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Relationship of refractive index with optical energy gap and average energy gap for II-VI and III-V group of semiconductors

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Abstract

Refractive index (n) of II-VI and III-V groups of semiconductors have been calculated using Optical energy gap (E_g) and average energy gap $(E_g)_{avg}$ data. On the basis of best fit data, new relations have been proposed for the calculations of refractive index. The calculated values of refractive index from the new relations have been compared with the values reported by different researchers, an excellent agreement has been obtained between them.

Keywords: Refractive index, optical energy gap, average energy gap, II-VI and III-V groups of binary semiconductors.

INTRODUCTION:

Refractive index of II-VI and III-V groups of semiconductors have been important parameter to study these semiconductors. This is because of their potential applications in a variety of Opto-electronic devices such as non-linear optics, light emitting diodes, photo-voltaic cells, photo-detectors, lasers, modulators, Integrated circuits and filters. Different researchers [1-5] have discussed various structural properties such as optical electronic and elastic of these semiconductors. Recently, Anani et al[6] have also proposed an equation describing relationship between refractive index and optical energy gap. But this equation cannot work properly for high and low values of refractive index[10].In the present paper on the basis of linear plots new relationship between refractive index and optical energy gap have been proposed. Many researchers [7-8] i.e., Readdy, Herve have also attempted to obtained relation between n and E_g. In this paper we developed linear relationship between refractive index ,optical energy gap, average energy gap.

The refractive index (n) is also an important fundamental property of tetrahedral semiconductors, and it is related to the local field inside the material [9]. Moss [10-11] proposed a general relationships between refractive index and optical energy gap, based on the concept that, in dielectric theory energy levels are scaled by a factor

$(\in_\infty)^2$ *or* n^4, *i.e.*

$$n^4 E_g = 95 \quad (1)$$

Ravindra et al. [12-13] have assumed that the difference between UV resonant energy (Penn Gap) or average energy gap and optical energy gap is constant. Using this concept they proposed the following relationship for refractive index given as

$$n = 4.084 - 0.62 E_g \quad (2)$$

Recently, Anani et al. [6] have also proposed a similar equation, given as

$$E_g = (17 - 5n)\, eV$$

or

$$n = 3.4 - 0.2\ Eg \quad (3)$$

It is clear from equations (2) and (3) that these equations are limited by the values of refractive index i.e. n = 4.084, and 3.4 respectively. These equations can not work properly for high and low values of refractive index[10]

Reddy et. al [9] have proposed the following equation for refractive index

$$n = -\ln \{0.102\ \Delta\ \chi^*\} \quad (4)$$

The co-rrelation between optical energy gap and electronegativity has been obtained by Duffy [14-15] in various binary systems, and is given as

$$\Delta\chi^* = 0.2688\ E_g \quad (5)$$

Using equations (4) and (5), n can be formulated as

$$n = -\ln \{0.027\ E_g\} \quad (6)$$

Many researchers [7-8] have also attempted to obtain relationship between n and E_g. But they failed to give realistic results and satisfactory explanation, except Moss10] and Ravindra et al. [12-13] upto some approximation. Therefore we have attempted to obtain equation for refractive index. For this purpose, first we have plotted n versus E_g, in figure 1for II-VI and III-V semiconductors. It is observed from the figure that semiconductors having common cation lie in the same straight line. We obtained four linear plots for Zn–, Cd–, Al–, and Ga–, series. On the basis of these linear plots the relationship between refractive index and optical energy gap can be approximated by the following equation.

$$n = K_1 - K_2 E_g \qquad (7)$$

where K_1 (dimensionless) and K_2 $(eV)^{-1}$ are constants for a particular common cation series of semiconductors. The numerical values of K_1 = 3.913, 3.294, 3.988, 4.082; and K_2 = 0.542, 0.453, 0.478, 0.523, respectively, for Zn–, Cd–, Al–, Ga– series. We have also studied the relationship between refractive index and average energy gap. For this purpose we have plotted n versus $(E_g)_{av}$ in figure2. We have observed from the figure 2that the trend in the plots is same as observed in figure1. But in this case we obtained five common cation series for which plots can be considered as linear. On the basis of these linear plots the relationship between n and $(Eg)_{av}$ can be approximated by the following equation.

