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DOI: 10.21776/ub.jpacr.2016.005.02.265 J. Pure App. Chem. Res., 2016, 5 (2), 116-124 26 August 2016 X The journal homepage www.jpacr.ub.ac.id p-ISSN : 2302 – 4690 | e-ISSN : 2541 – 0733 This is an open access article distributed under the terms of the Creative Commons Attribution-NonCommercial 4.0 International which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. (http://creativecommons.org/licenses/by-nc/4.0/) Spectroscopic and Radiative Properties of Several Nd3+ Ions in Borate Glass System J. Rajagukguk1,*, M. Djamal2, Suprijadi2, A. Aminuddin3, J.

Kaewkhao4 1 Faculty of Mathematics and Natural Sciences, Universitas Negeri Medan, Indonesia 2 Faculty of Mathematics and Natural Sciences, Institut Teknologi Bandung, Indonesia 40132 3Department of Physics, Universitas Pendidikan Indonesia, Indonesia 4Center of Excellence in Glass Technology and Materials Science, Nakhon Pathom Rajabhat University, Thailand *Corresponding e-mail : juniastel@yahoo.com Received 20 May 2016; Revised 24 September 2016; Accepted 26 September 2016 ABSTRACT Radiative properties and spectroscopic studies of several Nd3+ doped borate glass system have been reported.

Judd-Ofelt intensity parameter and other parameters like oscillator strength (f), effective bandwidth (? ? eff), radiative transition probabilities (AR), stimulated emission cross section (?), branching ratio (? R), radiative lifetime (? R) and experimental lifetime (? exp) for the hypersensitive Nd3+ doped Borate Glass are listed and discussed. The variation of ? 2 values for the different host matrix are expressed their covalency among Nd3+ ions in the glass matrix.

In this study, reported that the hypersensitive transition achieved at 4I9/2 ? 4G5/2, 2G7/2 centered at 580 – 585 nm range. Keywords: Borate glass, Judd-Ofelt, radiative INTRODUCTION In the several years and recently, laser gain medium based on Nd3+ doped glasses have been attracted much attention from researchers in the field of photonic and laser.

The above related to Nd3+ laser application such as optical amplifier, laser pumping, optical communication, optical waveguide, storage data optically, radar and medical instrumentation [1-5]. Medium gain laser characteristics for commercial laser required were must satisfied sharpness fluorescent lines, strong absorption bands and sensible for high quantum efficiency in accordance with the needed transition photon [6].The above requirements have been obtained by a small amount of concentration Nd3+ ions-doped glass material, since Nd3+ ions were able to produce population inversion for result stimulated emission in the visible range (such as emission transition at 4G7/2 ? 4I9/2, 4G7/2 ? 4I11/2, 4G7/2 ? 4I13/2) [7] and the NIR range (lasing transition 4F3/2 ? 4I9/2, 4F3/2 ? 4I11/2, 4F3/2 ? 4I13/2) [1].

Improved laser performance is strongly influenced by the composition of the host glass matrix and the concentration of doped ions, since the stimulated emission quality depends on host matrix in which the ions are incorporated [7,8]. Several types of commercial glass are generally used as a laser host matrix, i.e silicate, phosphate, borate glasses and several heavy metal oxide glasses [1,2,7,9].

Some of the results showed that the silicate glasses has its advantages as well as high chemical stability, high transparency for UV, low thermal expansion coefficient leading to strong thermal resistance, a small nonlinear refractive index, high surface damage threshold, J. Pure App. Chem. Res., 2016, 5 (2), 116-124 26 August 2016 X The journal homepage www.jpacr.ub.ac.id p-ISSN : 2302 – 4690 | e-ISSN : 2541 – 0733 117 large tensile fracture strength and good durability [10-12].

Those advantages made this type of glass are suitable for application as optical fiber or waveguide lasers [13]. Phosphate glass appropriately used as a host matrix for Nd3+ ions owned properties are low thermal-optical constants, low melting point, low glass transition temperature and high thermal expansion coefficient [14].

