International Letters of Chemistry, Physics and Astronomy *Online: 2015-03-25*
ISSN: 2299-3843, Vol. 48, pp 138-145
doi:10.18052/www.scipress.com/ILCPA.48.138
CC BY 4.0. Published by SciPress Ltd, Switzerland, 2015

Effect of Cu-doping on Urbach Energy and Dispersion Parameters of Cu:NiO Film deposited by CSP

Mohammed Odda Dawood*

Al_Mustansiriyah University, College of Science, Physics Department, Baghdad, Iraq

*E-mail address: mohammedodda619@yahoo.com

ABSTRACT

This work presents the effect of Cu-doping on Urbach energy and dispersion parameters of Cu:NiO thin film prepared by spray pyrolysis technique. UV-Visible spectrophotometer in the range 380-900 nm used to determine the absorbance spectra for various Cu-doping of Cu:NiO thin film. The absorbance and optical conductivity increased with increasing Cu-doping in the prepared films. Dispersion parameters that studied are decreased with increasing Cu-doping while Urbach energy increased.

Keywords: Dispersion Relation; NiO Thin Films; Urbach Enerygy

1. INTRODUCTION

The traditional TCO thin films such as Sn-doped In_2O_3, Al-doped ZnO, and Sb-doped SnO_2 have been widely studied. However, these traditional TCO often shows n-type conductivity and there is lack of p-type TCO thin film. NiO is a p-type TCO with an energy gap of 3.15 to 4.0eV[1].The optical constants (refractive index n and extinction coefficient k) and the film thickness are important parameters that affect the performance of an optical film in an optical system[2] and the optical simulation results are strongly dependent on the optical constants of the films [3]. NiO films are suitable for magnetores istance sensors, chemical sensors [4-5], electrochromic devices [6] and transparent p-type semi conducting layer, smart windows [7] and dye-sensitized photo cathodes [8-10].

Thin film of nickel oxide can be produced by different methods such as evaporation, sputter deposition, sol gel, electrochemical and chemical techniques [11-17].All the NiO thin film prepared methods offer different advantages depending on the application of interest and many efforts have been conducted to obtain films with the desirable physical and/or chemical properties [18].

In the present work, the influence of the Cu-doped on the Urbach energy and dispersion parameters of NiO films deposited by chemical spray pyrolysis is considered.

2. EXPERIMENTAL DETAILS

Nickel nitrite $Ni(NO2)_2$ was used as a source of NiO , for the doping agent $Cu(CH_3COO)_4$ was adopeted to prepare CuO in the percentage of 2% and 4%. These chemicals dissolved in 100 ml of re- distilled water to form an aqueous solution which was used to maintain the desired films on a microscopic glass slides the optimum parameters of the preparation conditions were arrived at the following :substrate temperature 400 ^{O}C ,spraying rate 4ml /min, substrate to nozzle was 30±1 cm, time period for spraying was 8 s , time interval waiting was 2min between, and filtered air as carrier gas was maintained at a pressure of 10^5 Pascal.

Film thickness was measured by gravimetric and was found to be 350 ± 20 nm. The Films were annealed at (450 ,500)ºCrespectiely . then optical transmittance was recorded in the wavelength range (380-900)nm by a Double beam UV-Visible spectrophotometer (Shimadzu Company Japan) .

3. RESULTS AND DISCUSSION

Absorbance spectra that recorded by using UV-Visible spectrophotometer in the range 380-900 nm are determined in Fig.1 of Cu:NiO thin film. From this figure, it can notice the increases of absorbance with increasing Cu additive in the Cu:NiO thin films. This behavior can be attributed to the formation of secondary levels in the band structure. While the reflectance that shown in Fig. 2 take other behavior depend on wavelength.

