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Studying of Optoelectronic Properties for $(NiO)_x(MnO)_{1-X}$/Si Solar Cell

Asmaa Natiq Mohammed Ali

University of Baghdad, Collage of Science, Department of Physics

Abstract: ***We report the $(NiO)_x$-($MnO)_{1-X}$ thin films with different x content (0,0.1,0.2,0.3) prepared by pulse laser deposition technique at RT using Nd:YAG laser of λ=1064 nm, average frequency 6 Hz and pulse duration 15 ns .These films were deposited on Si substrate to from the $(NiO)_x$-($MnO)_{1-X}$Heterojunction for Solar Cells. The optical absorption spectra showed that all films have direct energy gap . The band gap energy of this films decreased with increasing x content. I-V measurements for heterojunctions. The short-circuit current (Isc), open circuit voltage (Voc), and fill factor(F.F) have been studied, Also from I-V measurements it is observed that The best achieved efficiency was obtained around 3.1 % at (x=0.3) and also the value efficiency for $(NiO)_x$-($MnO)_{1-X}$heterojunction increases with increasing of x content for all samples***

Keyword: $(NiO)_x$-($MnO)_{1-X}$ thin films, $(NiO)_x$-($MnO)_{1-X}$ /Si Heterojunction, optical Properties, PLD technique

1. Introduction

Manganese oxide(MnO) is an inorganic compound [1]. The compound is produced on a large scale as a component of fertilizers and food additives. It is often non stoichiometric. MnO uses include: a catalyst in the manufacture of allyl alcohol, ceramics, paints, colored glass, bleaching tallow and textile printing.[2]. Nickel oxide (NiO) is a semi-transparent, stable wide direct band-gap material (3.56eV) [3], It is the chemical compound. NiO adopts the NaCl structure, with octahedral Ni(II) and O2− sites. The conceptually simple structure is commonly known as the rock salt structure. Like many other binary metal oxides It is growing fast due to their importance in many applications such as, electro chromic device [4], solar thermal absorber, Tandem dye-sensitized solar cells (TDSSC) [5], battery cathode and gas sensors [6]. thin films which can be produced by several techniques such as: reactive evaporation, electrochemical deposition[7] molecular beam epitaxy[8]. magnetron sputtering technique, ,sol-gel technique[9], pulsed laser deposition, , chemical vapor deposition and spray pyrolysis., Among these, we will focus PLD technique to prepare $(NiO)_x$-$(MnO)_{1-X}$ /Si Heterojunction. PLD is a physical vapor deposition (PVD) technique where a high-power pulsedlaser beam is focused inside a vacuum chamber to strike a target of the material that is to be deposited[10], PLD is a simple and versatile technique that allows stoichiometry growth of a huge variety of composite materials and established method for high – quality thin film deposition and nano particles generation [11].The aim of this work is studying the effect of x content on the Optical Properties of $(NiO)_x$-($MnO)_{1-X}$ /Si Heterojunction.

2. Experimental Part

Pure Manganese oxide(MnO) and Nickel oxide (NiO) supplied with purity 99.5%, and 98% respectively, were used as start materials to prepare $(NiO)_x$-($MnO)_{1-X}$ films by pulsed laser deposition technique at different x content (0,0.1,0.2, and 0.3) using Nd:YAG laser with λ=1064 nm and puls duration 15 ns, these materials were mixed in gate mortar for one hour. After that, the mixture was pressed at 5 Ton to form a target with 2.5 cm diameter and 4 cm thickness. Finally, the targets were sintering at temperature 873K to ensure the homogeneity of the materials. $(NiO)_x$-($MnO)_{1-X}$thin films were deposited on Si substrate to prepare $(NiO)_x$-($MnO)_{1-X}$/Si heterojunction at different x content by PLD technique. The optical properties of the deposited films were measured in wavelength range (190 to1100) nm using UV-VIS spectrophotometer (Optima-3000). A solar cell under illumination characterized by short-circuit current (Isc) open circuit voltage (Voc), ,fill factor(F.F) and the power conversion efficiency ().have been studied, the value efficiency for $(NiO)_x$-($MnO)_{1-X}$/Si heterojunction increases with increasing of x content for all samples.

