarmah
Department of Physics, Digboi College P.O. Digboi- 786171, Assam, India

Abstract: *The AC conduction mechanism of vacuum deposited Neodymium Oxide (Nd_2O_3) nano films with Aluminium top and counter electrodes were investigated at temperature range 302-528 K and within the thickness range 90-175 nm. The variations of capacitance (C) with frequency (0.06-50 kHz) at different temperatures were also observed. It was found that the capacitance was frequency dependent at all temperatures but almost independent in the high frequency range beyond 1 kHz. From the variation of dielectric loss (tanδ) with frequency it was seen that tanδ values decrease rapidly with frequency and attains a minimum value. The variation of C with T at various frequencies was also studied and was found that C almost remain constant almost upto 440 K and then increases sharply with temperature. At low frequencies C increases sharply with temperature. From the tanδ versus T characteristics at different frequencies it was observed that in the temperature range upto 460 K. tanδ almost remained constant but increased sharply with T at frequencies below 1 kHz or below. A non-linear variation of $1/C^2$ with voltage did not indicate the presence of Schottky barriers. Nd_2O_3 nano films show low capacitance density 0.0021 $\mu F\ cm^{-2}$ and low dielectric loss 0.008 at 1 kHz and at 300 K. On account of stable properties, low dielectric loss and high dielectric constant the application of Nd_2O_3 nano films in electronic microcircuits will give promising result.*

Keywords: *AC conduction, activation energy, capacitance density, dielectric loss, dielectric constant*

I. Introduction

With the development of integrated thin film circuits many investigations of the dielectric films have been made. Investigators have directed their attention to thin insulating nano films of rare earth oxides owing to their excellent mechanical, thermal and chemical stability. Many researchers [1-5] had carried out research work on different properties of Neodymium oxide (Nd_2O_3) thin films at different conditions using different deposition techniques. In this paper we are going to present the ac properties of vacuum deposited Nd_2O_3 nano films of different thicknesses at different temperatures.

II. Experimental

2.1. Film preparation

The thin film Al|Nd_2O_3|Al structures were fabricated in a series of vacuum deposition using suitable masks in each case at a pressure about $2x10^{-5}$ Torr. Samarium oxide of purity 99.9% (Lieco Industries Inc, New York) were vacuum deposited over aluminium from tungsten basket at 393 K substrate temperature. The rate of deposition was varied from 0.062 to 0.133 nm s^{-1}. The oxide films were then stored in dry air for 2-3 days and then counter electrodes were deposited to complete the Al-Nd_2O_3-Al sandwiched structures. The films were then baked in air at about 373 to 473 K for 2-4 hours and then stored in dry air for a week to obtain stable properties. The sandwiched structures were then annealed at about 10^{-2} Torr pressure to a maximum of temperature 530 K in repeated heating and cooling cycles. The area of the oxide films were always much larger than the effective electrode area, so that the leakage current would be negligible. Prior to evaporation the oxide was degassed for 30 to 45 minutes under the shutter by heating the tungsten basket under low power conditions.

2.2 Area and thickness measurements

The film thickness'd' of Nd_2O_3 was determined capacitively at 1kHz, taking the dielectric constant (ϵ_r) of Nd_2O_3 as 12.64 [ref. 5]. The effective area of the Al| Nd_2O_3|Al structures were finally measured using a travelling microscope.

2.3 AC measurements

The capacitance (C) and dielectric loss factor (tan δ) were measured at different frequencies from 0.06-50 kHz and at different temperatures within 297 to 528 K and within the thickness range 90-175 nm using Marconi bridge (TF 2700). An external audio-frequency generator was employed to energize the bridge. Capacitance with the change of voltage at constant frequency was also measured.

III. Results

The vacuum deposited Nd_2O_3 when examined by the X-ray diffraction methods were found to be amorphous.

3.1 Effect of frequency

The variation of C with f (0.06-50 kHz) at various temperatures (302-528 K) of thickness 115 nm is shown in Fig. 1. It is observed that the capacitance is frequency dependent at all temperatures but almost independent in the high frequency range beyond 1 kHz.

The variation of tan δ with frequency is shown in Fig. 2. The tan δ value decreases rapidly with f and attains a minimum value.

