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Structural, optical and dielectric properties of CdTe thin films prepared by screen printing technique

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Abstract. The systematic study of structural, optical and dielectric properties of CdTe thin film was demonstrated in present article. The CdTe thin film was prepared by simply screen printing technique and sintered at temperature 510°C in open environment. The energy dispersive analysis of X-ray (EDAX) was employed for quantitative conformations of deposited CdTe thin film. An XRD analysis discloses polycrystalline nature of CdTe thin film. The XRD pattern, exhibiting sharp peaks due to sintering process, is well indexed to cubic structure and determined value of lattice parameter is $a=6.425 \text{ \AA}$. The structural parameter like crystallite size (D), dislocation density (δ) and strain (ϵ) were also calculated. The presence of rings and spots in is attributing the crystalline nature of CdTe thin film. The optical response was studied by UV-Visible-NIR spectroscopy and the prepared thin film was found to be having direct band gap of 1.4 eV. The absorption maximum at 840 nm was found to obey Urbach's law and determined value of Urbach's energy and steepness constant are 145meV and 0.179, respectively. Behaviors of Dielectric parameter like dielectric constant, capacitance and the Dissipation factor D or Tan δ of the screen printed CdTe thin film were studied at different temperatures in the frequency range of 10 kHz to 1 MHz. The results are discussed in detail.

Keywords: CdTe thin film, Screen printing technique, Urbach's energy.

I. Introduction

CdTe of group II-VI come out as one of the most suitable materials for photovoltaic applications, because of two attractive optical characteristics of this material for photo voltaic conversion of sun light [1], first on is Energy band gap, for CdTe it is found to be less than 2eV provides optimal matching with spectrum of sunlight and second it having large absorption co-efficient due to its direct mode of main optical transition [2-3]; these two optical characteristics provides permits to use CdTe thin film as active material in fabrication of solar cell [4]. CdTe also available in both, n-type and p-type conducting [5]. Deposition techniques produce many variations in physical properties of thinfilms in this consideration numbers of technique have been adopted to synthesizes CdTe thinfilms viz Closed-spaced sublimation [6], vacuum-evaporation [7], thermal evaporation [8], Dip-coating [9], RF sputtering [10], chemical bath deposition [11], screen printing [12] etc. Out of these all techniques screen printing have its owned advantages, as most economical as well as simple one in terms of required technologies for deposition of thin film. Screen printing is not limited to substrate sizes, hence it most suitable for large scale deposition. Polycrystalline semiconductor thin film is suitable to fabricate electronic and optoelectronic devices, to fulfill this criteria screen printing followed by sintering consider as most appropriate technique [13]. In this present work thin film of CdTe were deposited by screen printing method. Deposited films were farther sintered at temperature 510°C in room environment for a constant interval of time [14]. Farther utilization of developed CdTe thin film As Absorbing larey in the fabrication of solid state device, it is important to study its physical, optical and dielectrical properties [15,16] is the main an objective of this paper.

II. Materials and methods for thin film deposition

The CdTe thin film was prepared by screen printing technique and deposited thin film was sintered at 510°C temperature. Chemical slurry was prepared by mixture of 99.999% pure Cadmium Telluride powder from Alfa Aesar, Cadmium Chloride (CdCl_2) powder by Sisco Research Laboratories and ethylene glycol by Sigma-Aldrich. CdCl_2 is taken as 10% weight of Cadmium Telluride and few drops of ethylene glycol was added in mixture of CdTe and CdCl_2 to make chemical slurry viscous enough, mixing and dispensing done by using a mortar and a pastel as appropriate for screen printing technique [17-18]. This chemically synthesized slurry finally printed over pre-clean glass substrate by using squeegee passes through the screen. The thickness of the prepared films were preserved by filling the space between two layers of invisible tapes fixed down the sides edges of glass slide by means of squeegee in single glide. Thus it was observed that printed thin films have on an average thickness of 4 μm using such an arrangement. The printed CdTe thin film further attempt Low temperature drying at 120°C in open atmosphere for duration of 4 hours to avoid cracks formation and improves continuity of deposited layer, which is considering as an significant surface parameter for thin films [19]. Function of Cadmium Chloride in synthesized slurry was as sintering flux because CdCl_2 is one of the members of hygroscopic material. Melting point

of CdCl_2 is about 568°C , due to the hygroscopic nature, the compound start to evaporate at temperature higher than 400°C , hence it is more important to have sintering temperature must be greater than 400°C [19]. Consequently dried thin film was sintered at 510°C .