3. Results and Discussion

From UV-Visible near IR absorption spectrum the optical measurements for pure and doped (NiO) films with MnO deposited by pulses laser on glass substrates with different MnO content (0, 0.1, 0.2, and 0.3) wt % at RT is carried out in the wavelength range 450–1100 nm. Fig.(1) shows the transmittance of the $(NiO)_x(MnO)_{1-X}$ films deposit on glass at different x contents. In general, it can be observed that the transmittance increases with increasing of λ for all prepared samples .Also, the transmittance decreases with increasing of MnO content this is because of increasing the absorbance leads to create of localized states in the gap consequently the samples because more opaque to the incident light and caused to decrease in the T. Below 600 nm there is a sharp fall in the transmittance of the films for all films, which is due to the strong absorbance of the films in this region while the structure tends to be more transparent in the long wavelengths region.

Fig.(2) shows the absorbance spectrum as a function of wavelength for (NiO)x-(MnO)1-X thin films prepared at RT. It is clear that absorbance decreases with increasing λ for all samples. Also, it is cleared that absorbance increases with increasing of MnO content. However, the increase in absorbance can be explained as being due to the increase in reflectionand decrease in the transmission.

Fig.(3) shows that the variation of the absorption coefficient versus the wavelength at different x content of $(NiO)_x$($MnO)_{1-X}$ films. It can be noticed that α increases with increasing of x content for all samples as listed in Table(1) and this is due to create of localized states in the gap. This results is good agreement with [12].

Fig.(4) and Table(1)) Shows the Tauc curves which used to calculate the energy gap for all samples. It is revealed from the figures that the optical energy gap decreases with increasing x content .When x content increases from 0 to 0.3 the energy gap decreases from (3.5 to 1.8)eV. This is may be attributed to fact the addition of NiO to the MnO made the material more opaque (more absorbance)[13].

The refractive index for $(NiO)_x$-($MnO)_{1-X}$ films has been calculated from the equation [14]:

$$n = (4R/(R-1)^2-K)^{1/2}-(R+1/R-1)\ldots\ldots\ldots\ldots(1)$$

where n is refractive index andR is the reflectance.

The value of refractive index increases with increasing of x content is shown in Fig(5). the value of refractive index increases with increasing of x content from(2.02-2.4) at RT. which means decreasing of the reflection where the refractive index depends on it.

Fig.(6) shows the variation of extinction coefficient (k) as a function of wavelength at different x content. The values of extinction coefficient are determined by using equation [15]:k = αλ/4π. The extinction coefficient increases from 4.25 to 9.51 with increasing of from 0 to 0.3 at RT due to more grain boundaries with addition of NiO to MnO and decreased the energy gap as a result to increasing the absorption as shown in Fig(6)and Table (1), The plots of real and imaginary (ε_r and ε_i) parts of the dielectric constant with wavelength in the range of 190–1100nm for $(NiO)_x$-($MnO)_{1-X}$ thin films are shown in figure (7). It is observed that ε_r and ε_i increased with increasing of x content This behavior is in agreement with Elabd [16].

Figure 8 and 9 show the I-V characteristics of the $(NiO)_x$($MnO)_{1-X}$ /Si Hetrojunctions were measured under dark and illumination with power density 1000 w/cm2 at different x content(0,0.1,0.2,0.3).

From the first region of the figure 8 where the value of the voltage between (1-3)V which is given approximated by an expression of the type I~ exp(q V/β kBT), where β is the ideality factor . It can be observed that the value of β decreases from 2 to 1.84when x content increases from 0 to 0.1 ,while β increases at x=0.2 equal to 2.4. but then value of β decreases from 2.4 to 1.2 when x content increases from 0.2to 0.3. The value of β>1 may be attributed to the recombination of electrons and holes in the depletion region and also to the increased effect of the applied voltage[17]. Also, we can notice from figure (9) two regions: a linear region at low illumination intensities, and a tendency for a saturation region at high illumination intensities. This figure show that the short circuit current (Isc) and open circuit voltage (Voc) were determined by the intersect of photocurrent curve with x and y axis. Also, maximum voltage and current for solar cell were found; full factor (F.F)and efficiencyη).Table(2)represents the I-V parameters for $(NiO)_x$-$(MnO)_{1-X}$ /Si solar cell with different x content. it can be observed that the efficiency have the values (1.33,2,2.6, and3.1) with increasing of x content (x=0,01,0,2.and0.3) % respectively, The best x content found to be (x=0.3) which gives the high value of efficiency (η= 3.1%).