Moreover, the borate glass properties have been reported as well high transparency, high density, appropriate bandwidth, suitable for infrared transmission, high mechanical stability, corrosion resistivity and inexpensive [2,15]. In addition, the other types of glasses and crystals have been reported as well as a host of Nd3+ ion laser such as Nd3+ doped alkali niobium zinc tellurite glasses [16], Nd3+ doped barium titanium silicate glasses [17], Nd3+ ions in fluoro-phosphate glasses [18], Nd3+ doped lanthanum calcium borate glasses [19] and Nd^{3+} doped alkali boro germanate glasses [20].

In this paper discussed some of the parameters needed in the determination of the glass composition doped Nd^{3+} ion to be used as a laser gain medium. This discussion is limited to the composition of glasses based on borate glass former. As for the parameters that were examined in a laser medium are absorption spectrum, intensity analysis, emission spectrum, energy level, emission cross section, radiative lifetime, etc.

THEORY Optical Spectroscopic The optical spectra of the laser medium affected by the concentration of Nd^{3+} and glass structure as host matrix which the ion in the host matrix have the transition energy level vary with the Nd^{3+} concentration. The energy level depends on covalency and asymmetry of Nd^{3+}- O bond in the host matrix [10,21].

For the Nd^{3+} ions doped some different host material such as glass material can be observed the energy level Ej by a Taylor series expansion [22]. (1) Where Ej is the energy levels of the Nd^{3+} ion in the host matrix from the measurement of absorption spectra, E0j is the zero order Energy level of the Nd^{3+} ion, , are the partial derivatives and ? Pi, ? 4f are the variations of the interactions with the host matrix [23].

The experimental energy levels observed, and then obtained the deviation of the levels energy by the equation: (2) Where M is the number of absorption bands and J expresses the number of parameters on the theoretical energy values. Judd-Ofelt Parameters The intensity of absorption bands determined by the experimental oscillator strength (fexp) that related to particular transition.

Oscillator strengths were determined according to Judd-Ofelt theory [2,24]. (3) Where ? is the molar absorption coefficient, ? is energy (cm-1). The area of the absorption curve utilized for calculating the right side of integral, concentration of the Nd^{3+} ion in J. Pure App. Chem. Res., 2016, 5 (2), 116-124 26 August 2016 X The journal homepage www.jpacr.ub.ac.id p-ISSN : 2302 – 4690 | e-ISSN : 2541 – 0733 118 mole/lit and the optical length of glass in cm.

The optical density or absorptivity according to Ber's adioved y ? (?) is = (1/cl) log (I0/I) where c is the concentration of Nd^{3+} ion (mole/lit), l is the optical path in the medium. The theoretical oscillator strength of an induced electric-dipole transition from ground state ? J to an excited state ? 'Js gin b (4) Where (2J + 1) is the multiplicity of the lower states, m is the mass of the electron, ? is the setting of absorption peak, ? ? (? = 2,4,6) are JO intensity parameters and the ? ||U(?)|| ? are the doubly reduced unit tensor operations calculated in the intermediate coupling approximation [25,26].

The equation of the root mean square deviation (? frms) clarifies the quality of the fit known is given by (5) where fexp and fcal are the experimental and calculated oscillator strengths, respectively, M is the number of absorption bands used in account, i and f refers the total number of levels included in the fit. Radiative Properties Radiative transition of the laser transition 4F3/2 ? 4I11/2 covered by the transition probability (AR), radiative lifetime (? R), stimulated emission cross section (? em), Branching ratio (? R) are calculated by using of the Judd-Ofelt parameters (?).

The relation of the initial level ? J to ? 'Jtheaous tnsiibiltis (AR) ves [27] (6) Where Sed and Smd are the electric dipole and magnetic dipole line strengths given as and (7) The quality of the laser transition 4F3/2 ? 4I11/2 observed by size stimulated emission cross-section and calculated with using of Fuchtbabauer-Ladenburg method.

(8) Where ? p is the peak wavelength of the emission peak, c is the speed of light, n is the refractive index, A(a JbJit ditvetnsiiprobaly nd ? ? eff is an effective line width. The area under of emission peak is used for calculation of full-width at half-maximum. The effective line width of the emission given as (9) Where Imax is the maximum intensity at fluorescence emission peaks.