III. Characterization techniques

Thicknesses of sintered CdTe thin film was determined by gravimetric weight difference method. Weight difference was measured with the help of sensitive microbalance and film density was assumed as the bulk density of CdTe (5.85gm.cm^{-3}) [20]. The structural study of deposited CdTe thin film by screen printing method, which was sintered at 510°C carried out by means of the X- ray diffraction patterns obtained in Cu- $K\alpha$ radiation ($\lambda = 1.5406 \text{ \AA}$) from a Philips X-ray diffractometer (XRD) model XPERT MPD. The selected area electron diffraction (SAED) pattern and an energy dispersive analysis by X-ray (EDAX) for quantitative measurement of the sample composition for deposited CdTe thin films was also carried out. Optical band gap and other solid state optical parameters of thin film sintered at 510°C obtain from absorbance spectra by UV-VIS-NIR spectrometer from perkin elmer, model Lambda-19. The dielectric properties like dielectric constant (ϵ), capacitance(C) and loss tangent ($\tan \delta / D$) of the films were calculated from the a.c. measurements of impedance, capacitance and phase angle measured as a function of frequency and temperature.

Table 1 Stoichiometric confirmation of grown sample using EDAX analysis.

Weight (%)		Atomic (%)	
Cd	Te	Cd	Te
52.2	47.8	55.29	44.71

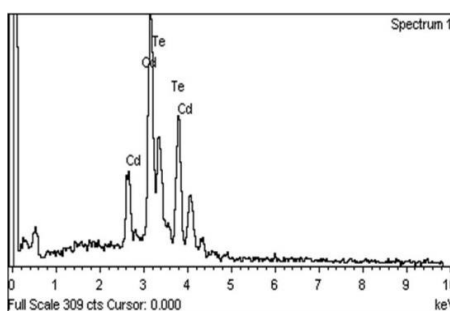


Figure 1 The EDAX spectrum of Screen printed CdTe thin film.

IV. Results and discussion

The CdTe thin film was deposited by screen printing technique and was sintered at 510°C temperature. The chemical composition was tested by energy dispersive analysis of X-ray (EDAX). The EDAX spectrum(Figure 1) shows the presence of Cd and Te in nearly stoichiometric proportion. No extra peaks were found in EDAX pattern; suggest the purity of prepared thin film. The powder XRD was employed to determine the structure of deposited CdTe thin film. The XRD pattern of CdTe thin film is well indexed to cubic structure with Pmm2 space group. The sharp peaks in XRD pattern attributes crystalline nature of thin film, as shown in Figure 2. The determined value of lattice constant is $6.425 \text{ \AA}$. The results of XRD are well matched with reported data (JCPDS card No. 15-770). The crystallinity of compound depends on crystallographic parameters like crystallite size, strain energy and dislocation density and their determined values are 20.43 nm , $1.997 \times 10^{-3} \text{ line}^{-2}.\text{m}^{-4}$ and $2.83774 \times 10^{-5} \text{ line/m}^2$, respectively using following relations [21].

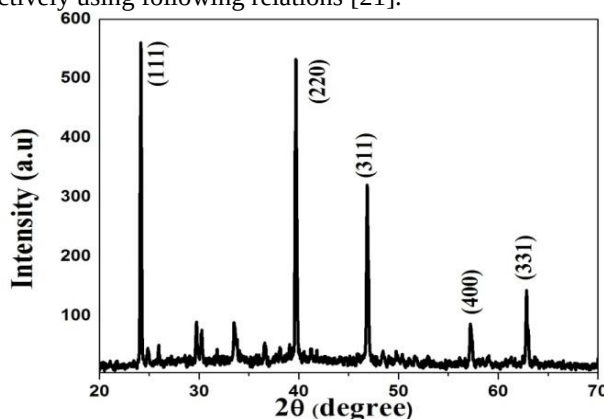


Figure 2 Powder XRD pattern of CdTe thin film.