$$n = K_3 - K_4 (E_g)_{av}$$

where K_2 (dimensionless) and K_{21} $(eV)^{-1}$ constants for a particular common cation series of binary semiconductors. The numerical values of K_3 = 3.171, 3.744, 4.008, 6.015, 7.051; and K_4 = 0.102, 0.195, 0.188, 0.533, 0.806, respectively, for Zn–, Cd–, Al–, Ga–, In- series.

RESULTS AND DISCUSSION:

The present paper reports different co-rrelations between n, E_g and($E_g)_{avg}$ for II-VI and III-V groups of binary semiconductor. The values of refractive index of these semiconductors have been calculated using equations (7). These calculated values of refractive index for both II-VI and III-V semiconductors, and reported in table1, together with the experimental values [9-10], the values given by Reddy et al, and Moss. It is observed from the comparison that our calculated values of n using equations (7) and (8) are in excellent agreement within 1.16% and 1.03%, respectively, with the experimental values. On the other hand n values given by Moss, and Reddy et al. deviate by 9.28% and 11.57% respectively, from the experimental values. Therefore our equations (7) and (8) are the improvement over the work of Moss and Reddy et al. But when we compared between equations (7) and (8), equation (8) founds suitable to calculate n for binary semiconductors belonging to II-VI and III-V group, because it is applicable for a number of semiconductors, and also gives realistic results.

CONCLUSION:

The Refractive index which is a fundamental property of semiconductors ,Moss[10-11] proposed a power relationship between n and E_g, Ravindra et al[12-13] proposed a relation for n and E_g, Ananie et al [6] ,but the values calculated by above researchers can not work properly for high and low values of n. The linear relationship developed in this paper in equations(7-8)are simple and useful ,the results of these calculated values work for all range of n. The knowledge of n not listed in the experimental values but calculated by proposed relation may be of great use in

potential application regarding opto-electronic properties binary semiconductors, which may be of great use in today semiconductors devices such as lasers, modulators, light-emitting diodes and integrated circuits.

Table 1: The values of refractive index (n), optical energy gap (E_g) and average energy gap $(E_g)_{av}$ of binary semiconductors

S. No.	**Compound II-VI**	***n***					$(E_g)_{av}$	E_g
		Exp. [9]	**Reddy [9]**	**Moss [10]**	**Cal. Eq. (7)**	**Cal. Eq. (8)**	**Kumar [17]**	**Expt. [9,16]**
1	ZnO	1.92	2.291	2.25	1.906	1.918	12.26	3.70
2	ZnS	2.27	2.335	2.28	-	2.315	8.37	-
3	ZnSe	2.43	2.651	2.46	2.449	2.387	7.67	2.58
4	ZnTe	2.70	2.784	2.54	2.665	2.618	6.91	2.26
5	CdS	2.38	2.724	2.51	2.208	2.376	7.00	2.40
6	CdSe	2.49	3.068	2.73	2.480	2.499	6.37	1.80
7	CdTe	2.70	3.234	2.85	-	2.626	5.72	1.44
	Compound III-V							
8	BN	2.10	2.073	2.13	-	-	10.85	-
9	AlN	2.16	2.264	2.23	2.171	2.161	9.79	3.8
10	AlP	2.75	2.501	2.37	-	-	5.88	-
11	AlAs	3.00	2.829	2.57	2.960	2.993	5.38	2.16
12	AlSb	3.19	3.129	2.78	3.223	3.195	4.31	1.60
13	GaN	2.40	2.421	2.33	2.382	-	9.13	3.25
14	GaP	2.90	2.793	2.55	2.910	2.924	5.79	-
15	GaAs	3.30	3.299	2.90	3.350	3.260	5.16	1.40
16	GaSb	3.79	3.810	3.29	3.658	3.805	4.14	0.81
17	InP	3.10	3.360	2.94	-	3.143	4.85	-
18	InAs	3.50	4.621	4.03	-	3.433	4.49	-
19	InSb	3.95	5.314	4.79		3.973	3.82	-

