**International Archive of Applied Sciences and Technology**
Int. Arch. App. Sci. Technol; Vol 8 [4] December 2017: 19-27
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www.soeagra.com/iaast.html

IAAST
ONLINE ISSN 2277- 1565
PRINT ISSN 0976 - 4828

CODEN: IAASCA ORIGINAL ARTICLE

DOI: .10.15515/iaast.0976-4828.8.4.1927

# Study of optical behavior of $Cd_{1-x}Zn_xSe$ thin films by using lattice parameters prepared by vacuum evaporation technique

**Sarita[1]and Rajesh Kumar[2]**
[1]Department of Physics, Govt. (P.G.) College, Hisar, [2] Deptt. of Basic Engg., COAE&T, CCS HAU, Hisar
Email:[1]mrs.saritasaroha@rediffmail.com,[2]er.rajduhannit@gmail.com

**ABSTRACT**

*Semiconducting ternary system is a class of tailored and engineered materials in which lattice parameter and other foundational parameters could be continuously varied by selecting binary constituents and their relative compositions. The electronic and optical properties of ternary semiconductor materials of group II-VI have been extensively studied due to their important luminescent properties and quantum size effect. A ternary system of $Cd_{1-x}Zn_xSe$ compound of ZnSe and CdSe can be engineered better for application purpose by suitably choosing the compositional parameters. Thin films of $Cd_{1-x}Zn_xSe$ with variable composition ($0 \le x \le 1$) have been deposited onto highly clean glass substrates by vacuum evaporation technique. The optical characterization of as-deposited films had been done by using Hitachi Spectrophotometer model U-3400 at room temperature. The transmission spectra were used to determine the refractive index (n), thickness and extinction coefficient of $Cd_{1-x}Zn_xSe$ thin films. The refractive index (n) of the films is decreasing and extinction coefficient (k) is increasing with wavelength for all the samples. The real part of dielectric constant (ε') and the imaginary part of dielectric constant (ε'') are also studied. The thickness of films of $Cd_{1-x}Zn_xSe$ with different composition of x is (x = 0.0, 0.2, 0.4,0.6, 0.8, 1.0) found to be 632 nm, 1781 nm, 2506 nm, 1497 nm, 670 nm and 416 nm respectively.*

**Key Words:** *Optical properties, Ternary semiconductors, Vacuum evaporation.*

**Received 21.09.2017** **Revised 16.10.2017** **Accepted 30.10.2017**

**Citation of this article**
Sarita and Rajesh Kumar . Study of optical behavior of $Cd_{1-x}Zn_xSe$ thin films by using lattice parameters prepared by vacuum evaporation technique. Int. Arch. App. Sci. Technol; Vol 8 [4] December 2017 : 19-27.

## INTRODUCTION

Thin films are essential for multitude of production areas, such as thermal barrier coatings and wear protections, enhancing service life of tools and to protect materials against thermal and atmospheric influences [1,2].Ternary system of cadmium and zinc selenides ($Cd_{1-x}Zn_xSe$) is attracting a great deal of attention due to their fundamental, experimental and applied interest in thin film devices. The technological interest in polycrystalline based devices is mainly caused by their very low production costs. Although (CdZn)Se materials have been synthesized by many researchers [3,5-7], there are very few reports in the literature on the effect of annealing of (CdZn)Se thin films. It is important to study the effect of annealing on the physical properties of (CdZn)Se thin films. Thin films of (CdZnSe) can be obtained by chemical bath deposition (CBD) [3,4,6], vacuum evaporation [7-9], molecular beam epitaxy [10], electron beam pumping [11] etc. Among these techniques, thermal vacuum evaporation is simpler and more cost effective than the other methods for large area deposition.$Cd_{1-x}Zn_xSe$ thin films with a variable composition ($0 \le x \le 1$) has been developed onto highly cleaned non conducting glass substrates by thermal vacuum evaporation technique. The objective is to study optical behavior by transmission spectra. J.C. Manifacier et.al (1976) is used to calculate the optical constants of thin film material by using transmission spectra (envelope method) as given by [12]. The study of both the refractive index as well the extinction coefficient of the films is done [13]. The losses are also studied with increasing k and wavelength [14].The thickness of the films is also calculated with the help of transmission spectra.