Then the radiative life time (? R) is given with reverse of the sum AR(? J, ? 'J (10) J. Pure App. Chem. Res., 2016, 5 (2), 116-124 26 August 2016 X The journal homepage www.jpacr.ub.ac.id p-ISSN : 2302 – 4690 | e-ISSN : 2541 – 0733 119 DISCUSSIONS Judd-Ofelt analysis The oscillator strength (fexp) determined experimentally by substituting of the absorption spectra obtained from the measurement of results. Judd-Ofelt parameters obtained from the absorption spectra have been measured at room temperature.

These values used for calculating oscillator strength each of the absorption bands in accordance with eq. (3). The experimental and theoretical oscillator strength of some Nd3+: doped borate glasses former showed in Table 1. The value of energy levels, especially at 4I9/2 ? 4G5/2, 2G7/2 transitions for some materials with various concentrations also presented in Table 1.

In this paper selected Nd3+ concentrations that have the best potential for the emission spectra of each reference. Table 1. Hypersensitive absorption transition (from the ground state, 4I9/2 ? 4G5/2, 2G7/2) for Nd3+ : borate glass Glasses structure ? p (nm) xNd3+ (mole%) E xpt (cm -1) E cal (cm -1) fexp x 10 -6 fcal x10 -6 75B2O3.13PbO.5Bi2O3.5Al2O3 [2] 580 2.0 17.212 17.199 20.70 20.86 99Bi2ZnOB2O6 [27] 585 1.0 17.094 - 20.63 - 25LiO;25GeO2;49B2O3 [20] 0.5 19.477 - - -

20CdO.15Bi2O3-79.5B2O3 [28] 582 0.5 - - 5.12 5.11 72.75B2O3;4.5CaO-22.37La2O3 [29] 583 1.0 - - 1.1649 1.1642 20NaF;30PbO;49.5B2O3 [22] 582-585 0.5 17.153 17.123 22.41 22.42 20NaCl;30PbO;49.5B2O3 [22] 582-585 0.5 17.185 17.220 22.31 22.29 35Bi2O3;30Na2O;34B2O3[30] 582-585 1.0 17.065 - 16.0 16.2

35PbO;30Na2O;34B2O3[30] 582-585 1.0 17.605 - 15.0 15.3 49.5PbO;30B2O3;10TiO2-10AlF3 [31] 585 0.5 17.094 17.300 16.090 16.033 67 B2O3;12Li2O;20Na2O [32] 582-585 1.0 17.118 - - - 67 B2O3;12Li2O;20K2O [32] 582-585 1.0 17.089 - - - 49.5 B2O3;49.5Na2O [33] 580 1.0 - - 26.37 26.31 49.5B2O3;24.75Na2O;24.75NaF [33] 580 1.0 - - 19.90 19.90 20B2O3;69.5Bi2O3;10SiO2 [34] 586 0.5 - - 5.53 5.20 Figure 1. Transmission spectra of 1.0

mole% Nd3+ doped borate glass system Table 1 reflected the hypersensitive absorption band located in the 580-586 nm wavelength range with the Nd3+ concentrations to be potential as a laser medium are 0.5; 1.0 and 2,0 mole%. Absorption band due to the content of the composition of Nd3+ ions in the glass material, this affects the shape, peak position and intensity of the transition.

The difference of hypersensitive wavelength position of several glass mediums are attributed to J. Pure App. Chem. Res., 2016, 5 (2), 116-124 26 August 2016 X The journal homepage www.jpacr.ub.ac.id p-ISSN : 2302 – 4690 | e-ISSN : 2541 – 0733 120 differences in the crystal field asymmetry which makes the peak position split.

In addition, the intensity of the absorption peak of hypersensitivity split was also caused by changes in the content of the composition glass. On the other hand, some medium glasses have the same absorption peak, which splits disappearances have occurred by expansion of homogeneity [33]. The oscillator strength values are strongly influenced by the type and composition of other metal compounds as modifiers of the glass network structure.

The high content of the borate not guarantee can increase the value of the oscillator strength, but becomes interesting that the current composition of 49.5 mole% boric produced high oscillator strength values. The transmission spectra of 1.0 mole% Nd3+ doped borate glass system in the wavelength range 300-1000 nm is shown in Figure 1.

The transmission spectra shows ten sensitive bands derived from the state of 4I9/2 to various excited states. The transmission peaks centered at 354 nm, 430 nm, 474 nm, 524 nm, 580 nm, 625 nm, 679 nm, 744 nm, 802 nm and 871 nm were attributed to 2D5/2, 2P1/2, 2G9/2, 4G7/2, 2G7/2+4G5/2, 2H11/2, 4F9/2, 4F7/2, 4F5/2, 4F3/2 transitions respectively Table 2.