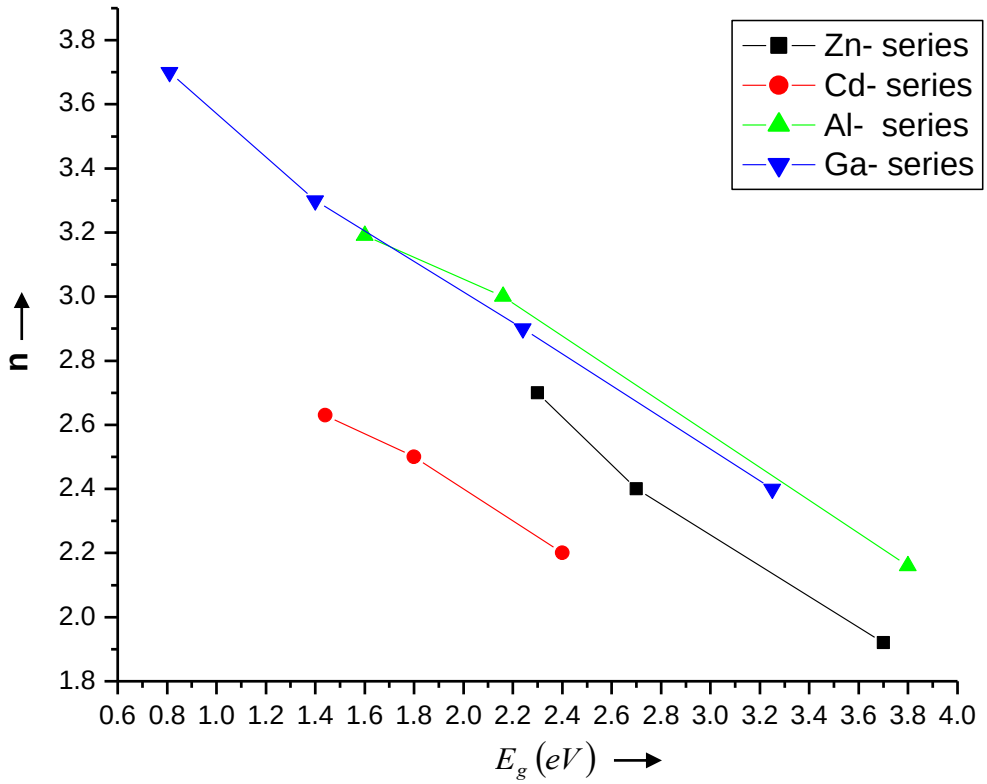

Figure 1

n = Refractive index
E_g = Optical energy gap

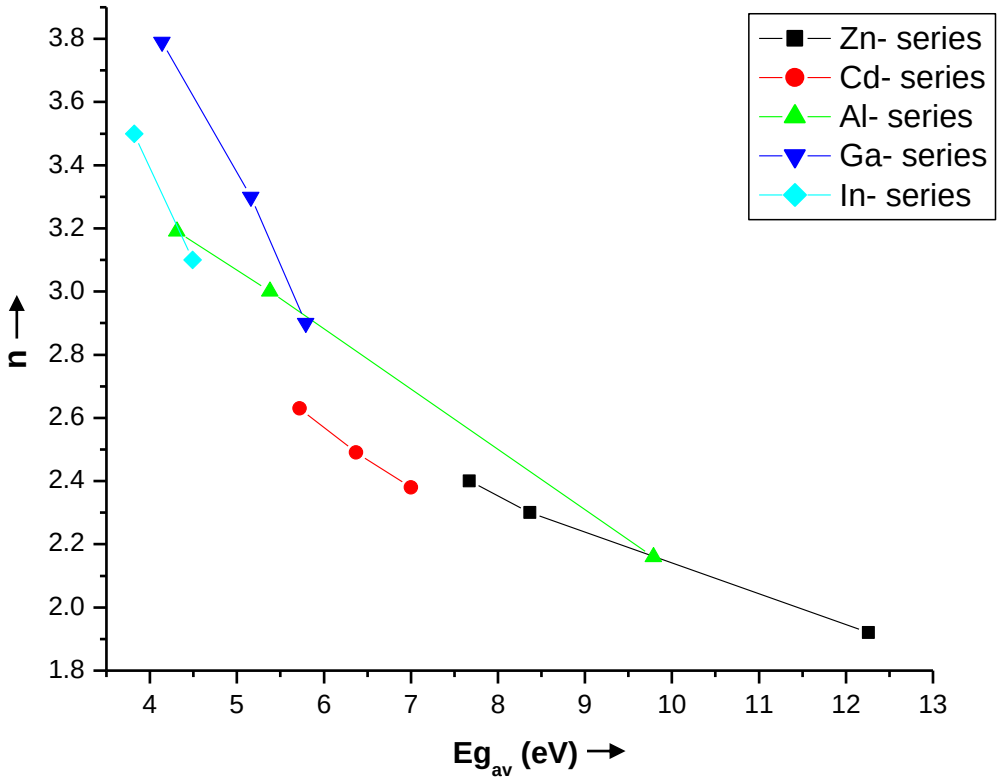

Figure 2

n = Refractive index
$E_{g,\,av}$ = Overage energy gap

REFERENCE

[1] N.M. Ravindra Suhil Auluck and V.K. Srivastava, Phys. Stat. Sol **(b) 93**, K155 (1979).

[2] R.R. Reddy, Y.N. Ahammed, P.A. Azeem, K.R. Gopal, B.S. Devi and T.V.R. Rao, Indian J. Phys, **77A**, 237 (2003).

[3] L. Pauling, The Nature of the Chemical bond, 3rd ed. Cornell University Press, Ithaca (1960).

[4] R.R Reddy, Y.N. Ahammed, K.R. Gopal, P.A. Azeem, T.V.R. Roa, and P.M. Reddy, Opt. Mater **14**, 355 (2000).

[5] R.R. Reddy, K.R. Gopal, K. Narasimhulu, L.S.S. Reddy, K.R. Kumar, C.V.K. Reddy, and S.N. Ahmed, Opt. Mater in press (2008).

[6] M. Anani, C. Mathieu, S. Lebid, Y. Amar, Z. Chama and H. Abid, Comput. Mater. Sci **41**, 570 (2008).

