Kondensirovannye Sredy Mezhfaznye Granitsy 2020 vol.22 N2, pages 225-231

The study of the luminescence of solid solutions based on yttrium fluoride doped with ytterbium and europium for photonics

Kuznetsov S.V., Nizamutdinov A.S., Madirov E.I., Konyushkin V.A., Nakladov A.N., Voronov V.V., Yapryntsev A.D., Ivanov V.K., Semashko V.V., Fedorov P.P.
Kazan Federal University, 420008, Kremlevskaya 18, Kazan, Russia

Abstract

© 2020 Voronezh State University. All right reserved. The majority of the global market for solar photovoltaic devices is based on silicon technology. It is very important to increase their effi ciency through the use of luminescent coatings, including those converting radiation from the UV-blue region of the spectrum into the near-infrared range, where silicon absorbs radiation most effi ciently (Stokes or downconversion luminescence), or from the infrared region of the spectrum in the near-infrared range (up-conversion luminescence). The aim of this research was to synthesize and study the spectral-kinetic characteristics of single-phase solid solutions of Y1-x-yEuxYbyF3 and to determine the quantum yield of down-conversion luminescence. Using the method of high-temperature melting, single-phase samples of solid solutions of Y1-x-yEuxYbyF3 with orthorhombic system were synthesized. For the series of samples with different Eu3+/Yb3+ ratios, upon double doping with these ions, the formation of the corresponding solid solutions with a crystal lattice of the b-YF3 phase was confi rmed. Their chemical composition was determined using the energy dispersion analysis, and it was established that it corresponds to the nominal one. It was shown that both Eu3+ and Yb3+ ions become luminescent upon excitation at wavelengths of 266 nm and 296 nm. This indicates these compounds as promising sensitisers of UV radiation. In this case, upon excitation at a wavelength of 266 nm, luminescence of Eu2+ ions was recorded. The maximum quantum yield values (2.2 %) of the ytterbium downconversion luminescence in the near-infrared wavelength range upon excitation at a wavelength of 266 nm were recorded for YF3:Eu:Yb with the Eu3+:Yb3+ ratios of 0.1:10.0 and 0.05:5.00.

http://dx.doi.org/10.17308/kcmf.2020.22/2834

Keywords

Down-conversion luminescence, Phosphors, Rare earth fluorides, Solar panels

References

[1] Weber E. R. Photovoltaics moving into the terawatt age. In: Proc. SPIE 10368, Next Generation Technologies for Solar Energy Conversion VIII. 2017; 10368: 1036803. DOI: https://doi. org/10.1117/12.2277978

[2] Seibt M., Kveder V. Gettering Processes and the Role of Extended Defects. In: Advanced Silicon Materials for Photovoltaic Applications. John Wiley & Sons, Ltd; 2012. pp. 127-188. DOI: https://doi.org/10.1002/9781118312193.ch4

[3] Turkevych I., et al. Strategic advantages of reactive polyiodide melts for scalable perovskite photovoltaics. Nature Nanotechnology. 2019:14(1): 57-63. DOI: https://doi.org/10.1038/s41565-018-0304-y

[4] Abdollahi Nejand B., et al. Vacuum-assisted growth of low-bandgap thin fi lms (FA 0.8 MA 0.2 Sn 0.5 Pb 0.5 I 3) for all-perovskite tandem solar cells. Advanced Energy Materials. 2020; 10(5): 1902583. DOI: https://doi.org/10.1002/aenm.201902583

[5] Im J. H., et al. 6.5 % efficient perovskite quantum-dot-sensitized solar cell. Nanoscale. 2011; 3(10): 4088-4093. DOI: https://doi.org/

[6] Huang X., Sanyang H., Wei H., Xiaogang L. Enhancing solar cell efficiency: The search for luminescent materials as spectral converters. Chemical Society Reviews. 2013; 42(1): 173-201. DOI: https://doi. org/

[7] Trupke T., Green M. A., Würfel P. Improving solar cell effi ciencies by down-conversion of high-energy photons. Journal of Applied Physics. 2002; 92(3): 1668-1674. DOI: https://doi.org/

[8] Yao H., Shen H., Tang Q. Highly luminescent up/down conversion thin fi lms prepared by a room temperature process. Thin Solid Films. 2019; 683: 1-7. DOI: https://doi.org/10.1016/j.tsf.2019.05.010

[9] Loiko P. A., Khaidukov N. M., Mendez-Ramos J., Vilejshikova E. V., Skoptsov N. A., Yumashev K. V. Upand down-conversion emissions from Er3+ doped K2YF5 and K2YbF5 crystals. Journal of Luminescence. 2016; 170: 1 - 7. D O I : H t t p s ://d o i . o r g/1 0 . 1 0 1 6/j . jlumin.2015.10.016

[10] Li L., Lou C., Cao H., Diao H., Karunakaran S. K. Enhancing concentrator monocrystalline Si solar cells by down conversion Ce3+-Yb3+ co-doped YAG phosphors. Applied Physics Letters. 2018; 113(10): 101905. DOI: https://doi.org/10.1063/1.5043221

