IRJSE International Research Journal of Science & Engineering
Int. Res. J. of Science & Engineering, Special Issue A12, February, 2023 SJIF Impact Factor 6.70
ISSN: 2322-0015 https://doi.org/10.5281/zenodo.7839072
RESEARCH ARTICLE OPEN ACCESS

Synthesis and study of $CsPbBr_3$ by using antisolvent recrystallization method for solar cell applications

Chopade MK[1], Gadekar KB[1], Rahane SN[2], Bade BR[2], Waman VS[3], Jadkar SR[2], Kamble MM[*4]

[1] PDEA's Prof. R.M. Art's, Commerce and Sciences College, Akrudi, Pune 411044 (India)
[2]Department of Physics, Savitribai Phule Pune University, Pune 411007 (India)
[3]P. E. S. Modern College of Arts, Science and Commerce, Shivajinagar, Pune 411005 (India)
[4]PDEA'S Anantrao Pawar College, Pirangut, Mulshi, Pune 412115 (India)
Corresponding author Email: mmkamble14@gmail.com

Manuscript Details
Available online on https://www.irjse.in
ISSN: 2322-0015

Editor: Dr. Arvind Chavhan

Cite this article as:
Chopade MK, Gadekar KB, Rahane SN, Bade BR, Waman VS, Jadkar SR, Kamble MM. Synthesis and study of $CsPbBr_3$ by using antisolvent recrystallization method for solar cell applications, *Int. Res. Journal of Science & Engineering,* 2023, Special Issue A12:141-146.
https://doi.org/10.5281/zenodo.7839072

Article published in Special issue of International Conference on "Recent Trends in Materials Science, Synthesis, Characterization and Applications (RTMS-2023)" organized by Department of Physics, Anekant Education Society's, Tuljaram Chaturchand College of Arts, Science and Commerce, Baramati, Dist Pune, Maharashtra, India (Autonomous) date, January 3-4, 2023.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this license, visit http://creativecommons.org/licenses/by/4.0

Abstract

The cesium lead bromide ($CsPbBr_3$) perovskite gets considerable attention due to its excellent stability and moisture-tolerance aspects. In this study, a structural, optical and morphological property of $CsPbBr_3$ was investigated. The $CsPbBr_3$ was synthesized at room temperature by an antisolvent recrystallization method using Cesium Bromide (CsBr), Lead Bromide ($PbBr_2$), Oleylamine (OAm) and Oleic acid (OA). The Oleic acid is acts as the capping ligand. The Synthesized $CsPbBr_3$ nanoparticles were confirmed by X-Ray diffraction pattern. The optical bandagap and absorption were investigated from UV-Visible spectroscopy. In this work sample showed a bright green photo-luminescence when the sample was excited by 365 nm UV lamp. The morphology and elemental compositions were analyzed using SEM and EDAX. The results obtained are important for the synthesis of perovskite materials at room temperature for optoelectronic devices.

Keywords: Nanocrystals, Perovskites, Photovoltaics, $CsPbBr_3$, Thin film, Capping ligands, Room temperature synthesis.

Introduction

The scientific communities are searching the semiconductor materials that are easy to fabricate, stable in operating devices, and abundant elements in nature for the next generation of optoelectronics.

In the recent years, Perovskite materials have gained much attention particularly in the field of photovoltaics due to its outstanding optoelectronic properties and it could compete with silicon. The success and fast improvement in perovskite optoelectronics mainly due to their facile fabrication, chemical versatility, and excellent optoelectronic properties. In all inorganic counterparts ($CsPbX_3$, X = I, Br, Cl) with changing inorganic Cs cation shows progress in stability and charge carrier transfer properties [1]. The $CsPbBr_3$ perovskite material has excellent optoelectronic properties such as large light absorption coefficient, high carrier mobility, long diffusion length, long electron-hole diffusion length, tunable direct bandgap with low trap state density, and simple to manufacture [2,3]. Thus $CsPbBr_3$ is the excellent candidates for the application in solar cells [4], light emitting diode [5], photodetectors [6], lasers [7], high-energy ray detectors.[8]