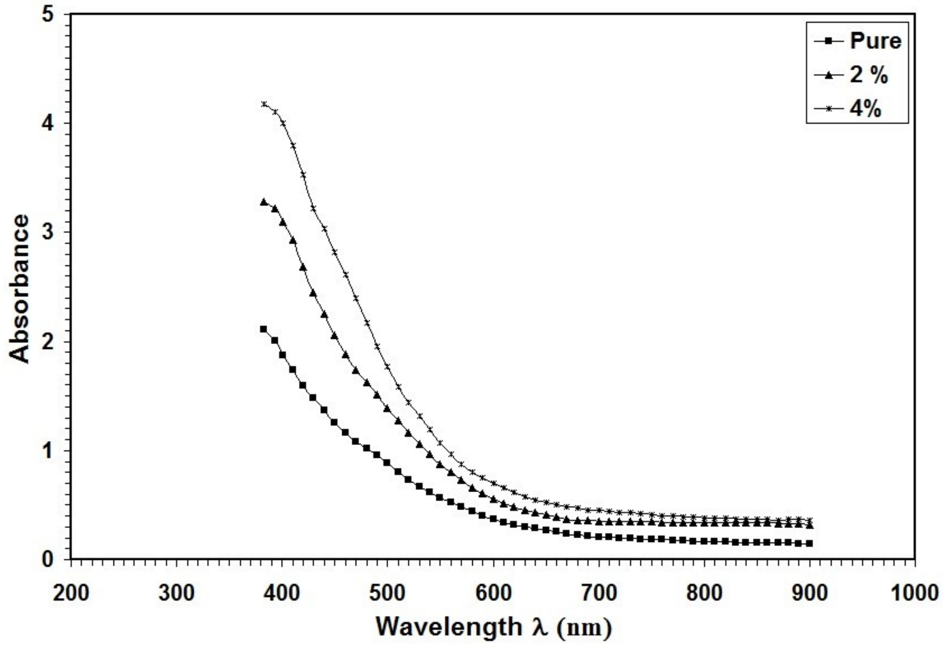

Fig. 1. Plot of absorbance spectra vs wavelength of Cu:NiO thin film.

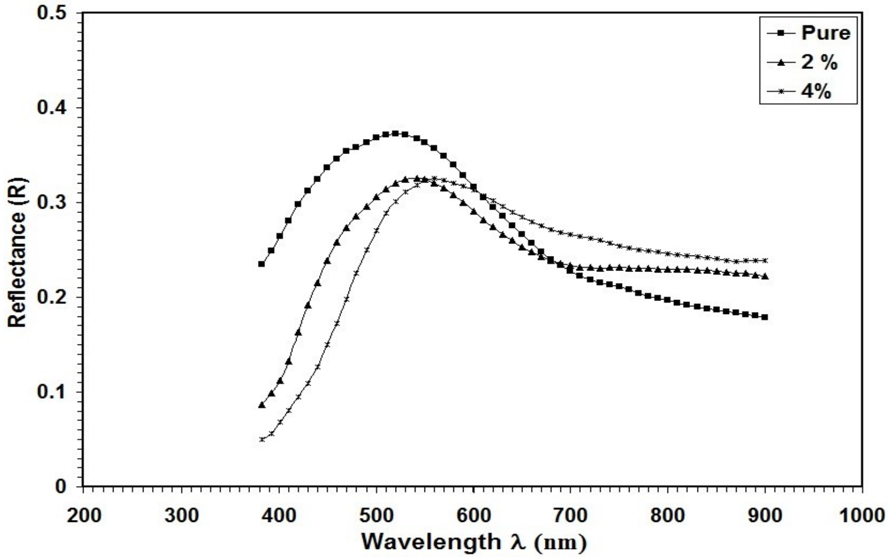

Fig. 2. Plot of reflectance spectra vs wavelength of Cu:NiO thin film.

Real (ε_1) and imaginary (ε_2) dielectric constants are determined from the following relations [19]:

$$\varepsilon_1 = n^2 - k^2 \tag{1}$$

$$\varepsilon_2 = 2nk \tag{2}$$

Where n is the refractive index and k is the extinction coefficient. Figs.3-4 shows the behavior of real and imaginary dielectric constant with wavelength. From these figures it can notice that the dielectric constant increases with increasing Cu additive in Cu:NiO thin films at wavelength greater than 500 nm.