[7] R.R. Reddy, Y.N. Ahammed, K.R. Gopal, P.A. Azeem and T.V.R. Rao, Indian Journal of Pure and Applied Physics **40**, 471 (2002).

[8] P.J.L. Herve, L.K.J. Vandamme, Infrared Phys. **35**, 609 (1994).

[9] R.R. Reddy, Y.N. Ahammed, K.R. Gopal, D.V. Raghuram, Optical Materials **10**, 95 (1998).

[10] T.S. Moss, Phys. Stat. Sol. **(b) 131**, 415 (1985).

[11] T.S. Moss, Proc. Phys. Soc. B 63, 167 (1950).

[12] N.M. Ravindra, S. Anuch, V.K. Srivastava, Phys. Status Solid, (b) 93, K115 (1979).

[13] V.P. Gupta, N.M. Ravindra, Phys. Status Solid, (b) 100, 715 (1980).

[14] J.A. Duffy, J. Phys. **C13**, 2979 (1980)

[15] J.A. Duffy, Bonding energy levels and bands in inorganic solids, Longman, Edinberg, New York (1990).

[16] J.A. Duffy, J. Phys. **C13**, 2979 (1980)

[17] J.A. Duffy, Bonding energy levels and bands in inorganic solids, Longman, Edinberg, New York (1990).

[18] V. Kumar, G.M. Prasad and D. Chandra, J. Phys. Chem. Solids **58**, 463 (1997).