Judd-Ofelt parameters (x 10-20) and spectroscopic quality factor (? 4/ ? 6) of the excellent concentration of Nd3+ (x) : doped borate glasses based Glasses xNd3+ (mole%) Parameter ? 2 ? 4 ? 6 ? 2ZnOB 2O 6 [27] 1.0 2.67 3.31 3.98 0.83 25LiO;25GeO 2;49B 2O 3 [20] 0.5 4.84 5.97 4.59 1.22 25NaO;25GeO 2;49B 2O 3 [20] 0.5 5.75 3.44 3.73 0.92 25KO;25GeO 2;49B 2O 3 [20] 0.5 5.89 3.95 2.85 1.38 25RbO;25GeO 2;49B 2O 3 [20] 0.5 6.18 3.63 2.45 1.48 20NaF;30PbO;49.5B 2O 3 [22] 0.5 4.69 5.09 6.50 0.78 20NaCl;30PbO;49.5B 2O 3 [22] 0.5 4.84 5.31 6.32 0.84 75B 2O 3.13PbO.5Bi 2O 3.5Al 2O 3 [2] 2.0 4.53 4.17 6.44 0.65 20CdO.15Bi 2O 3- 79.5B 2O 3 [28] 0.5 1.44 3.42 2.89 1.18 35Bi 2O 3;30Na 2O;34B 2O 3[30] 1.0 4.72 2.12 3.93 0.54 35PbO;30Na 2O;34B 2O 3[30] 1.0 4.81 1.97 3.94 0.50 49.5PbO;30B 2O 3;10TiO 2- 10AlF 3 [31] 0.5

5.82 1.88 4.74 0.21 67 B 2O 3;12Li 2O;20Na 2O [32] 1.0 5.95 7.82 9.84 0.79 67 B 2O 3;12Li 2O;20K 2O [32] 1.0 10.83 7.73 9.04 0.85 49.5B 2O 3;49.5Na 2O [33] 1.0 7.79 3.03 2.80 1.055 49.5B 2O 3;24.75Na 2O;24.75NaF [33] 1.0 5.33 2.84 4.90 0.579 20B 2O 3;69.5Bi2O 3;10SiO 2 [34] 0.5 3.52 4.19 3.86 1.01 The oscillator strength values as shown in Table 1 were used to determine of Judd-Ofelt parameters, 2, 4, and 6 by using of least-square fitting method in eq. (4).

Judd-Ofelt parameters of several Nd3+ doped glasses for hypersensitive transition given in Table 2. There is one material [28] shown that intensity parameters 2 < 2, this condition represent the high covalent bonding that means there was broadening asymmetry around the environments glass [18].

Table 2 showed generally was observed that 2 > ? 4,6 [2,20,30,31,31,33] indicate the higher covalency of the ion-ligand bond lower symmetry of the Nd3+ ion site. This result also explained that the higher intensity of hypersensitive transition and the nephelauxetic effect possessed by these glass [22]. The higher values of ? 4 and ? 6 [20,22,28,32,34] for the glasses indicated their mechanics have higher rigidity. Then, the spectroscopic quality factor J.

Pure App. Chem. Res., 2016, 5 (2), 116-124 26 August 2016 X The journal homepage www.jpacr.ub.ac.id p-ISSN : 2302 – 4690 | e-ISSN : 2541 – 0733 121 known from ? = (? 4/ ? 6 for to find the channel through which the excited metastable state to the ground state [2].

Radiative Properties The Judd-Ofelt parameters (? ?) used for determining of various spectroscopic parameters such as effective bandwidth (? ? eff), fluorescence lifetime (? R), radiative transition probabilities (AR), stimulated emission cross section (?) and branching ratio (? R) as given in Table 3. These parameters are calculated using the eq.

(6) – (10) for N3+ : borate glass of 4F3/2 ? 4I11/2 level transition. Refer to the reported by Q.

Nie et al [35] that the materials suitable to be used as a laser medium is supposed to have some requirements such as large effective bandwidth, long fluorescence lifetime, high stimulated emission cross-section and high branching ratio. In Table 3 shown that the value of these parameters is almost equal to each other of the glass material then stated that borate glasses which contained Nd3+ potentially be used as a laser gain medium. Table 3.