Table 1: Optical properties parameters of $(NiO)_x$-($MnO)_{1-X}$ films at different x content and RT

Ta(K)	X content	Eg(eV)	$10^4{}_*\alpha$ (cm)-1	n	k	εr	εi
RT	pure	3.5	8.9	2.02	4.25	4.08	0.000172
	0.1	2.7	10.14	1.95	4.84	3.8	0.000189
	0.2	2.4	13.91	2.13	6.64	4.57	0.000284
	0.3	1.8	16.97	2.4	9.51	5.76	0.000456

Table 2: I-V parameters for$(NiO)_x(MnO)_{1-X}$/Sihetrojunctions at different x content.

	X content	I_{sc} (mA)	V_{oc} (V)	I_m (mA)	V_m(v)	F.F	η%	β
$(NiO)_x$-$(MnO)_{1-X}$ /Si	0	0.22	7	4	0.1	2.66	1.33	2
	0.1	0.3	10	6	0.1	0.2	2	1.84
	0.2	0.21	9	4	0.2	0.529	2.6	2.4
	0.3	0.25	8	5	0.23	0.64	3.1	1.2

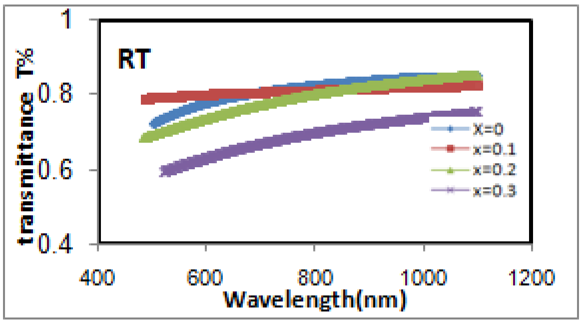


Figure 1: Transmittance spectrum as a function of wavelength for $(NiO)_x$-($MnO)_{1-X}$films at RT and different x content

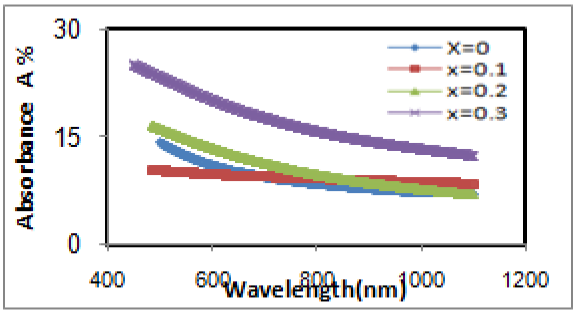


Figure 2: Absorbance as a function of wavelength for$(NiO)_x$-($MnO)_{1-X}$films at RT and different x content

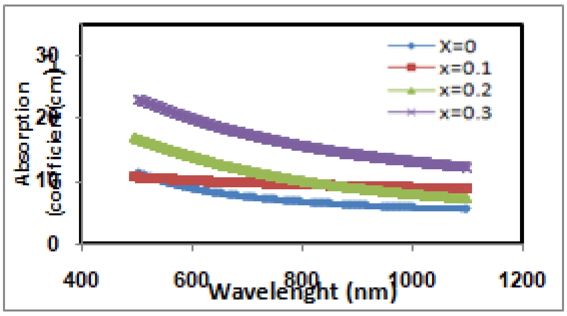


Figure 3: Absorption coefficient as a function of wavelength for $(NiO)_x$-$(MnO)_{1-x}$films at RT and different x content

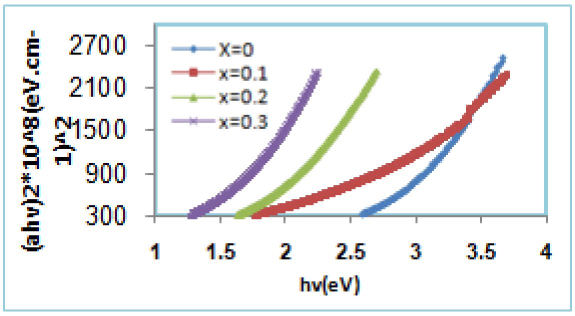


Figure 4: Optical energy gap as a function of hν for $(NiO)_x$-$(MnO)_{1-x}$ films at RT and different x content.