There exists several methods to synthesize $CsPbBr_3$ including hot injection method, conversion method, solution temperature lowering (STL) method, inverse-temperature crystallization etc. The solution-processed semiconductor material synthesis has received tremendous attention in the field of photovoltaics. Herein, we report a quality $CsPbBr_3$ NPs synthesized at room temperature from oleic acid and oleylamine ligands by a simple Anti solvent recrystallization method. After synthesizing $CsPbBr_3$, structural, optical, morphological and compositional properties have been investigated with various analytical techniques.

Methodology

The Cesium Bromide (CsBr, 99.999 %), Lead Bromide (PbBr2, 99.999 %), Oleylamine (OAm, 70 %), Oleic acid (OA, 90 %) were used with the purity level as mentioned in parenthesis. The chemicals mentioned above used for the synthesis of $CsPbBr_3$ were procured from Sigma-Aldrich and used without further purification and processing. The N, N- Dimethylformamide (DMF 99.8 %), n- hexane (Aldrich) and toluene (99.5 %) were purchased from HPLC India with AR grade.

a. Preparation of $CsPbBr_3$ nanoparticles and thin film

The $CsPbBr_3$ nanoparticles were synthesized at room temperature by a simple antisolvent recrystallization method using two different precursors (CsBr, $PbBr_2$), solvent (DMF) and ligands (OA & OAm). Nucleation starts immediately after the injection of solvent. The CsBr (0.2 mmol) and $PbBr_2$ (0.2 mmol) were dissolved in 5 ml of DMF and stirred until it converts into transparent solution at ambient temperature. Later, 500 µl of OA and 200 µl of OAm were added to the precursor solution to stabilize it. Then 2 ml precursor solution injected drop-wise into anti solvent toluene (10 ml), under continuous stirring. Within 5-10 second, the green colloidal solution was obtained. Figure 1 shows the schematic procedure for the $CsPbBr_3$ synthesis.

b. **Purification of $CsPbBr_3$ Material:**

The solution prepared by the procedure mentioned above containing $CsPbBr_3$ was then taken out and centrifuged at 4500 rpm for 10 min. The centrifuge sediment was given twice a toluene and n-hexane wash, and the final sediment of $CsPbBr_3$ was collected and redispersed in toluene for further characterizations. The soda-lime glass was used as a substrate to deposit a thin film of $CsPbBr_3$. The substrates were carefully cleaned sequentially in acetone and double distilled water. The $CsPbBr_3$nanoparticles solution was deposited on the soda-lime substrate by drop cast method, and the deposited films were dried at room temperature for 2 hour and used for further characterizations.

c. Film and Nanoparticles characterization:

The synthesised $CsPbBr_3$ thin film and nanoparticles has been investigated by different characterization techniques for the detailed study of Structural, Optical and Morphological Properties. The X-ray diffraction pattern was obtained by X-ray diffractometer (Bruker D8 Advance, Germany) using CuKα line (λ = 1·54 Å). The absorbance of the $CsPbBr_3$ was measured using a JASCO, V-670 UV–visible spectrophotometer in the range of 300-1200 nm. The steady-state photoluminescence (PL) spectra were recorded. The samples were excited using 430 nm line for recording steady-state PL. The surface morphology of the $CsPbBr_3$ film is investigated using scanning electron microscopy.