## EXPERIMENTAL

The as-deposited thin films of $Cd_{1-x}Zn_xSe$ alloy at different composition (x= 0, 0.2, 0.4, 0.6, 0.8, 1) have been deposited by using vacuum evaporation technique (Vacuum Coating Unit Model 12A4).The fine powder of different $Cd_{1-x}Zn_xSe$ ($0 \leq x \leq 1$) compositions have been used as a starting material for deposition. The limiting compositions (x=0 and x= 1.0) are the case of binary CdSe and ZnSe compounds as the composition at x=0 and x=1 gives CdSe and ZnSe binary system respectively and used directly for evaporation. Thin films of these compositions of $Cd_{1-x}Zn_xSe$ alloy have been deposited onto highly cleaned non conducting glass substrates by using vacuum evaporation technique. The substrate was cleaned in aqua-regia, washed in distilled water, acetone and isopropyl alcohol (IPA). The optical study of transmission spectra has been done by “Hitachi Spectrophotometer” model U-3400 at room temperature in the range of 400-850 nm. The measurement of the transmission *T* of light through a parallel-faced dielectric film in the region of transparency is done to determine the real and imaginary parts of the complex refractive index $\eta = n - ik$, as well as the thickness *t.* If we assume that the film is weakly absorbing and substrate is completely transparent, then using Manifacier envelope method the refractive index (n) and extinction coefficient (k) of the film on a transparent substrate can be evaluated from the transmission spectra.

$$n = [N + (N^2 - n_0^2 n_1^2)^{1/2}]^{1/2} \qquad \text{…………….(1)}$$

Where

$$N = \frac{n_0^2 + n_1^2}{2} + 2n_0 n_1 \frac{T_{max} - T_{min}}{T \quad T} \qquad \text{……………………………(2)}$$

$$P = \frac{C_1[1 - (T_{max}/T_{min})^{1/2}]}{C_2[1 + (T_{max}/T_{min})^{1/2}]}$$

Where C1= $(n+n_0)(n_1+n)$, C2=$(n-n_0)(n_1-n)$

$$k = (-\lambda/4\pi t)\ln P \qquad \text{…………….(3)}$$

Equation (1) shows that *n* is explicitly determined from $T_{max}$, $T_{min}$, $n_1$ and $n_0$ at the same wavelength. From equation (2) we can find α. The thickness *t* of the layer can be calculated from using equation (4).

$$t = \frac{M\lambda_1\lambda_2}{2(n(\lambda_1)\lambda_2 - n(\lambda_2)\lambda_1)} \qquad \text{…………….(4)}$$

Where *M* is the number of oscillations between the two extrema ( M = 1 between two consecutive maxima or minima) , λ1, $n(\lambda_1)$ and $\lambda_2$, $n(\lambda_2)$ are the corresponding wavelengths and indices of refraction. Knowing *t* and α , extinction coefficient k can be calculated from equation (3). Complex dielectric constant is given by

$$\varepsilon^* = \varepsilon' - i\,\varepsilon'' \qquad \text{…………….(5)}$$

The relation between complex dielectric constant and complex refraction index is given by

$$\varepsilon^*(\lambda) = n^2(\lambda)$$

or

$$\varepsilon^*(\lambda) = (n-ik)^2 \qquad \text{…………….(6)}$$

$$\varepsilon' - i\varepsilon'' = n^2 - k^2 - 2ink$$

Equating real and imaginary parts, we get

$$\varepsilon' = n^2 - k^2 \qquad \text{…………….(7)}$$

And $\varepsilon'' = 2nk$ …………….(8)