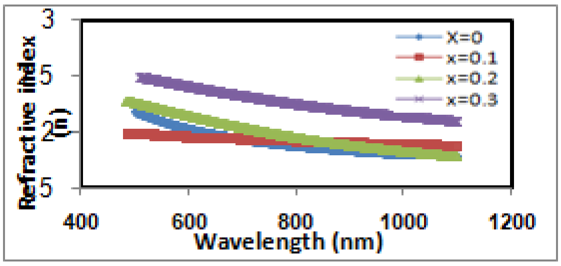


Figure 5: Refractive index as a function of wavelength for $(NiO)_x$-$(MnO)_{1-x}$films at RT and different x content

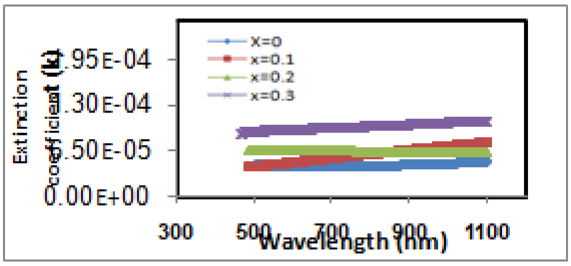
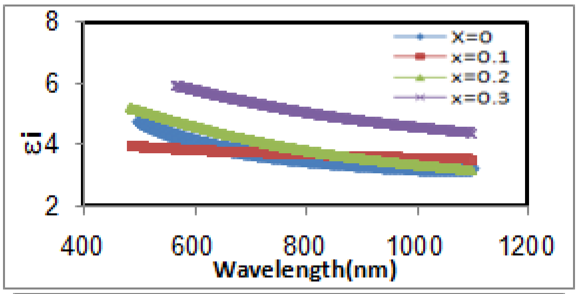


Figure 6: extinction coefficient as a function of wavelength for $(NiO)_x$-$(MnO)_{1-x}$films at RT and different x content.



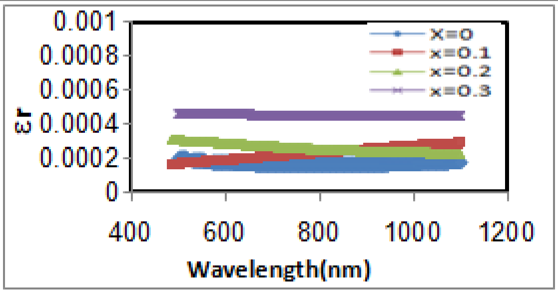


Figure 7: Real part of dielectric constant as a function of wavelength for $(NiO)_x$-$(MnO)_{1-x}$ films at different x content at RT..

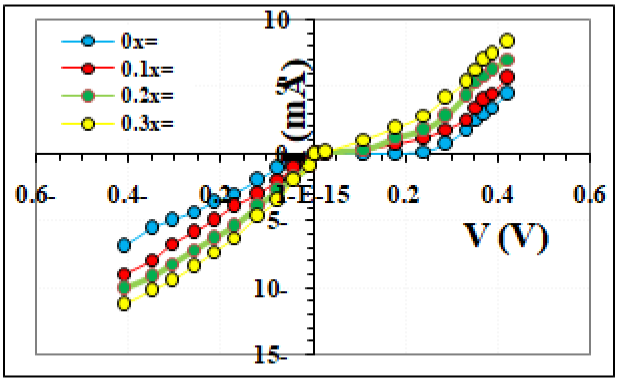


Figure 8: I-V characteristics under dark for $(NiO)_x$-$(MnO)_{1-x}$ /SiHeterojunction at forward and reverse bias voltage at different x content