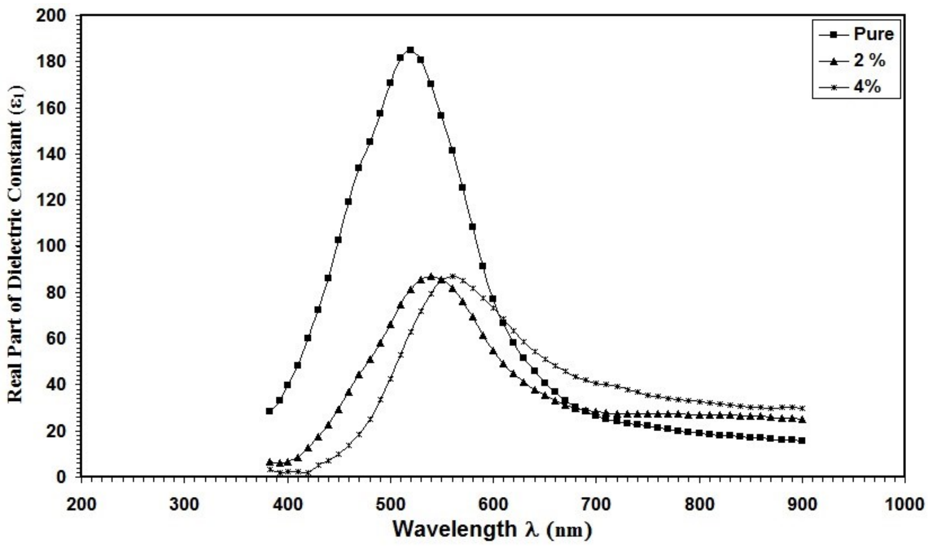

Fig. 3. Plot of real part of dielectric constant vs wavelength of Cu:NiO thin film.

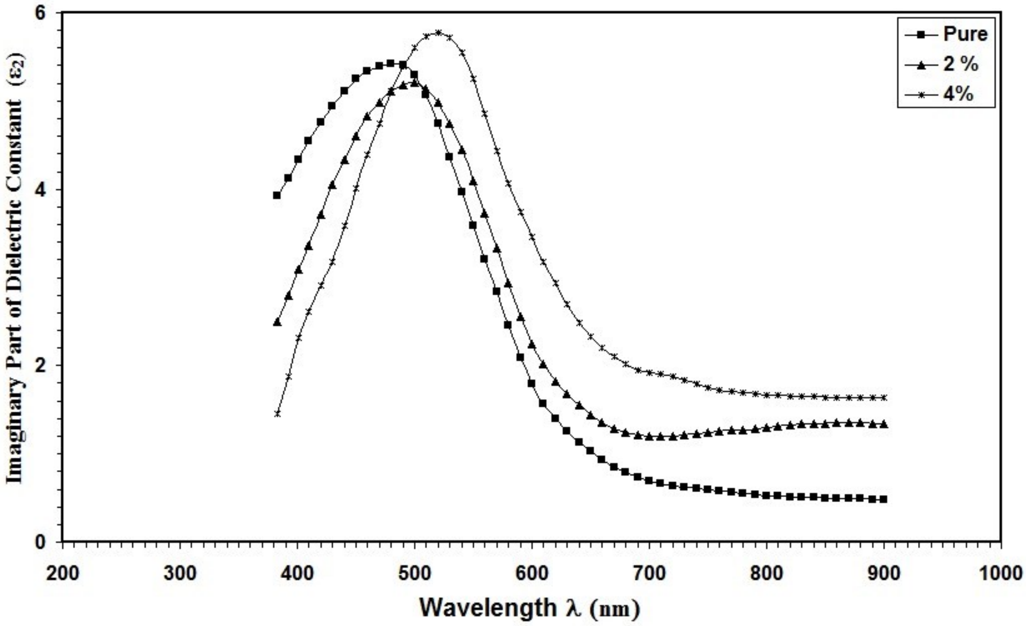

Fig. 4. Plot of imaginary part of dielectric constant vs wavelength of Cu:NiO thin film.

Optical conductivity behavior is represented in Fig.5. From this figure, it can notice that the optical conductivity increases with increasing Cu additive in Cu:NiO thin films at wavelength greater than 500 nm.