$$D = \frac{0.9\lambda}{\beta \cos \theta} \quad (1)$$

$$\varepsilon = \frac{\beta \cos \theta}{4} \quad (2)$$

$$\delta = \frac{1}{D^2} \quad (3)$$

Where, β is the broadening of the diffraction line measured at half of its maximum intensity (rad) FWHM, λ is the X-ray wavelength (1.5406 Å), and θ is Bragg's angle of diffraction.

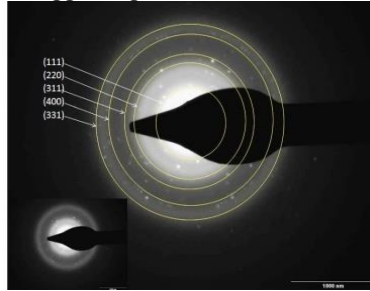


Figure 3 SAED pattern of deposited CdTe thin film.

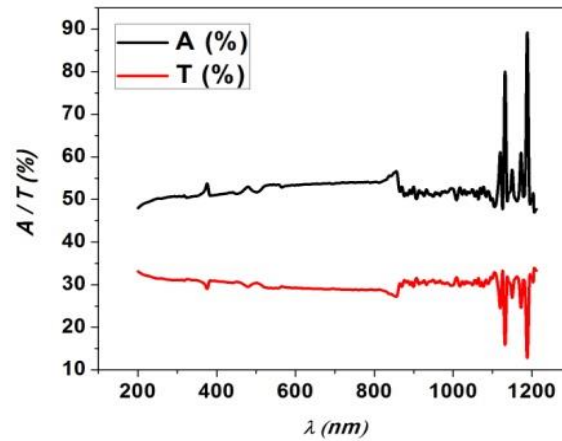


Figure 4 The plot of absorbance and transmittance with respect to wavelength.

The transmission electron microscopy was employed to determine the crystallinity of CdTe thin film. The presence of ring and spots SAED pattern suggests the crystalline nature of prepared thin film [22]. The ring was indexed to cubic structure, which is similar to the XRD results. The indices were also determined, as shown in Figure 3 which is in good agreement with XRD data. The crystallization is occurred due to high temperature (510°C) sintering of the deposited CdTe thin film.

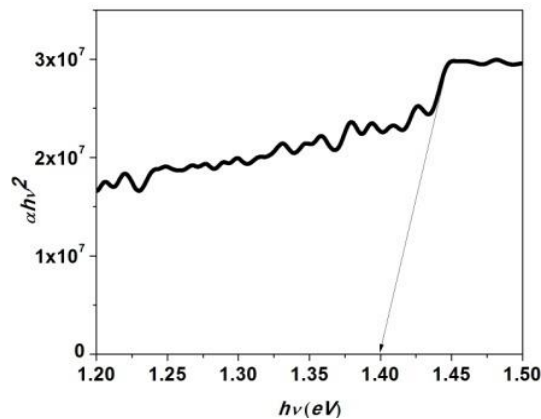


Figure 5 The graph of $(\alpha h\nu)^2$ vs. $h\nu$ of sintered CdTe thin film.

The optical response of CdTe thin film was studied by UV-Visible-NIR spectroscopy in spectral range 200-2000nm. The absorbance and transmittance were measured from the CdTe thin film, as shown in Figure 4. The absorption co-efficient was calculated from the experimental data and it's the higher values suggest the application of CdTe in optoelectronic device. It noted that the most prominent absorption/transmission edge arises at 840 nm.