## RESULTS AND DISCUSSION

The transmission spectra of vacuum evaporated $Cd_{1-x}Zn_xSe$ thin films are shown in figure 4.5. It can be seen from transmission spectra that all films have good transparency of about 60% in the visible region. It can be seen that the numbers of peaks are increasing in the film. Transmission spectra of these films are used to determine the optical constant 'n' & 'k'. The thickness of films of $Cd_{1-x}Zn_xSe$ with different composition of x is (x = 0.0, 0.2, 0.4,0.6, 0.8, 1.0) comes out 632 nm, 1781 nm, 2506 nm, 1497 nm, 670 nm and 416 nm respectively. Plots of n and k versus λ for vacuum evaporated of $Cd_{1-x}Zn_xSe$ films are shown figure 4.6 (a), (b), (c), (d), (e) and (f). From these graphs it is clear that refractive index (n) of the films is decreasing and extinction coefficient (k) is increasing with wavelength for all the samples. In all samples as we move from the absorption edge towards the longer wavelength transitions involving donor level, acceptor level, traps and even intraband transition would become more pronounced. This would results in more loses which are reflected in the increased k with the increasing wavelength . The given table 4.1, 4.2, 4.3, 4.4, 4.5 and 4.6 shows the variation of refractive index (n) and Extinction coefficient (k) with wavelength for $Cd_{1-x}Zn_xSe$ thin films respectively. The variation of real part of dielectric constant (ε') and imaginary part of dielectric constant (ε'') with wavelength shows in figure 4.7 (a), (b), (c), (d), (e) and (f). From these plots it is clear that the real part of dielectric constant (ε') is increasing with wavelength and the imaginary part of dielectric constant (ε'') is decreasing with wavelength for all the composition of (x).

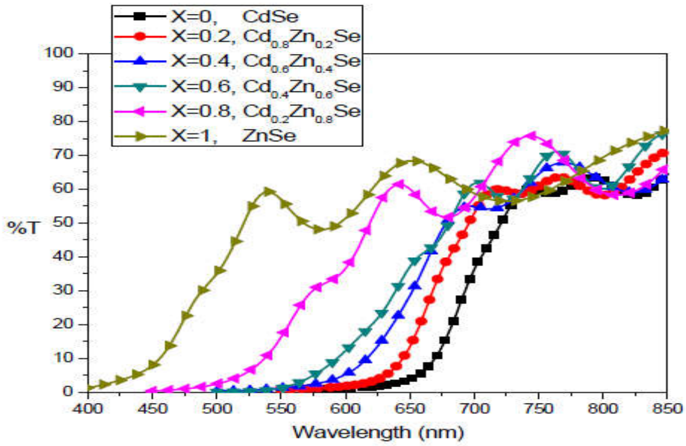

**Fig.1: Optical Transmission spectra of Vacuum Evaporated Cd1-xZnxSe representative films (x= 0.0, 0.2, 0.4, 0.6, 0.8, 1.0)**

**Table 1: Variation of Refractive Index (n) and Extinction Coefficient (k) with wavelength of Vacuum Evaporated CdSe Thin Film.**

| λ(nm) | Tmax | Tmin | N | n | k |
|---|---|---|---|---|---|
| 725 | 55.250 | 50.120 | 2.181 | 1.940 | 0.0159 |
| 750 | 63.102 | 56.540 | 2.177 | 1.938 | 0.0283 |
| 775 | 63.850 | 57.456 | 2.148 | 1.920 | 0.0302 |
| 800 | 65.236 | 59.659 | 2.055 | 1.860 | 0.0329 |
| 825 | 66.586 | 60.563 | 2.073 | 1.872 | 0.0360 |
| 850 | 68.587 | 62.456 | 2.054 | 1.860 | 0.0401 |

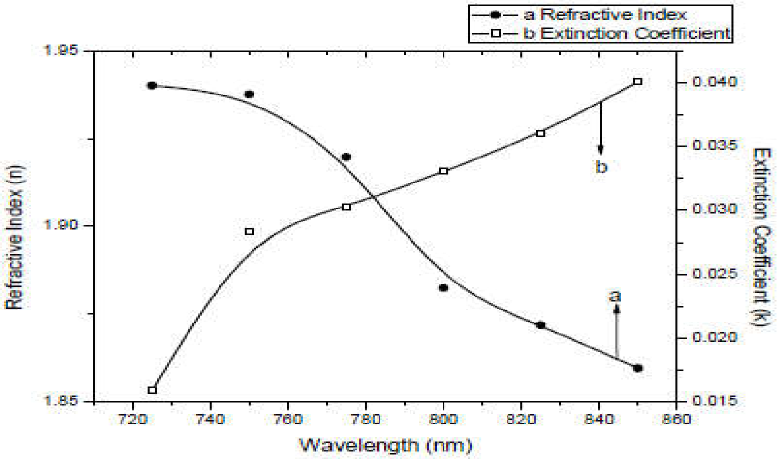

**Figure 1(a): Variation of Refractive Index (n) and Extinction Coefficient (k) with wavelength of Vacuum Evaporated CdSe Thin Film.**