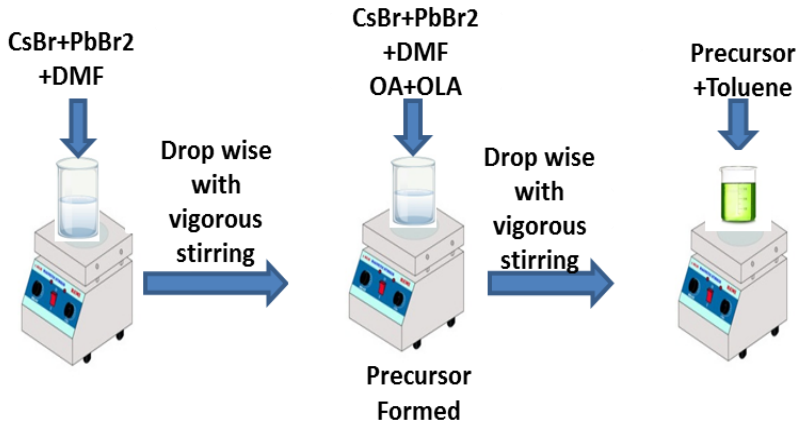

Figure 1. Schematic reaction procedure of CsPbBr3 synthesis

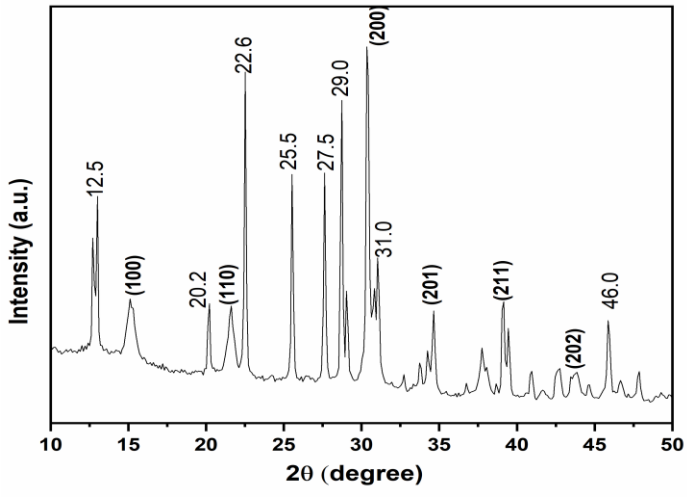

Figure 2. XRD pattern of the $CsPbBr_3$ thin film

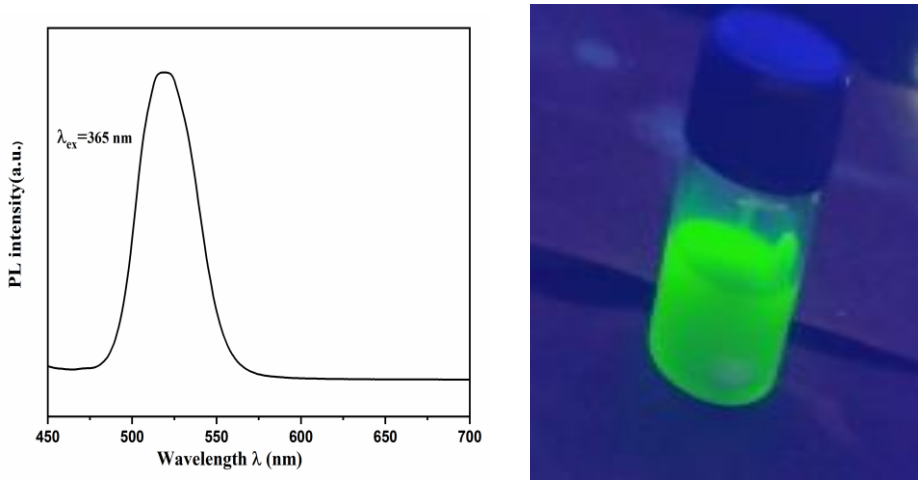

Figure 3 a) PL emission spectra b) digital image of $CsPbBr_3$ solution under the 365 nm UV lamp