Excitation wavelength (? exc), wavelength peak (? p), effective bandwidth (? ? eff), radiative transition probabilities (AR), stimulated emission cross section (?), branching ratio (? R), radiative lifetime (? R) and experimental lifetime (? exp) for the hypersensitive Nd3+ doped Borate Glass and emission transition 4F3/2 ? 4I11/2 Glasses structure ? ex (nm) ? p (nm) ? ? eff (nm) A R (s -1) p) x10 -20 (cm 2) R R (? exp (? 99Bi2ZnOB2O6 [27] 808 1063 29.00 3407 4.33 0.04 145 62.0 75B2O3.13PbO.5Bi2O3.5Al2O3 [2] 580 1065 18.81 7.89 0.74 264 - 20CdO.15Bi2O3-79.5B2O3 [28] 1064 - 1696 - 0.543 - - 20NaF;30PbO;49.5B2O3 [22] 1063 - 2077 - 0.494 238 - 20NaCl;30PbO;49.5B2O3 [22] 1063 - 2070 - 0.487 235 - 35Bi2O3;30Na2O;34B2O3[30] 808 1067 43 1581 2.0 0.552 349 35PbO;30Na2O;34B2O3[30] 808 1065 43 1285 1.8 0.548 426 49.5PbO;30B2O3;10TiO2-10AlF3 [31] 805 1070 34 1184 2.6 0.52 470 230 67 B2O3;12Li2O;20Na2O [32] 514 1069 3092 6.16 0.499 26 - 67 B2O3;12Li2O;20K2O [32] 514 1050 4110 8.84 0.512 21 - 49.5 B2O3;49.5Na2O [33] 800 1067 18.83 4.24 0.443 470 153 49.5B2O3;24.75Na2O;24.75NaF [33] 800 1062 17.84 4.18 0.378 347 151 20B2O3;69.5Bi2O3;10SiO2 [34] 800 1075 1130 2.20 0.536 The composition of glass structure in the Table 3 is the optimum value selected from each reference.

So the quality of the materials is also influenced by the amount of the glass composition in the host matrix. Kumar K et al [2] report that the fluorescence radiative lifetime optimum obtained when 75 mole% of B2O3 (BINLAB2), the higher emission cross section of 4F3/2 4I11/2 level obtained at 8 mole% PbO (BINLAB3).

The difference shown by branching ratio, which were the greatest results given by BINLAB2, followed BINLAB3 and the next BINLAB1. The intensity of the Nd3+ ion at 4F3/2 4I11/2 transition level so important to consider in a laser medium therefore the addition of SiO2 content could be increased of the intensity and lifetime level [35].

The highest of the radiative transition probabilities at 4F3/2 4I11/2 level transition in Table 3 are given by Nd3+ doped 67B2O3;12Li2O;20K2O and J. Pure App. Chem. Res.,

2016, 5 (2), 116-124 26 August 2016 X The journal homepage www.jpacr.ub.ac.id p-ISSN : 2302 – 4690 | e-ISSN : 2541 – 0733 122 67B2O3;12Li2O;20Na2O glasses [32].

It is claimed the radiative lifetime both glasses are lower than others and according to reported of Y.Chen et.al [36] that the high radiative transition probability and low radiative lifetime are considered to improve the radiative quantum efficiency of the laser medium. Emission spectrum The shapes and position emission spectra were recorded for the NIR range transition shown in Figure 2.

According to the energy level diagram of Nd3+ in glass, the NIR emission located at around 940-946, 1060-1070 and 1335-1346 nm that are attributed to the 4F3/2 ? 4I9/2, 4I13/2, and 4I11/2 transition respectively. Furthermore, the shape and peak position emission spectra of Nd3+ doped glass borate by exciting at 582 nm and 0.50 mole% Nd3+ content shown in Figure 3.

Figure 2 Energy level diagram of Nd3+ Figure 3 NIR Emission spectra of Nd3+ The position of emission peak wavelength of the 4F3/2 ? 4I11/2 transition shifted a few nanometers due the electric dipole transition of Nd3+ ions are very sensitive to the surrounding. This transition assigned as hypersensitive effect and can used to figure out of Nd3+-O covalency bond [30].