The CdTe thin film is found to possess direct band gap and it is determined by plotting the graph of $(\alpha h\nu)^2$ vs. $h\nu$ (Figure 5), using Equation (4). The determined value of band gap is 1.4 eV. The typical optical parameters like extinction co-efficient, refractive index, imaginary and real part of dielectric constant defines the optical response of thin film and their variations with $h\nu$ were plotted in Figure 6(a-d), respectively.

$$\alpha h\nu = A(h\nu - E_g)^n \quad (4)$$

The absorption edge at 840nm was found to obey Urbach's rule. As shown in Figure 7, $\ln\alpha$ was plotted against $h\nu$ and value of Urbach's energy was calculated from the slope of $\ln\alpha$ - $h\nu$ curve. The presence of Urbach's tail depicts the presence of electron/exciton-phonon interaction in CdTe thin film. Another origin for Urbach's tail is the presence structural and thermal disorder. As shown in plot of $\ln\alpha$ - $h\nu$ we have fitted Urbach's tail to experimental data of absorption co-efficient and Urbach's energy has been obtained. The Urbach's energy of absorption edge can also be uttered by $E_U = k_B T / \sigma$, where σ is known as the steepness parameter which describe the steepness of the absorption edge. The presume value of the steepness parameter (σ) at room temperature is 0.179 corresponding to Urbach's energy 145 meV for screen printed CdTe thin film. The smaller values of Urbach's energy may be attributed to ordered structure in sintered CdTe film [23,24].

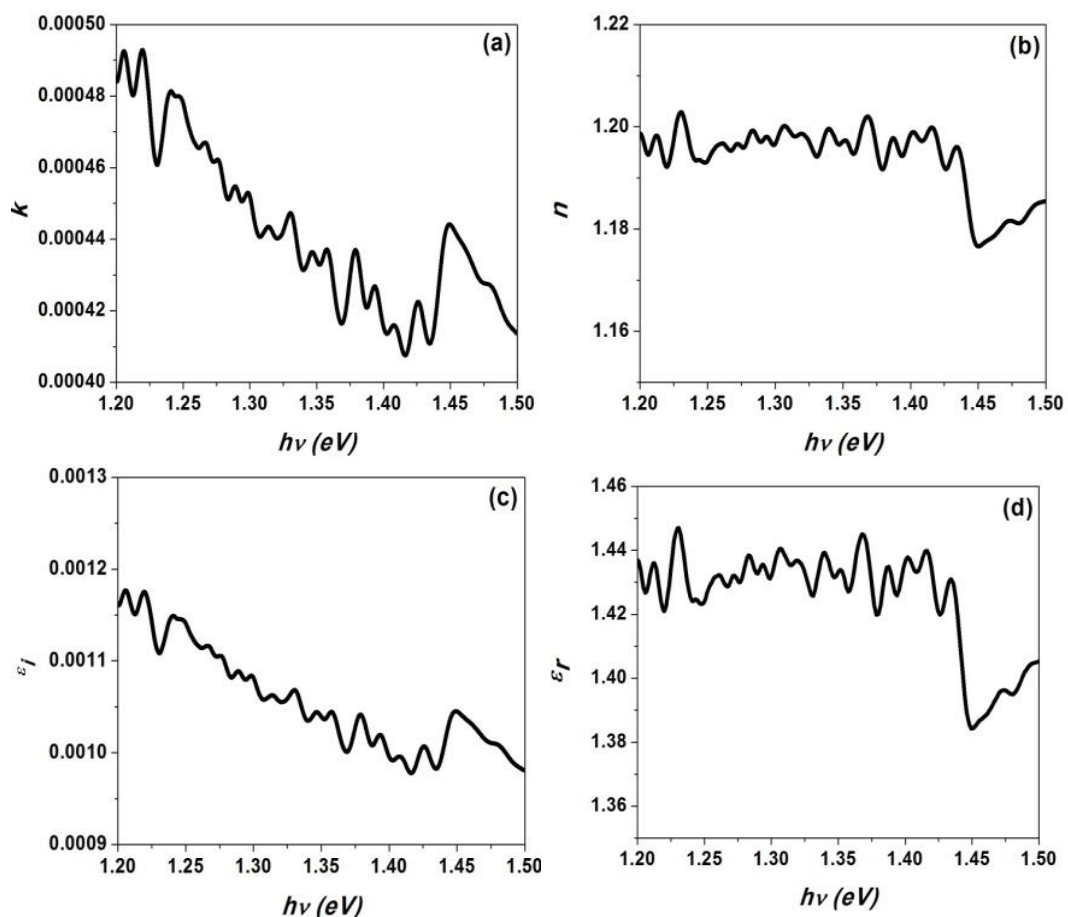


Figure 6 Variation of optical parameters of CdTe thin film with photon energy (a) extinction co-efficient, (b) refractive index, (c, d) imaginary and real part of dielectric constant.