**Table 2: Variation of Refractive Index (n) and Extinction coefficient (k) with wavelength of Vacuum Evaporated $Cd_{0.8}Zn_{0.2}Se$ Thin Film.**

| λ(nm) | Tmax | Tmin | N | n | k |
|---|---|---|---|---|---|
| 700 | 55.560 | 49.104 | 2.335 | 2.031 | 0.0059 |
| 725 | 62.380 | 56.210 | 2.153 | 1.923 | 0.0093 |
| 750 | 63.850 | 57.890 | 2.109 | 1.895 | 0.0103 |
| 775 | 65.110 | 59.230 | 2.082 | 1.878 | 0.0113 |
| 800 | 66.120 | 60.152 | 2.075 | 1.873 | 0.0122 |
| 825 | 68.230 | 62.360 | 2.039 | 1.849 | 0.0136 |
| 850 | 69.560 | 63.450 | 2.040 | 1.850 | 0.0147 |

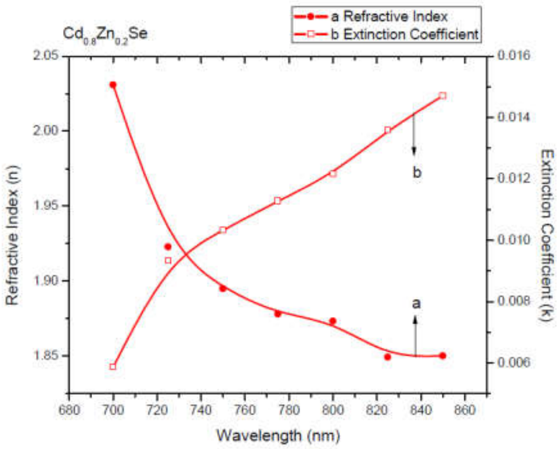

**Figure 1(b): Variation of Refractive Index (n) and Extinction Coefficient (k) with wavelength of Vacuum Evaporated $Cd_{0.8}Zn_{0.2}Se$ Thin Film**

**Table 3: Variation of Refractive index (n) and Extinction coefficient (k) with wavelength of Vacuum Evaporated $Cd_{0.6}Zn_{0.4}Se$ Thin Film**

| λ(nm) | Tmax | Tmin | N | n | k |
|---|---|---|---|---|---|
| 700 | 57.970 | 50.325 | 2.411 | 2.073 | 0.0051 |
| 725 | 63.426 | 54.410 | 2.409 | 2.072 | 0.0072 |
| 750 | 67.177 | 57.230 | 2.401 | 2.068 | 0.0087 |
| 775 | 68.882 | 58.580 | 2.391 | 2.062 | 0.0096 |
| 800 | 69.564 | 59.253 | 2.375 | 2.054 | 0.0101 |
| 825 | 70.246 | 60.230 | 2.335 | 2.031 | 0.0106 |
| 850 | 70.928 | 60.980 | 2.315 | 2.019 | 0.0112 |