[11] Serrano D., Braud A., Doualan J.-L., Camy P., Benayad A., Menard V., Moncorge R. Ytterbium sensitization in KY3F10: Pr3+, Yb3+ for silicon solar cells effi ciency enhancement. Optical Materials. 2011; 33(7): 1028-1031. DOI: https://doi.org/10.1016/j. optmat.2010.07.023

[12] Fischer S., Ivaturi A., Jakob P., Krämer K. W., Martin-Rodriguez R., Meijerink A., Goldschmidt J. C. Upconversion solar cell measurements under real sunlight. Optical Materials. 2018; 84: 389-395. DOI: https://doi.org/10.1016/j.optmat.2018.05.072

[13] Kuznetsov S., Ermakova Y., Voronov V., Fedorov P., Busko D., Howard I. A., Turshatov A. Upconversion quantum yields of SrF2:Yb3+, Er3+ submicron particles prepared by precipitation from aqueous solution. Journal of Materials Chemistry C. 2018; 6(3): 598-604. DOI: https://doi.org/10.1039/C7TC04913G

[14] Fischer S., Ivaturi A., Jakob P., Krämer K. W., Martin-Rodriguez R., Meijerink A., Richards B., Goldschmidt J. C. Upconversion solar cell measurements under real sunlight. Optical Materials. 2018; 84: 389-395. DOI: https://doi.org/10.1016/j. optmat.2018.05.072

[15] Lyapin A. A., Gushchin S. V., Kuznetsov S. V., Ryabochkina P. A., Ermakov A. S., Proydakova V. Yu., Voronov V. V., Fedorov P. P., Artemov S. A., Yapryntsev A. D., Ivanov V. K. Infrared-to-visible upconversion luminescence in SrF2:Er powders upon excitation of the 4I13/2 level. Optical Materials Express. 2018; 8(7): 1863-1869. DOI: https://doi.org/10.1364/OME.8.001863

[16] Rozhnova Yu. A., Kuznetsov S. V., Fedorov P. P., Voronov V. V. Synthesis of up-conversion Ho3+ and Er3+ doped strontium fluoride luminophores for visualiser of two-micron radiation. Kondensirovannye sredy i mezhfaznye granitsy = Condensed Matter and Interphases. 2016; 18(3): 408-413. Available at: https://journals.vsu.ru/kcmf/article/view/150/107 (In Russ., abstract in Eng.)

[17] Alexandrov A. A., Mayakova M. N., Voronov V. V., Pominova D. V., Kuznetsov S. V., Baranchikov A. E., Ivanov V. K., Lysakova E. I., Fedorov P. P. Synthesis of upconversion luminophores based on calcium fluoride. Kondensirovannye sredy i mezhfaznye granitsy = Condensed Matter and Interphases. 2020; 22(1): 3-10. DOI: https://doi.org/10.17308/kcmf.2020.22/2524

[18] Van Der Ende B. M., Aarts L., Meijerink A. Nearinfrared quantum cutting for photovoltaics. Advanced Materials. 2009; 21(30): 3073-3077. DOI: https://doi. org/10.1002/adma.200802220

[19] Piper W. W., DeLuca J. A., Ham F. S. Cascade fluorescent decay in Pr3+-doped fluorides: Achievement of a quantum yield greater than unity for emission of visible light. Journal of Luminescence. 1974; 8(4): 344-348. DOI: https://doi.org/10.1016/0022-2313(74)90007-6

[20] Yasyrkina D. S., Kuznetsov S. V., Ryabova A. V., Pominova D. V., Voronov V. V., Ermakov R. P., Fedorov P. P. Dependence of quantum yield of upconversion luminescence on the composition of fluorite-type solid solution NaY1-x-yYbxEryF4. Nanosystems: Physics, Chemistry, Mathematics. ifmo.ru/en/articles-2/volume4/--5/physics/paper07/

[21] Ding M., Lu C., Cao L., Song J., Ni Y., Xu Z. Facile synthesis of b-NaYF4:Ln3+ (Ln = Eu, Tb, Yb/Er, Yb/Tm) microcrystals with down- and up-conversion luminescence. Journal of Materials Science. 2013; 48(14): 4989-4998. DOI: https://doi.org/10.1007/s10853-013-7285-x

[22] Tao F., Wang Z., Yao L., Weili C., Li X. Synthesis and photoluminescence properties of truncated octahedral Eu-Doped YF3 submicrocrystals or nanocrystals. The Journal of Physical Chemistry C. 2007; 111(8): 3241-3245. DOI: https://doi.org/10.1021/jp065905z

[23] Sveshnikov B. Ya., Shirokov V. V. On the dependence of measurements of the average duration and yield of luminescence during quenching on the law of interaction of molecules. Optika i spektroskopiya [Opt. Spectrosc. (USSR)]. 1962; 12(5): 320.

[24] Kuznetsov S. V., Nizamutdinov A. S., Proydakova V. Yu., Madirov E. I., Voronov V. V., Yapryntsev A. D., Ivanov V. K., Gorieva V. G., Marisov M. A., Semashko V. V., Fedorov P. P. Synthesis and luminescence of Sr1---yYbxEuyF2+x+y solid solutions for photonics. Inorganic Materials. 2019; 55(10): 1031-1038. DOI: https://doi.org/10.1134/S002016851910008X