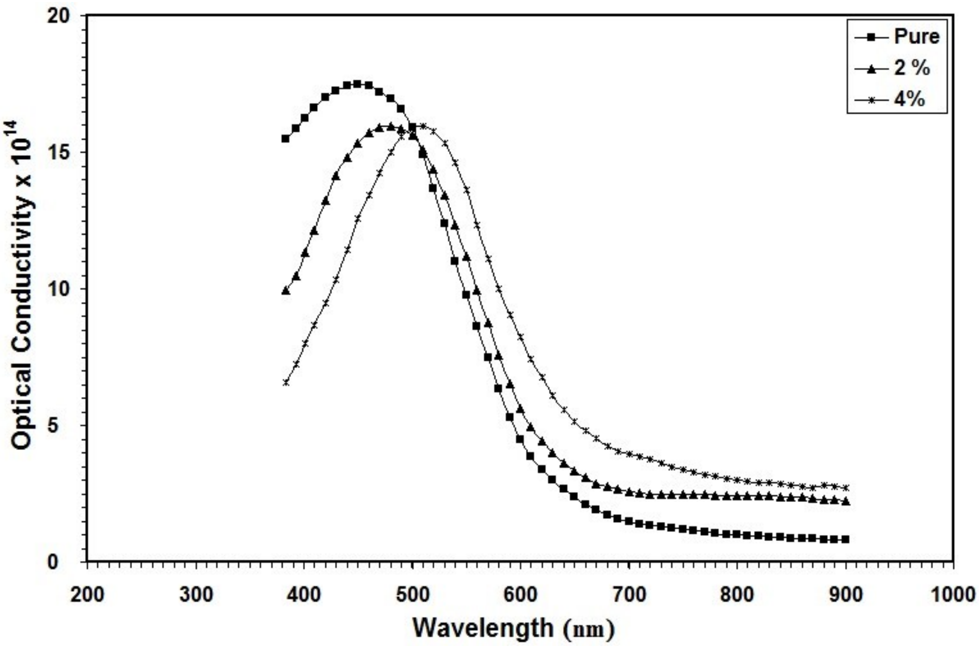

Fig. 5. Plot of optical conductivity vs wavelength of Cu:NiO thin film.

The observed exponential sub-band gap absorption tails in experimentally measured optical spectra were explained using the Urbach–Martienssen rule[20-21]with the following mathematical formulation:

$$\alpha = \alpha_o(\frac{E_o}{E_U}) \tag{3}$$

The parameter E_o corresponds to the energy of the lowest free excited state at zero lattice temperature, while E_u is the Urbach energy. This parameter determines the steepness of the Urbach tail.

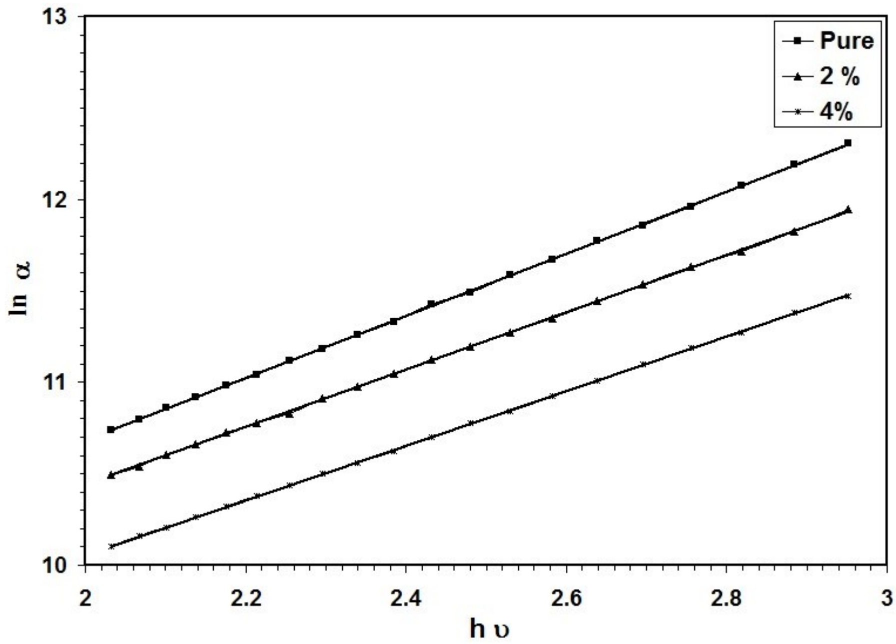

Fig. 6. Plot of lnα vs hυ of Cu:NiO thin film.

Plotting $(n^2-1)^{-1}$vs. $(h\upsilon)^2$ allows us to determine the oscillator parameters. E_o and E_d values were calculated from the slope and intercept on the vertical axis of $(n^2-1)^{-1}$vs. $(h\upsilon)^2$ plot, as shown in Fig.