The peak wavelength shifted when the Nd3+ doped into the host glass due the nephelauxetic effect [37-38], this occurs due to electron orbitals with 4f configuration disabled in the host ligand field [39]. The intensity of the 4I9/2 ? 4G5/2+ 2G7/2 level transition for Nd3+ is higher than the other transition and this is in accordance with the hypersensitive regulations of the transitions such as J ? 2; ? L ? 2 and ? S = 0 [38].

The energy level structure of Nd3+ ion will be contracted with the increase in the intersection of the both oxygen and 4f orbitals leading to the wavelength shift. From the emission spectra transition in Table 3 observed that the peak emission of the 20B2O3;69.5Bi2O3;10SiO2 glasses[34] higher than others glass because this glass has a higher polarizability of the Bi-O bond.

The emission spectra depends on ? 4 and ? 6 parameters because have related to the rigidity of the host glass. In Table 3 there are three types of glass composition which have the signifies a higher stimulated emission cross section [2,32] and the consequence is the increase of the branching ratio percentage. CONCLUSIONS It has been observed the performance of the Nd3+ doped borate glass former.

This paper focused to discuss of optical properties such as absorption spectra, oscillator strength f, Jud- Ofelt parameters ? 2,4,6, branching ratio ? R, radiative transition probabilities AR, emission spectra and radiative lifetime ? R for special of the hypersensitive transition Nd3+ from 4F3/2 J. Pure App. Chem. Res., 2016, 5 (2), 116-124 26 August 2016 X The journal homepage www.jpacr.ub.ac.id p-ISSN : 2302 – 4690 | e-ISSN : 2541 – 0733 123 level to 4I11/2 level.

The highest of the oscillator strength obtained when the current of 49,5 mol% boric nevertheless the high content of borate not guarantee can increase the value of the oscillator strength. The quality of the materials is also influenced by the amount of the glass composition in the host matrix, but for to obtain the high of radiative transition, such as ? em, AR and ? R of the laser medium proposed to use of borate-lithium-potassium oxide glass.

So, each glass materials have the advantages of each in accordance with the expected parameters. REFERENCES [1] Chen, Y. J., Gong, X. H., Lin, Y. F., Luo, Z. D., & Huang, Y. D., Opt. Mat.,2010, 33(1), 71-74. [2] Kumar, K. V., Kumar, A. S., Opt. Mat., 2012, 35, 12-17 [3] De Sousa, D. F., Nunes, L. A. O., Rohling, J. H., Baesso, M. L., Appl. Phys. B, 2003, 77, 59-63 [4] Zhu, X., Jain, R. Opt. Lett., 2007, 32, 2381-2383 [5] Ams, M., Dekker, P., Marshall, G. D., Withford, M. J., Opt.

Lett., 2009, 34, 247-249 [6] Semwal, K., Bhatt, S. C., IJP, 2013, 1 (1), 15-21 [7] Rajagukguk, J., Kaewkhao, J., Djamal, M., Hidayat, R., Suprijadi., and Ruangtaweep, Y., J. Mol. Struct., 2016, 1121, 180-187. [8] Cruz, E. D. R., Kumar, G. A., Torres, L. A. D, Martinez, A., Garcia, O. B. Opt. Mat., 2001, 18, 321-329 [9] Murthy, D. V. R., Sasikala, T., Jamalaiah, B. C., Babu, A. M., Kumar, J. S., Jayasimhadri, M., Moorthy, L. R., Opt. Commun.,

2011, 284, 603-607 [10] Chimalawong, P., Kaewkhao, J., Kedkaew, C., Limsuwan, P., J. Phys. Chem. Solids, 2010, 71 965-970 [11] Yanbo, Q., Da, N., Mingying, P., Lyun, Y., Danping, C., Jianrong, Q., Congshan, Z. Akai, T., J. Rare Earths, 2006, 24 (6) 765 – 770 [12] Zhou, Q., Xu, L., Liu, L., Wang, W., Zhu, C., Gan, F., Opt. Mat., 2004, 25 (3) 313 – 319 [13] Li, S. L., Wang, K. M., Chen, F., Wang, X. L., Fu, G., Lu, Q. M., Li-Li Hu, Shen, D. Y., Ji. Ma, H., Nie, R. Surf. Coat. Tech.,