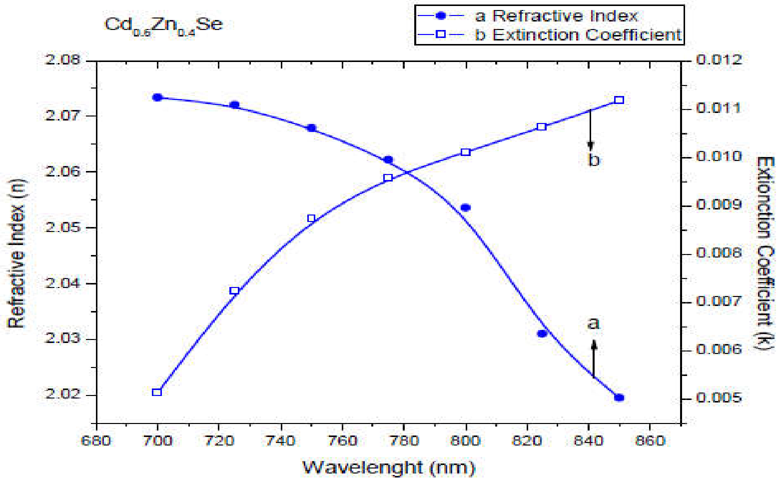

**Figure 1(c): Variation of Refractive Index (n) and Extinction Coefficient (k) with wavelength of Vacuum Evaporated $Cd_{0.6}Zn_{0.4}Se$ Thin Film.**

**Table 4: Variation of Refractive index (n) and Extinction Coefficient (k) with wavelength of Vacuum Evaporated $Cd_{0.4}Zn_{0.6}Se$ Thin Film.**

| λ(nm) | Tmax | Tmin | N | n | k |
|---|---|---|---|---|---|
| 675 | 53.878 | 44.230 | 2.840 | 2.291 | 0.0066 |
| 700 | 61.921 | 50.230 | 2.753 | 2.250 | 0.0113 |
| 725 | 68.132 | 54.369 | 2.740 | 2.243 | 0.0150 |
| 750 | 75.125 | 59.120 | 2.706 | 2.227 | 0.0189 |
| 775 | 75.423 | 60.230 | 2.628 | 2.188 | 0.0196 |
| 800 | 75.890 | 60.823 | 2.604 | 2.176 | 0.0205 |
| 825 | 76.371 | 62.012 | 2.535 | 2.140 | 0.0213 |
| 850 | 76.470 | 62.134 | 2.530 | 2.137 | 0.0220 |

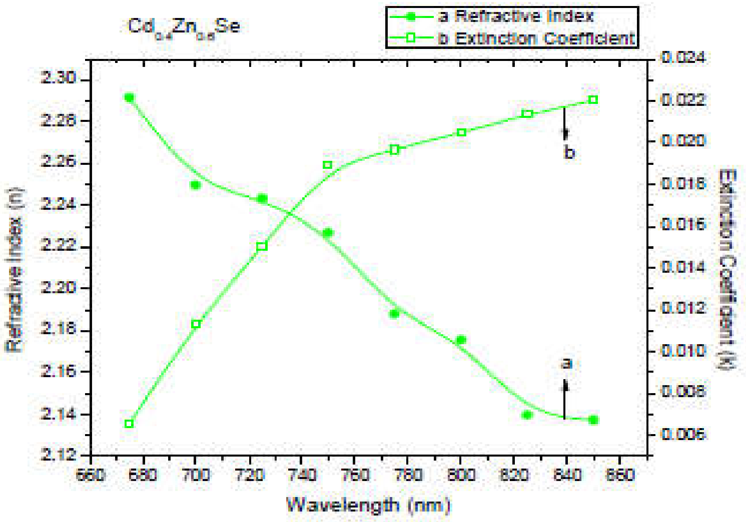

**Figure 1(d): Variation of Refractive Index (n) and Extinction Coefficient (k) with wavelength of Vacuum Evaporated $Cd_{0.4}Zn_{0.6}Se$ Thin Film.**

**Table 5: Variation of Refractive index (n) and Extinction Coefficient (k) with wavelength of Vacuum Evaporated $Cd_{0.2}Zn_{0.8}Se$ Thin Film.**

| λ(nm) | Tmax | Tmin | N | n | k |
|---|---|---|---|---|---|
| 625 | 58.652 | 42.284 | 3.605 | 2.624 | 0.0211 |
| 650 | 61.760 | 47.651 | 3.063 | 2.395 | 0.0241 |
| 675 | 66.570 | 51.400 | 2.955 | 2.345 | 0.0300 |
| 700 | 70.265 | 53.890 | 2.922 | 2.330 | 0.0350 |
| 725 | 74.702 | 57.690 | 2.809 | 2.277 | 0.0406 |
| 750 | 75.180 | 58.001 | 2.807 | 2.276 | 0.0425 |
| 775 | 75.326 | 58.065 | 2.809 | 2.277 | 0.0441 |
| 800 | 75.789 | 58.450 | 2.799 | 2.272 | 0.0460 |
| 825 | 75.992 | 58.890 | 2.771 | 2.259 | 0.0476 |
| 850 | 76.180 | 59.125 | 2.761 | 2.254 | 0.0493 |