The refractive index n_∞ at infinite wavelength can be determined by the following relation [22]:

$$\frac{n_\infty^2 - 1}{n^2 - 1} = 1 - (\frac{\lambda_o}{\lambda})^2 \tag{4}$$

The plot of $(n^2-1)^{-1}$ vs. λ^{-2} was plotted to obtainn1n_∞value of Cu-doped NiO thin films. The intersection with $(n^2-1)^{-1}$ axis is $(n_\infty^2-1)^{-1}$andhence, n_∞^2 at λ_o equal to ε_∞ (high-frequency dielectric constant).

The S_o and λ_o values were obtained from the slope of $1/S_o$ and intercept of $(S_o\lambda_o^2)^{-1}$of the curves plotted.

The M_{-1} and M_{-3} moments of the optical spectra can be obtained from the following relations [23]:

$$E_o^2 = \frac{M_{-1}}{M_{-3}} \tag{5}$$

$$E_d^2 = \frac{M_{-1}^3}{M_{-3}} \tag{6}$$

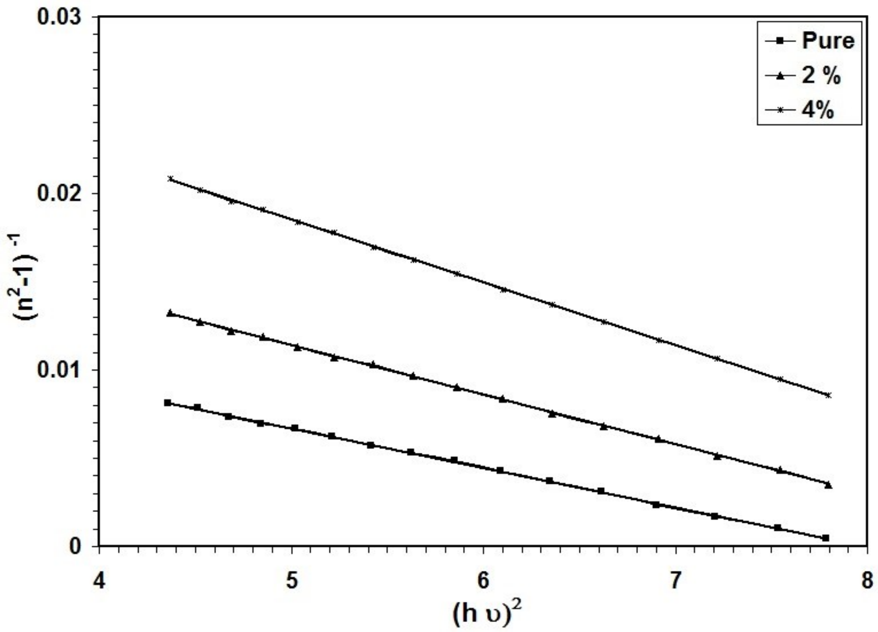

Fig. 7. Plot of $(n^2\text{-}1)^{-1}$ vs $(h\upsilon)^2$ of Cu:NiO thin film.

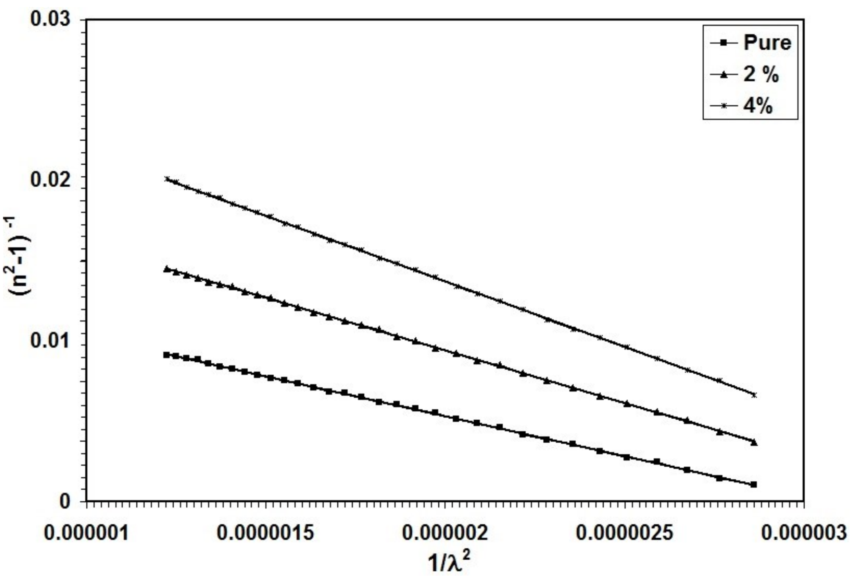

Fig. 8. Plot of $(n^2\text{-}1)^{-1}$ vs $1/\lambda^2$ of Cu:NiO thin film.