Intense peak of the XRD patterns suggests the noticeable ordered nature of the system. But growth mechanism leave sum defect either simple or multifaceted defects such as defect centers, micro voids, imperfections, cracks, etc. These defects play very vital role in transport phenomena of charge carrier, as these defects creates defect states e.g. shallow and deep traps, acting as donor or acceptors. Such type of traps is allowed energy levels, present in forbidden gap and they affect the transport phenomena of film to a high extent by acting as traps and recombination centers for charge carriers. These traps may lead to the probable formation of electric dipoles, responsible for the dielectric behavior of thin film. Transport of charge carriers between these traps, jump to an acceptor from a donor state. Which results as formation of dipole by each pair of traps, contributes to distributed dielectric relaxation [25].

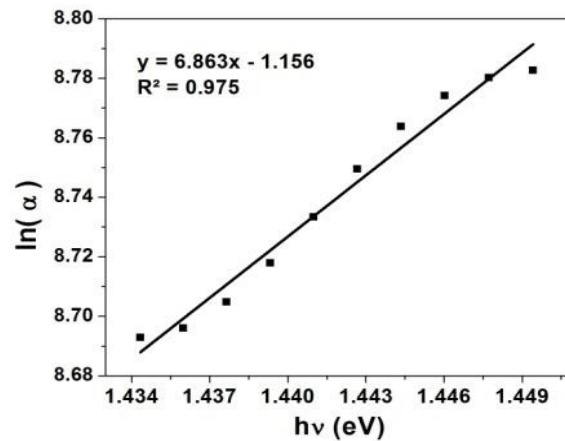


Figure 7 Urbach's absorption tail in optical spectra of CdTe thin film.