2005, 200 598-601 [14] Seshadari, M., Rao, K. V., Rao, J. L., Rao, K. S. R. K., Ratnakaram, Y. C., J. Lum., 2010, 130 536-543 [15] Naftaly, M., Jha, A. J. Appl. Phys., 2000, 87 2098 – 2104 [16] Babu, S. S., Rajeswari, R., Jang, K., Jin, C. E, Jang, K. H., Seo, H. J, Jayasankar, C. K., J. Lum., 2010, 130 1021-1025 [17] Martin, L. L., Rios, S., Martin, I. R, Gonzales, P. H., Caceres, J. M., Creus, A. H. J. Alloys Compd., 2013, 553 35-39 [18] Florez, A.,

Ulloa, E. M., Cabanzo, R. J. Alloys Compd., 2009, 488, 606-611 [19] Senthilkumar, M., Kalidasan, M., Sugan, S., Dhanasekaran, R., J. Cryst. Growth, 2013, 362 189-192 [20] Kumar, S., Khatei, J., Kasthurirengan, S., Koteswara, K. S., Ramesh, K. P. J. Non- Cryst. Solids, 2011, 357 842-846 [21] Rajagukguk, J., Hidayat, R., Suprijadi, Djamal, M., Ruangtaweep, Y., Horprathum, M., and Kaewkhao, J.,

KEM, 2016, 675-676, 424-429 [22] Mohan, S., Thind, K. S., Sharma, G., Gerward, L. Spectrochim. Acta, Part A, 2008, 70 1173-1179 [23] Wong, E. Y. J. Chem. Phys., 1961, 35 544 J. Pure App. Chem. Res., 2016, 5 (2), 116-124 26 August 2016 X The journal homepage www.jpacr.ub.ac.id p-ISSN : 2302 – 4690 | e-ISSN : 2541 – 0733 124 [24] Jyothi, E. Y., Venkatramu, V., Babu, P., Jayasankar, C. K., Bettinelli, M., Mariotto, G., Speghini, A., Opt.

Mater. 2011, 33 928 – 936 [25] Judd, B. R. Phys. Rev., 1962, 127 750 – 761 [26] Kumar, G. A., De la Rosa, E., Desirena, H. Opt. Commun., 2006, 260 601 – 606 [27] Shanmugavelu, B., Venkatramu, V., Ravi kanth Kumar, V. V. Spectrochim. Acta, Part A, 2014, 122 422-427 [28] Pal, I., Agarwai, A., Sanghi, S., Aggarwai, M. P. Opt. Mat., 2012, 34 1171-1180 [29] Das, M., Annapurna, K., Kundu, P., Dwivedi, R. N., Buddhudu, S. Mate. Lett.,

2006, 60 222-229 [30] Karthikeyan, B., Philip, R., Mohan, S. Opt. Commun., 2005, 246 153 – 162 [31] Jamalaiah, B. C., Suhasini, T., Moorthy, L. R., Kim. I. L., Yoo, D. S., Jang, K. J. Lum., 2012, 132 1144 – 1149 [32] Ratnakaram, Y. C., Kumar, A. V., Naidu, D. T., Chakradhar, R. P. S., Ramesh, K. P., J. Lum., 2004, 110 65-77 [33] Karunakaran, R. T., Marimuthu, K., Arumugam, S., Babu, S. S., Luis, S. F. L., Jayasankar, C. K. Opt. Mat.,

2010, 32 1035-1041 [34] Bhardwaj, S., Shukla, R., Sanghi, S., Agarwal, A., Pal, I. Spectrochim. Acta, Part A, 2014, 117, 191-197 [35] Nie, Q., Li, X., Dai, S., Xu, T., Chen, Y., Zhang, X. Physica B, 2007, 400 88-92 [36] Chen, Y., Huang, Y., Huang, M., Chen, R., Luo, Z., J. Am. Ceram. Soc., 2005, 88(1) 19-23 [37] Saisudha, M. B., Ramakrisna, J., Opt. Mat., 2002, 18 403-417 [38] Saisudha, M. B., Ramakrishna, J. Phys. Rev. B.,

1996, 53(10) 6186 [39] Naftaly, M., A. Jha, J.appl. Phys., 2000, 87 2098

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