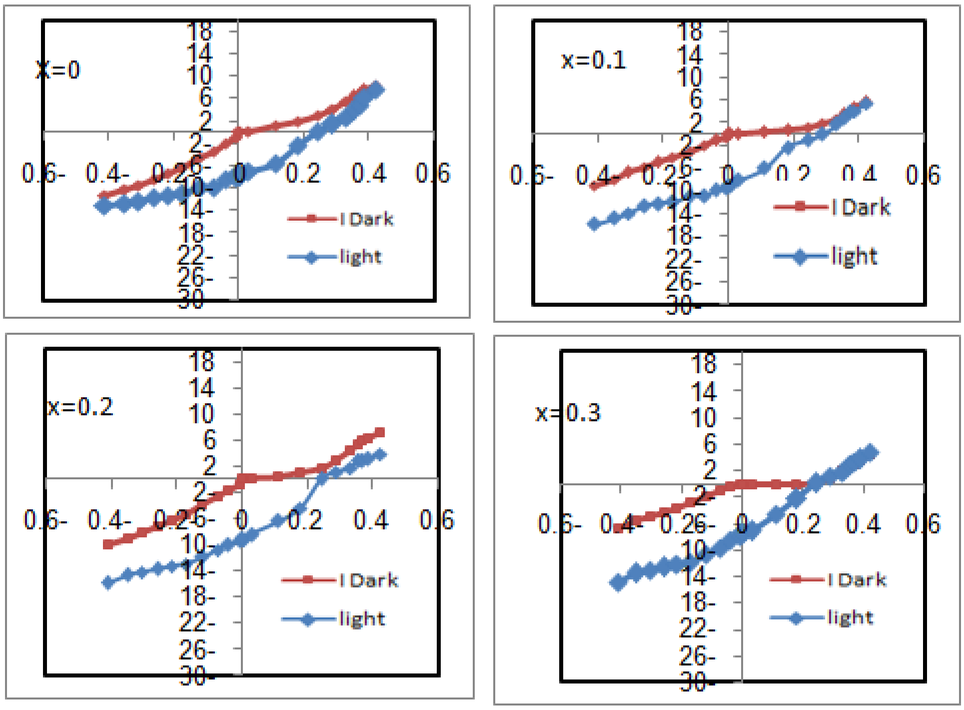


Figure 9: Dark and light I-V characteristics for $(NiO)_x$-$(MnO)_{1-x}$ /Sihetrojunctions at different x content (0, 0.1, 0.2, and 0.3)

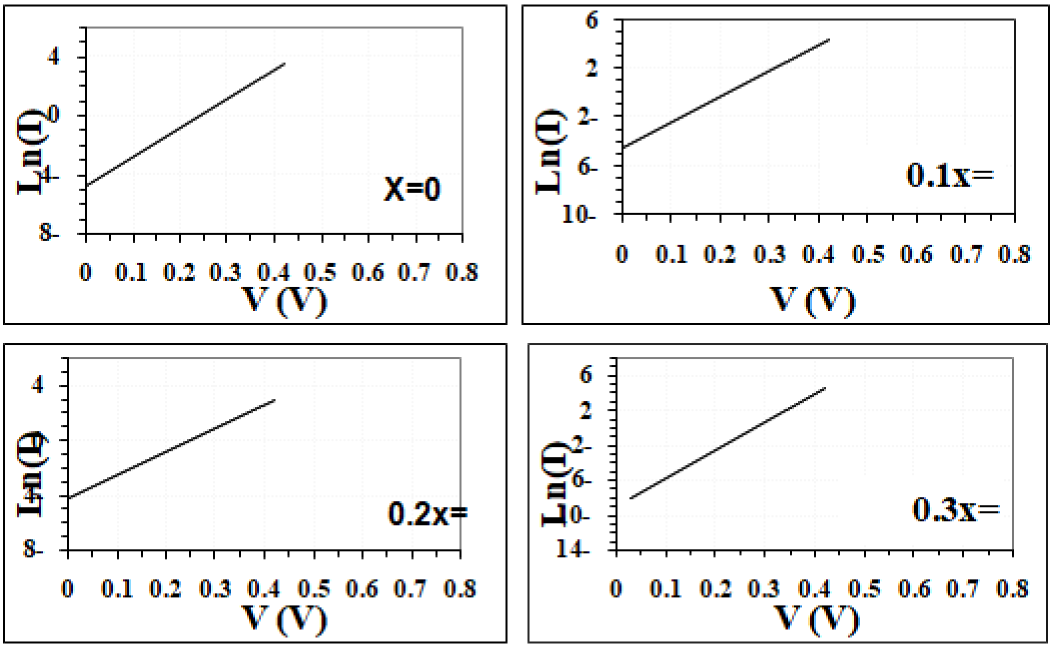


Figure 10: Variation of ln(I) with V at dark for $(NiO)_x$-$(MnO)_{1-x}$ /Sihetrojunctions at different x content (0, 0.1, 0.2, and 0. 3)

4. Conclusions

In conclusion, $(NiO)_x$-($MnO)_{1-x}$ thin films have been deposited on glass substrate by pulse laser deposition technique with different x content (0,0.1,0.2,0.3) at RT. In this study, the effect of x content on the Optical Properties of$(NiO)_x$-$(MnO)_{1-x}$/Si.Heterojunction were investigated . I-V Measurements were investigated. The results show that the optical transitions in (NiO)x-$(MnO)_{1-x}$ film is direct transition and the value of optical energy gap decreases with increasing of x content..The optical constants increases with increasing of x content. The maximum efficiency was obtained around 3.1 % at (x=0.3) . The dark current increases with increasing of x content for all samples. Under illumination, the photocurrent increases with increasing of x content for all samples.

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