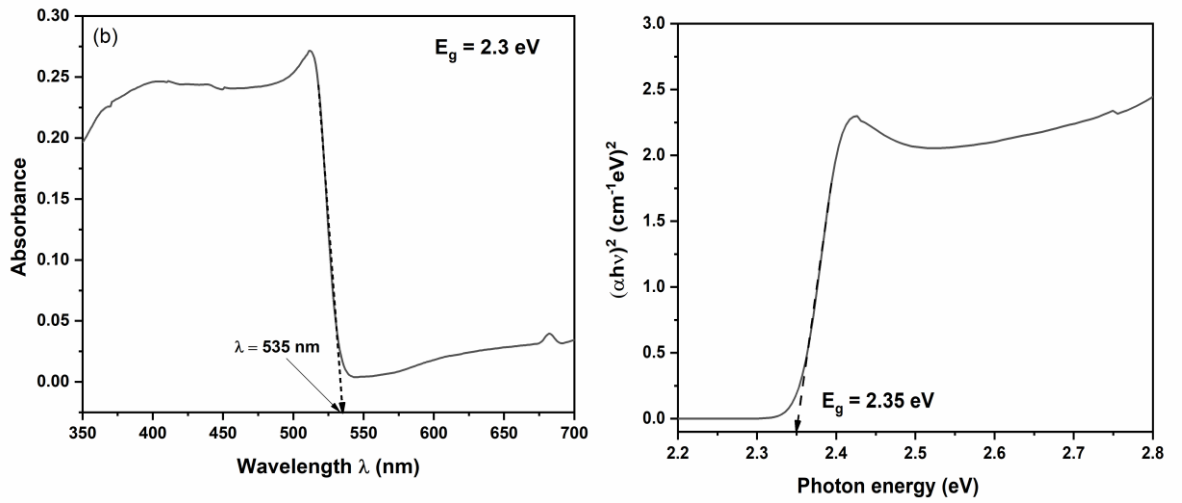

Figure4 a) UV- Visible absorption Spectra b)Tauc plot of $CsPbBr_3$

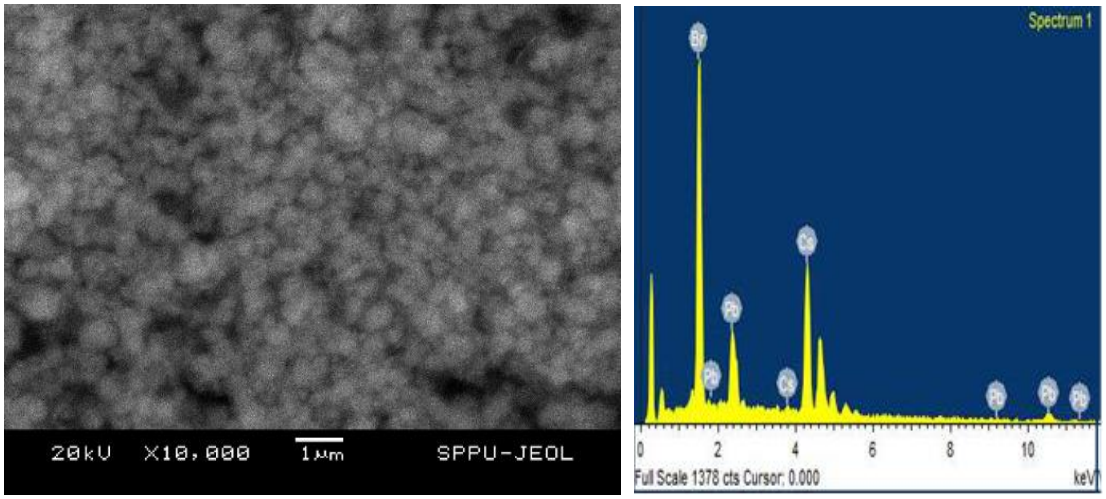

Figure 5 (a) SEM images of CsPbBr3 Thin Film (b) EDAX pattern of $CsPbBr_3$Thin FIlm

Table1: atomic percentages of Cs, Pb and Br

Element	Wt. (%)	At. (%)
Cs	39.38	32.30
Pb	17.91	9.42
Br	42.71	58.28

Result and Discussion

Growth Mechanism of CsPbBr3 Nanoparticles:

To synthesis $CsPbBr_3$ nanoparticles, two different precursors (CsBr and $PbBr_2$) and ligands (OLA and OA) and two different solutions (DMF and Toluene) were used. The 10 ml DMF solution was added drop-wise into two different precursors under continuous stirring. The precursors start to dissolve into DMF solution and convert it into transparent solution. At the initial stage, precursor concentration is too low to permit the growth of $CsPbBr_3$ nanoparticles, and no nucleation process occurs at this stage. After adding Ligands (OA, OAm)

precursor solution is formed. Then immediately, 2 ml precursor solution injected into 10 ml toluene with vigorous stirring, which can provide essential nutrients for crystallization and growth of larger $CsPbBr_3$ nanoparticles.

X-Ray diffraction analysis:

The X-ray diffraction (XRD) pattern of the $CsPbBr_3$ thin film is shown in figure 2. In the XRD pattern, the peaks at 2θ equal to 15.109°, 21.6204°, 31.037°, 34.543°, 37.748°, 44.660° are assigned to the (100), (110), (200), (201),(211) and (202) planes respectively. The XRD pattern shows the monoclinic crystal structure of the $CsPbBr_3$ with lattice parameter a = b = c = 5.83 Å. The results are well-matched with the previous reports and the JCPDS file no. (#18-0364) [9], the monoclinic $CsPbBr_3$ shows polycrystalline in nature. The diffraction peaks observed nearly at 2θ equal to 12.5°, 20.2°,22.6°, 25.5°, 27.5°,29.0°,31.0° and 46.0° are correspond to the secondary phases and it will vanishes after the annealing of the sample. The diffraction peaks are sharp and narrower, indicating the better crystallinity of the material.

UV- visible and Photoluminiscence spectroscopic analysis

To explore the optical properties of the $CsPbBr_3$Photolumenance (PL) was carried out. The PL studies shows that the emission from the $CsPbBr_3$ is in visible region with broad FWHM of 33 nm observed, as shown in Figure 3(a). The PL peak was located at 520 nm. The $CsPbBr_3$ nanoparticle showed bright green photo-luminescence when the sample was excited by 365 nm UV lamp as shown in fig. 3(b). After the confirmation of crystal structure of $CsPbBr_3$, the colloidal solution of the sample was used for UV-Visible spectroscopic measurements. The UV-Visible absorption spectra of $CsPbBr_3$ is shown in figure 4(a). The spectra shows a strong absorption peak at 535 nm, which is the bandgap absorption of $CsPbBr_3$ perovskite [10]. The optical band gap was estimated using the relation of $(\alpha h\upsilon)^2$ vs. $h\upsilon$, where α is an absorbance, h is the Planks constant and υ is frequency. The effective optical band gap energy is 2.3 eV.

Morphology and Composition Analysis of $CsPbBr_3$

The morphology and EDAX Spectra of the $CsPbBr_3$ sample is shown in figure 5(a) and 5(b). The SEM image of $CsPbBr_3$ sample shows the agglomeration of particles is visible in the mode under lower magnification. Table 1 shows the atomic percentages of Cs, Pb and Br. The EDAX confirms the presence of all elements in the materials. The excess in the lead (Pb) signal is due to the reabsorption of X-ray emission by cesium (Cs). Similarly, the excess in the bromide (Br) signal is due of the reabsorption of X-rays from Cs and Pb [11].

Conclusions

This work explains a detailed study of structural, optical and compositional analysis of $CsPbBr_3$ thin film and nanoparticles. We have successfully synthesized the $CsPbBr_3$ NPs at room temperature using antisolvent recrystallization method. The formation of $CsPbBr_3$ was confirmed from the XRD pattern. The UV-Visible spectroscopic analysis shows a strong absorption peak at 535 nm. The calculated bandgap energy of $CsPbBr_3$ was found to be 2.3 eV. The wavelength of PL emission spectra is at 520 nm with a narrow FWHM of 33nm have been observed. The EDAX pattern confirms the presence of all the elements in the material. The controlled room-temperature synthesis and formation of thin films of $CsPbBr_3$nanoparticles with promising properties can open a novel path for low-cost optoelectronic devices.