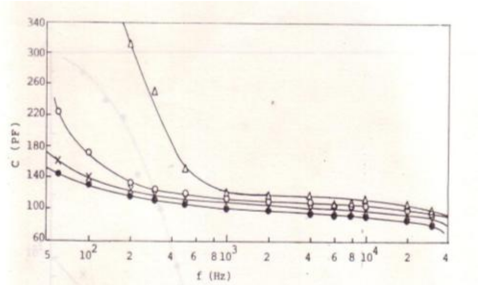

Fig.4.11. C versus f of a Nd_2O_3 film of d=115 nm at 302K(●); 473K(X); 488K(o) and 528K(Δ).

Fig. 1.

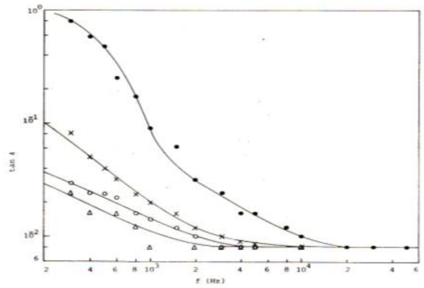

Fig.4.13. tan δ versus f of a Nd_2O_3 film of d=115 nm at 302K(Δ); 473K(o); 488K(X) and 528K(●).

Fig. 2

3.2 Effect of Temperature

The variation of C with T at different frequencies within the temperature range 302 to 528 K is shown in Fig. 3. It is seen that the C decreases first with T and then almost remain constant upto 440 K and then increases with T at different frequencies. At low frequency C increases rapidly with T. The variation of tan δ with T at different frequencies is shown in Fig. 4. In the temperature range upto about 460 K, tan δ almost remain constant but it increases sharply with T at frequencies 1 kHz or below.

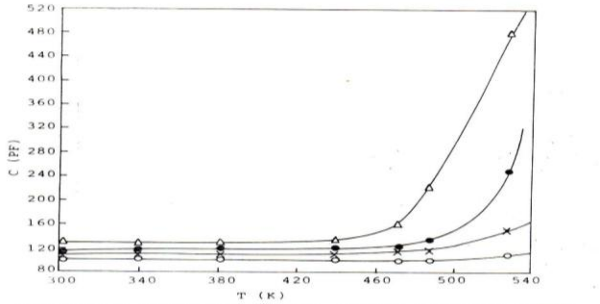

Fig.4.15. C versus T of a Nd_2O_3 film of thickness 115 nm at 0.06 kHz (Δ); 0.3kHz (●); 1kHz (X) and 10kHz(o).

Fig. 3

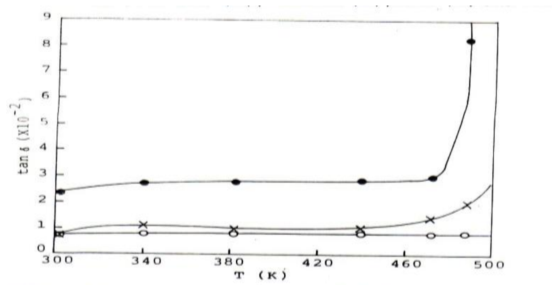

Fig.4.16. tan δ versus T of the film in figure 4.15 at 0.3kHz(●); 1kHz(X) and 10kHz(o).

Fig. 4

The temperature co-efficient of capacity (TCC) was calculated using the relation

$$TCC = \frac{1}{C_{500}} \frac{dC}{dT} \qquad 3$$

The value of TCC was found to vary from (2.5 to 3.25) $x10^{-2}K^{-1}$ for different film thicknesses at frequency 1 kHz.

3.3 Voltage effects

A non-linear variation of $1/C^2$ with voltage applied between the two electrodes is observed.

IV. Discussions

This study clearly indicates that the films prepared are amorphous in nature. The increase of both capacitance and tan δ towards the low frequency and in the high temperature region could be attributed to the effect of interfacial polarization in that region. The charge carriers existing in the dielectric film can migrate for some distance under the influence of an applied field. When such carriers are blocked at the electrodes a space-charge region results. This space-charge region leads to a substantial increase in capacitance towards low frequencies [7]. Similar observations for insulating films have been reported by earlier workers [8, 9]. The capacitance increases with temperature with a larger co-efficient could be due to the increase in film current caused by ionic motion with temperature.