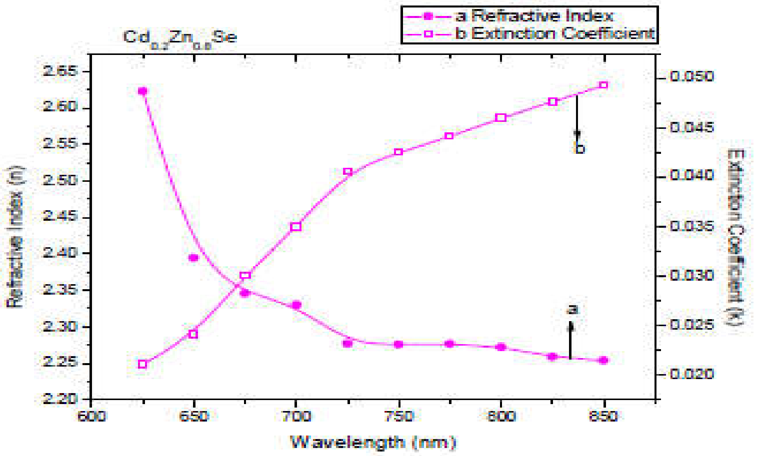

**Figure 1(e): Variation of Refractive Index (n) and Extinction Coefficient (k) with wavelength of Vacuum Evaporated $Cd_{0.2}Zn_{0.8}Se$ Thin Film.**

**Table 6: Variation of Refractive index (n) and Extinction Coefficient (k) with wavelength of Vacuum Evaporated ZnSe Thin Film.**

| λ(nm) | Tmax | Tmin | N | n | k |
|---|---|---|---|---|---|
| 525 | 54.560 | 40.920 | 3.458 | 2.564 | 0.0219 |
| 550 | 60.150 | 45.353 | 3.252 | 2.477 | 0.0311 |
| 575 | 63.767 | 48.422 | 3.116 | 2.418 | 0.0376 |
| 600 | 65.813 | 49.786 | 3.092 | 2.408 | 0.0423 |
| 625 | 66.836 | 51.150 | 3.002 | 2.367 | 0.0454 |
| 650 | 68.882 | 52.855 | 2.946 | 2.341 | 0.0503 |
| 675 | 70.246 | 54.560 | 2.853 | 2.298 | 0.0541 |
| 700 | 70.928 | 55.240 | 2.823 | 2.285 | 0.0572 |
| 725 | 72.974 | 56.265 | 2.846 | 2.294 | 0.0627 |
| 750 | 73.997 | 57.288 | 2.807 | 2.276 | 0.0665 |
| 775 | 75.020 | 57.970 | 2.801 | 2.273 | 0.0705 |
| 800 | 75.702 | 58.650 | 2.777 | 2.262 | 0.0739 |
| 825 | 76.725 | 59.330 | 2.771 | 2.259 | 0.0781 |
| 850 | 77.748 | 60.016 | 2.765 | 2.256 | 0.0823 |

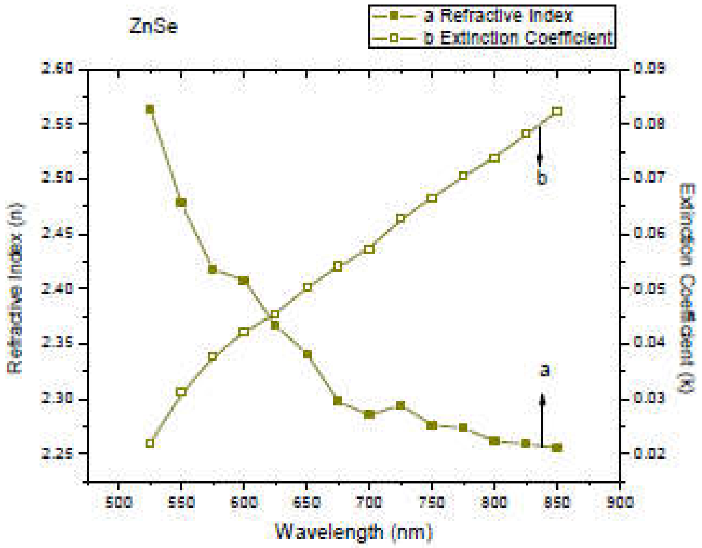

**Figure 1(f): Variation of Refractive Index (n) and Extinction Coefficient (k) with wavelength of Vacuum Evaporated ZnSe Thin Film.**