Acknowledgment

The author MKC is thankful to the Department of Physics, Savitribai Phule Pune University, Pune for using their facility.

Conflicts of interest: The authors stated that no conflicts of interest.

References

1. M. Kulbak, S. Gupta, N. Kedem, I. Levine, T. Bendikov, G. Hodes et.al. Cesium enhances long-term stability of

lead bromide perovskite-based solar cells. J. Phys. Chem. Lett., 2015; 7 : 167-172.

2. Sherkar, T. S., Cristina Momblona,Lidon Gil-Escrig, Jorge Ávila,Michele Sessolo,Henk J. Bolinket al. Recombination in perovskite solar cells: significance of grain boundaries, interface traps, and defect ions. ACS Energy Lett.2017; 2: 1214–1222
3. Dane W. De Quilettes, Sarah M. Vorpahl, Samuel D. Stranks, Hirokazu Nagaoka, Giles E. Eperon, Mark E. Ziffer et al. Impact of microstructure on local carrier lifetime in perovskite solar cells. Science,2015;348: 683–686.
4. W.S. Yang, J.H. Noh, N.J. Jeon, Y.C. Kim, S. Ryu, J. Seo, et al. High-performance photovoltaic perovskite layers fabricated through intramolecular exchange. Science,2015; 348: 1234-1237.
5. S.D. Stranks, H.J. Snaith. Metal-halide perovskites for photovoltaic and light-emitting devices,. Nat. Nanotechnol., 2015;10: 391-402.
6. M.I. Saidaminov, V. Adinolfi, R. Comin, A.L. Abdelhady, W. Peng, I. Dursun et al. Planar-integrated single-crystalline perovskite photodetectors. Nat. Commun.,2015; 6: 8724-8724.
7. S. Chen, K. Roh, J. Lee, W.K. Chong, Y. Lu, N. Mathews et al. A photonic crystal laser from solution based organo-lead iodide perovskite thin films. ACS Nano,2016; 10: 3959-396.
8. Jiali Peng, Chelsea Q. Xia , YalunXu, Ruiming Li, Lihao Cui, Jack K. Clegg et. al. Crystallization of CsPbBr3 single crystals in water for X-ray detection. Nature Communications; 2021; 12:1531-1541.
9. G. Hu, W. Qin, M. Liu, X. Ren, X. Wu, L. Yang, and Yin, S.Scalable room-temperature synthesis of plum-pudding-like Cs4PbBr6/CsPbBr3 microcrystals exhibiting excellent photoluminescence. J. Mater. Chem. C, 2019; 7:, 4733–4739.
10. J. Kulbak, D. Cahen, G. Hodes. How important is the organic part of lead halide perovskite photovoltaic cells? Efficient CsPbBr3 cells. J. Phys. Chem. Lett.,2015; 6: 2452–2456.
11. Kirti Agrawal , Syed Mohammad, Abid Hasan, Joanna Blawat, Nishir Mehta, Yuming Wang et al. Thermal, Physical, and Optical Properties of the Solution and Melt Synthesized Single Crystal $CsPbBr_3$ Halide Perovskite. Chemosensors, 2022; 10(369): 1-12.

© 2023 | Published by IRJSE

Submit your manuscript to a IRJSE journal and benefit from:

- ✓ Convenient online submission
- ✓ Rigorous peer review
- ✓ Immediate publication on acceptance
- ✓ Open access: articles freely available online
- ✓ High visibility within the field

Submit your next manuscript to IRJSE through our manuscript management system uploading at the menu "Make a Submission" on journal website

https://irjse.in/se/index.php/home/about/submissions

For enquiry or any query email us: editor@irjse.in