Table 1. The optical parameters of Cu:NiO thin films.

Sample	E_d (eV)	E_o (eV)	E_g (eV)	ε_∞	n(0)	M_{-1}	M_{-3} eV^{-2}	S_o $x10^{13}$ m^{-2}	λ_o νμ	U_E meV
Pure	51.8	6.20	3.100	9.30	3.05	8.30	0.215	7.64	361	584
2%	34.0	6.12	3.060	6.55	2.56	5.55	0.148	5.53	347	641
4%	26.4	5.81	2.905	5.54	2.35	4.54	0.134	4.69	326	671

4. CONCLUSION

The effect of Cu-doping on Urbach energy and dispersion parameters of Cu:NiO thin film is studied. The absorbance and optical conductivity increased with increasing Cu-doping in the prepared films. Dispersion parameters such as E_d, E_o, E_∞, n(0), M_{-1}, M_{-3}, S_o, and λ_o are decreased with increasing Cu-doping while Urbach energy increased.

References

[1] H. Sato, T. Minami, S. Takata, T. Yamada, "Transparent conducting p-type NiO thin-films prepared by magnetron sputtering", Thin Solid Films236 (1993) 27–31.

[2] A. M. El-Naggar, Opt. Laser Technol. 33 (2001) 237.

[3] X.S. Miao, T.C. Chong, Y.M. Huang, et al., Jpn. *J. Appl. Phys*. 38 (1999) 1638.

[4] U.S. Joshia, R. Takahashia, Y. Matsumotoa, H. Koinuma, Thin Solid Films 486(2005) 214-217.

[5] H. Sato, T. Minami, S. Tanaka, T. Yamada, Thin Solid Films 236 (1993) 27.

[6] S.H. Lin, F.R. Chen, J.J. Kai, Appl. Surf. Sci. 254 (2008) 3357.

[7] Z. Zhu, N. Wei, H. Liu, Z. He, Adv. Powder Technol., doi:10.1016/j.apt. (2010).06.008.

[8] X. Chen, Z. Zhang, C. Shi, X. Li, Mater. Lett. 62 (2008) 346–351.

[9] X. Ni, Q. Zhao, F. Zhou, H. Zheng, J. Cheng, B. Li, *J. Cryst. Growth* 289 (2006) 299–302.

[10] K.T. Kim, G.-H. Kim, J.-C. Woo, C. Kim, Surf. Coat. Technol. 202 (2008)5650–5653.

[11] D. Mutschall, S.A. Berger, and E. Obermeier, Proc. of 6thinternational meeting on chemical sensors, Gaithersburg, 28(1996).

[12] J.S. Svensson and C.G.Granqvist, Solar Energy Materials 16(1987)19.

[13] A. E Jiménez-González, J.G. Cambray, and A.A.Gutiérrez., Surface Engineering. 16(2000)77.

[14] A. E. Jiménez-González and J.G. Cambray, SurfaceEngineering. 16(2000)73.

[15] W. Brückner, R. Kaltofen, J. Thomas, M. Hecker, M.Uhlemann, S. Oswald, D. Elefant, and C. M. Schneider, *Journal of Applied Physics*. 94(2003)4853.

[16] L. Berkat, L. Cattin, A. Reguig, M. Regragui and J.C.BernedeMater. *Chem. and Phys.* 89(2005)11.

[17] J. I. Pankove, Optical processes in semiconductors, Prentice-Hall, New York (1971).

[18] S. A. Mahmoud, ShereenAlshomer, Mou'ad A. Tarawnh, "Structural and Optical Dispersion Characterisation of Sprayed Nickel Oxide Thin Films*", Journal of Modern Physics2* (2011) 1178-1186.

[19] J. Tauc, Amorphous and Liquid Semiconductors, London (1974).

[20] F. Moser, F. Urbach, Phys. Rev. 102 (1956) 1519.

[21] W. Martienssen, *J. Phys. Chem. Solids* 2 (1957) 257.

[22] A. K. Wolaton, T.S. Moss, Proc. Roy. Soc. 81 (1963) 5091.

[23] S. H. Wemple, M. DiDomenico, Phys. Rev. Lett. 23 (1969) 1156.

(Received 01 March 2015; accepted 19 March 2015)