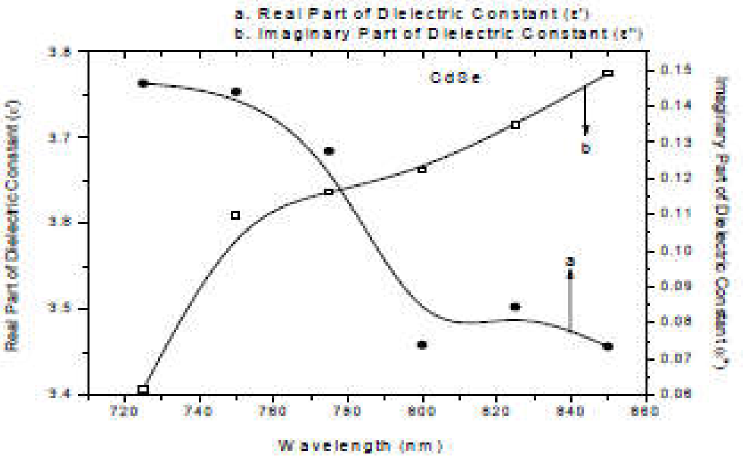

**Figure 1.1(a): Variation of Refractive Index (n) and Extinction Coefficient (k) with wavelength of Vacuum Evaporated CdSe Thin Film.**

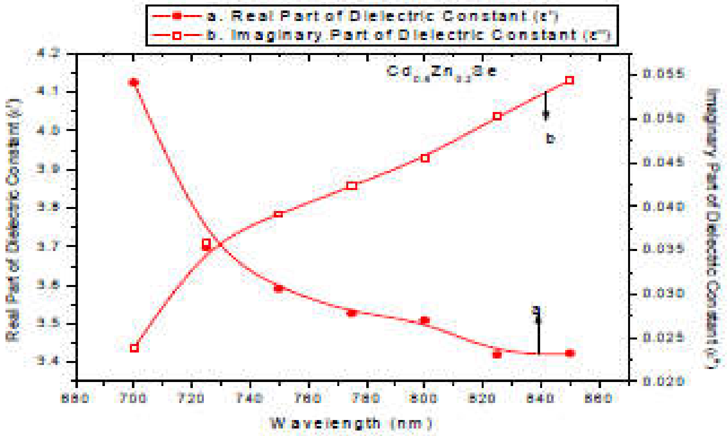

**Figure 1.1(b): Variation of Refractive Index (n) and Extinction Coefficient (k) with wavelength of Vacuum Evaporated $Cd_{0.8}Zn_{0.2}Se$ Thin Film.**

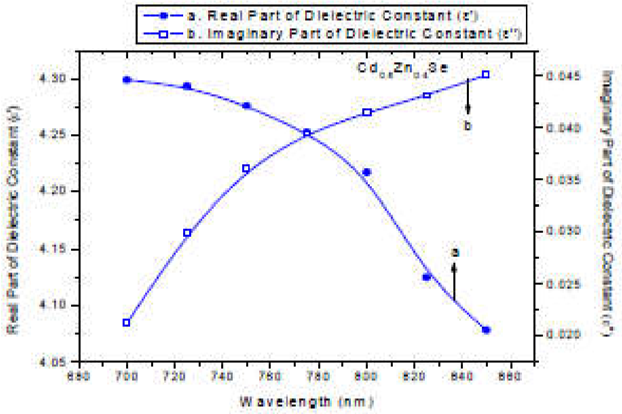

**Figure 1.1(c): Variation of Refractive Index (n) and Extinction Coefficient (k) with wavelength of Vacuum Evaporated $Cd_{0.6}Zn_{0.4}Se$ Thin Film.**