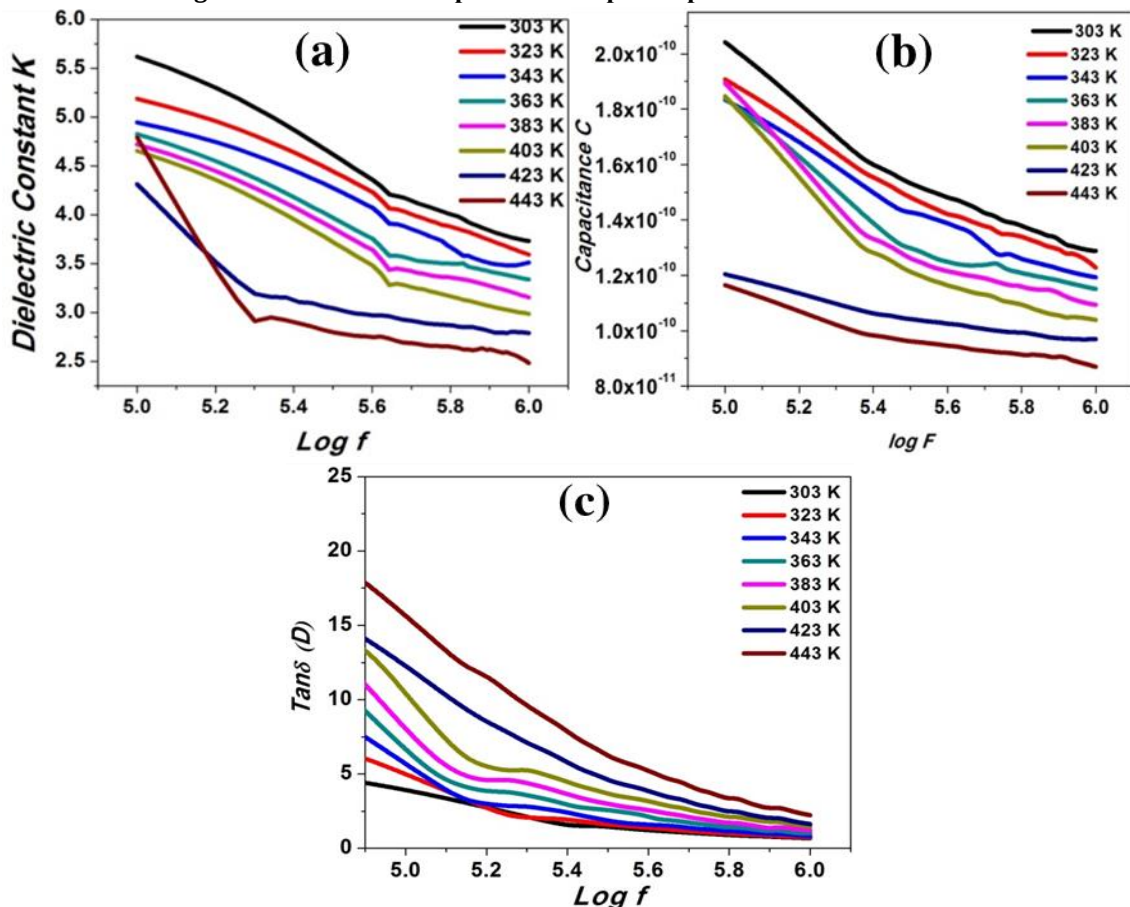


Figure 8 (a) Dielectric constant, (b) Capacitance, (c) Dissipation factor (D) of CdTe thin film as function of frequency and temperature.

In the present studies of the dielectric constant, capacitance and the dissipation factor D or Tan δ of the CdTe thin film were studied at different temperatures in the frequency range of 10 kHz to 1 MHz. The dielectric constant was measured with respect to the frequency at different temperatures within range from 303 K to 443 K shown in Figure 8 (a), while the corresponding capacitance and dissipation factor D are depicted in Figure 8 (b, c), respectively. The dielectric constant, capacitance and dissipation factor (D) decreases exponentially with increasing frequency. The plots also indicate that the value of the dielectric constant as well as capacitance decreases with an increase in temperature. But dissipation factor (D) was found to be increases with an increase in the temperatures. These results in a monotonous decrease in the value of dielectric constant and capacitance on increasing frequency may be credited to a collective involvement of electronic, ionic, interfacial polarization at low frequencies [26]. Tan δ is maximum at lower value of frequency and high temperature for sintered CdTe thin film. The plot of dissipation factor indicates that the thin film performance is thermally activated at higher temperature. This provides confirmative presence of space charge polarization.

V. Conclusions

The CdTe thin film was simply prepared by screen printing technique and sintered at temperature 510°C in open environment. The results of EDAX analysis show the purity of CdTe thin film and weight and atomic percentage was investigated. The structural characterizations are attributing to the fact that the prepared thin film has crystalline nature. The XRD pattern, exhibiting sharp peaks due to sintering process, is well indexed to cubic structure and determined value of lattice parameter is $a = 6.425 \text{ \AA}$. The optical response was studied by UV-Visible-NIR spectroscopy and the prepared thin film was found to be having direct band gap of 1.4 eV. The absorption maximum at 840 nm was found to obey Urbach's law and determined value of Urbach's energy and steepness constant are 145meV and 0.179, respectively. The presence of Urbach's tail depicts electrons/excitons with phonons as well as the static structural disorder.