The frequency dependence of tan δ suggests that the losses are caused by a conduction process and in this case the value of tan δ would decrease with the frequency according to a hyperbolical law (tan δ = 1/ωRC).

Fig. 5 show the plots of logω versus 1/T at three values of capacitance. The plots are linear and parallel. By equating the slope of logω versus 1/T plot to ϕ/R, the activation energy (ϕ) can be determined. The average ϕ values was found to be 0.73 eV. The large value of ϕ suggests that the conduction in the oxide films is ionic in nature and in this specific case the conduction could be due to the oxygen ion vacancies in the film structure.

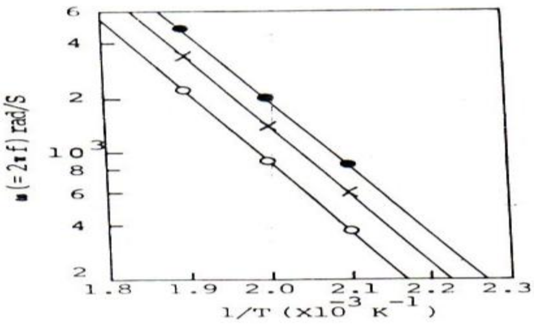

Fig. 5

Fig.4.19. Log ω versus 1/T of a Nd_2O_3 film of d = 115 nm at 128 PF (●); 140 PF(X) and 160PF(o).

The variation of tan δ with T reveals some structural defects or oxygen vacancies in the process of film formation [10]. The tan δ almost remain constant for temperature upto 440 K [Fig.4] and increases much more quickly above this temperature. This faster increase of tan δ can be assigned to the space charge polarization of thermally generated charge carriers [6].

The non-linear characteristics obtained from the plot of $1/C^2$ versus V do not indicate the presence of schottky barriers in these composites [11].

The calculated values of resistivity (ρ) at 300 K and at 1 kHz was found to be 10^7 to 10^8 ohm-meter (using the relation tan δ = 1/ωRC).

V. Conclusions

The Al-Nd_2O_3-Al MIM structures have been fabricated and characterized using AC conduction mechanism. Vacuum deposited Nd_2O_3 films were amorphous in nature. The average activation energy was found to be 0.73 eV. MIM capacitors show low capacitance densities 0.0021 μF cm^{-2} and low losses 0.008 at 1 kHz and at 300 K. The TCC at 1 kHz was found to be within (2.5 to 3.25)x10^{-2}K^{-1} at 500 K for different film thicknesses. AC properties did not alter when stored in dry air for several months. On account of stable properties, low dielectric loss and capacitance densities high dielectric constant the applications of Nd_2O_3 nano films in electronic microcircuits will give a promising result.

References

[1] D. Bloor and J.R. Dean *J. Phys. C, Solid State Phys, 5*, 1972, 1237.
[2] P. Deshmukh, P. Deshmukh and M. Chintamani, *J. Phys. C., 14*, 1981, 531.
[3] M. Langlet and F.D. Shannon, *Thin Solid Film, 186*, 1990, L1-L5
[4] H.T. Fulham and F.P. Roberts, *Proc. 8th Rare Earth Res. Conf., TA Henrie and RE Lindotron (New York : Golden and Reach, Vol-I)*, 1970
[5] V.S. Dharmadhikari and A. Goswami, *Thin Solid Films, 87*, 1982, 119
[6] H.B. Lal *J. Phys. C, 13*, 1980, 3969
[7] A. Von Hippel, E.P. Gross, F.G. Telstia and A. Geller, *Phys. Rev. 91*, 1953, 568
[8] F. Argall and A.K. Joncher, *Thin Solid Films, 2*, 1968, 185
[9] H.J. Birey, *J. Appl. Phys., 49*, 1978, 2898
[10] T. Tsutsumi, *Jpn. J. Appl. Phys., 9*, 1970, 735
[11] B. Bhushan, S.C. Kashyap and K.L. Chopra, *J. Appl. Phys. 52*, 1981, 2932