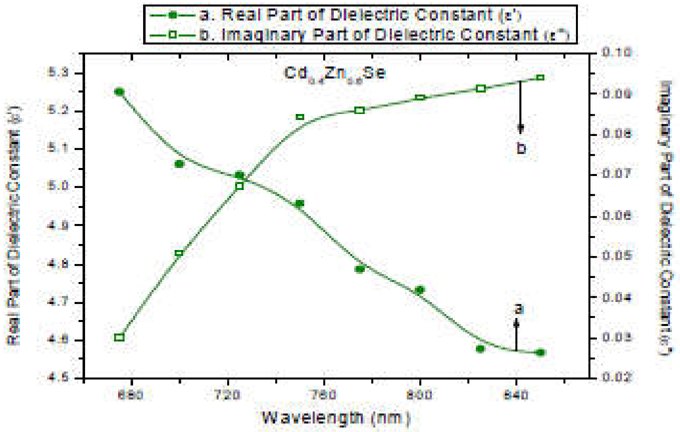

Figure 1.1(d): Variation of Refractive Index (n) and Extinction Coefficient (k) with wavelength of Vacuum Evaporated $Cd_{0.4}Zn_{0.6}Se$ Thin Film.

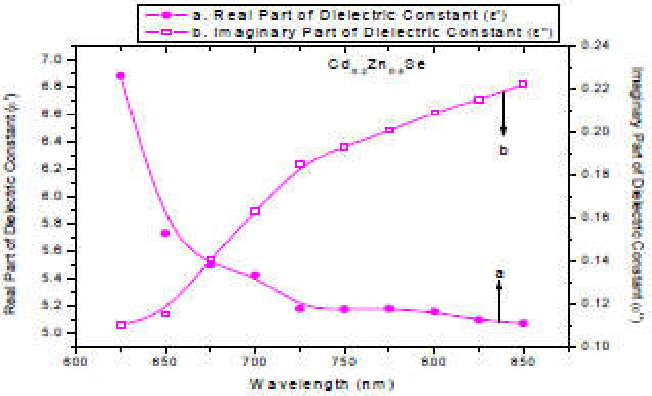

Figure 1.1(e): Variation of Refractive Index (n) and Extinction Coefficient (k) with wavelength of Vacuum Evaporated $Cd_{0.2}Zn_{0.8}Se$ Thin Film.

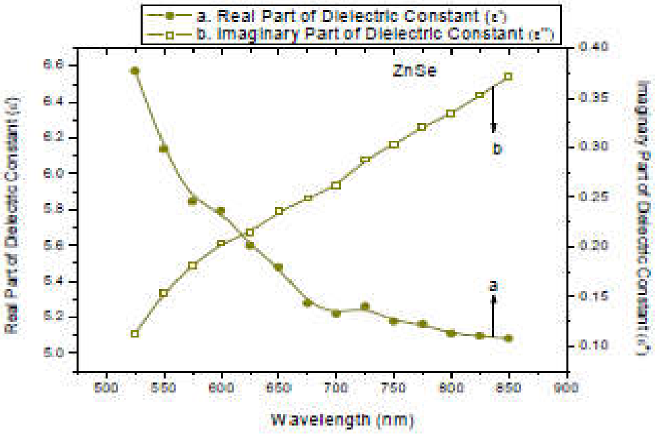

Figure 1.1(f): Variation of Refractive Index (n) and Extinction Coefficient (k) with wavelength of Vacuum Evaporated ZnSe Thin Film.

## CONCLUSION

It is seen that the refractive index decreases and the extinction coefficient increases with wavelength of all vacuum deposited $Cd_{1-x}Zn_xSe$ thin films. It is also seen that the deposited films are dark color, uniform, pin hole free and have better adhesion to the substrates. The thickness of films of $Cd_{1-x}Zn_xSe$ with different composition of x is (x = 0.0, 0.2, 0.4, 0.6, 0.8, 1.0) comes out 632 nm, 1781 nm, 2506 nm, 1497 nm, 670 nm and 416 nm respectively. From the graphs it is clear that the real part of dielectric constant (ε') is increasing with wavelength and the imaginary part of dielectric constant (ε") decreasing with wavelength for all the compositions (x).

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