VI. References

- [1] Y. D. Tembhurkar, International journal of science and research (ijsr) volume 5, 12, December 2016.
- [2] L. Gouda, Yelameli Ramesh Aniruddha, S.K.Ramasesha, Journal of Modern Physics, 2012, 3, 1870-1877.
- [3] S. Weng and M. Cocivera, chemistry of materials, Vol. 5, No. 10, 1993, pp. 1577-1580.
- [4] T. Suntola, mrs bulletin volume 18, issue 10 october 1993, pp. 45-47.
- [5] Nor A. Abdul-Manaf, Hussein I. Salim, Mohammad L. Madugu, Olajide I. Olusola and Imyhamy M. Dharmadasa, Energies 2015, 8, 10883-10903.
- [6] Bing Li, Lianghuan Feng, Jiagui Zheng, Wei Cai, Yaping Cai, Jingquan Zhang, Wei Li, Lili Wu, Zhi Lei, 1-4244-0016-3/06.
- [7] J. Aranda, J. L. Morenza, J. Esteve AND J. M. Codina, Thin Solid Films, 120 (1984) 23-30.
- [8] D. Geethalakshmi, N. Muthukumarasamy, Vol 1, Issue 1, Autumn Edition, September 2012, P 23-29.
- [9] S. Chandra Ray and K. Mallick, International Journal of Chemical Engineering and Applications, Vol. 4, No. 4, August 2013.
- [10] Rupali Kulkarnia, Sachin Rondiya, Amit Pawbakea, Ravindra Waykara, Ashok Jadhavara, Vijaya Jadhara, Ajinkya Bhordea, Abhijit Datec, Habib Pathand, Sandesh Jadhara, Energy Procedia 110 (2017) 188 – 195.
- [11] S. Deivanayagi, P. Jayamurugan, R. Mariappan, v. ponnuswamy, Chalcogenide Letters, Vol. 7, No. 3, March 2010, p. 159 – 163.
- [12] Vipin Kumar, J. K. Gaur, M. K. Sharma, T. P. Sharma, Chalcogenide Letters Vol. 5, No. 8, August 2008, p. 171 – 176.
- [13] Marc Burgelman, The Summer School. Technical University of Lodz. 1998. pp. 129-135.
- [14] Vipin Kumar, Sonalika Agrawal, D.K.Sharma, Kapil K. Sharma, D.K. Dwivedi, M.K. Bansal, Appl. Sci. Lett. 1(3) 2015, 86-89.
- [15] K. Punitha, R. Sivakumar, C. Sanjeeviraja, V. Ganesan, Appl. Surf. Sci. 344 (2015) 89–100.
- [16] Lianghuan Feng, Jingquan Zhang, Bing Li, Wei Cai, Yaping Cai, Lili Wu, Wei Li, Jiagui Zheng, Qiang Yan, Genpei Xia, Daolin Cai, Thin Solid Films 491 (2005) 104 – 109.
- [17] Vipin Kumar, J. K. Gaur, M. K. Sharma, T. P. Sharma, Chalcogenide Letters Vol. 5, No. 8, August 2008, p. 171 – 176.
- [18] Vipin Kumar, Sonalika Agrawal, D.K.Sharma, Kapil K. Sharma, D.K. Dwivedi, M.K. Bansal, Appl. Sci. Lett. 1(3) 2015, 86-89.
- [19] Vipin Kumar, D.K. Dwivedi, Optik Volume 124, Issue 16, August 2013, Pages 2345–2348.
- [20] Smt. Swapna Samanta, M. S. Shinde, Dipak Salunke and R. S. Patil, Arch. Appl. Sci. Res., 2015, 7 (11):10-15.
- [21] H.S. Patel, J.R. Rathod, K.D. Patel, V.M. Pathak, American Journal of Materials Science and Technology 1 (2012) 11–21.
- [22] M. P. Deshpande, Nitya Garg, Sandip V. Bhatt, Pallavi Sakariya, S. H. Chaki, Adv. Mat. Lett. 2013, 4(11), 869-874.
- [23] G.K. Solanki, Pratik Pataniya, C.K. Sumesh, K.D. Patel, V.M. Pathak, Journal of Crystal Growth 441 (2016) 101–106.
- [24] Zaher M. Nassar, Mehmet H. Yukselici, Asuman A. Bozkurt, Phys. Status Solidi B 253, No. 6, 1104–1114 (2016).
- [25] S.Suresh, Journal of Non-Oxide Glasses, 6, (2014), 47 – 52.
- [26] Ashok Kumar, B.P. Singh, R.N.P. Choudhary, Awalendra K. Thakur, Materials Chemistry and Physics, 99 (2006) 150–159.