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SYNTHESIS AND SPECTRAL ANALYSIS OF FAPbI3 PEROVSKITE QUANTUM DOTS AT ROOM TEMPERATURE IN VARIOUS SOLVENTS

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Abstract

In this study, $FAPbI_3$ perovskite quantum dots were synthesized at room temperature using ligand-assisted redeposition in the presence of various antisolvents. The resulting red-emitting quantum dots had an absorption edge at a wavelength of 700 nm, and the emission maxima appeared in the range of 650 nm to 800 nm, depending on the type of antisolvent. In addition, these results showed that the appropriate selection of the volume ratio of ligands during synthesis plays an important role in the formation of the quantum dot size. The synthesized $FAPbI_3$ perovskite quantum dots can be used to prepare solar cells, LED lamps, and photovoltaic (PV) devices due to their excellent optoelectronic properties.

Keywords: *LARP method, perovskite quantum dots, ligands, $FAPbI_3$, antisolvent, solar cells, emission spectrum*

Introduction

In the twenty-first century, the rapid development of the economy has led to an increase in energy consumption and the increasing attention to renewable energy sources based on solar cells (Zhang, Y., 2026). Solar cells based on high purity silicon are mainly used on an industrial scale. Such solar cells have disadvantages such as high efficiency, high stability, high assimilation efficiency, high material consumption, and high cost. Therefore, perovskite-structured materials for solar cells have attracted the attention of many researchers in the last decade (Sharma, R., Sharma, A., Agarwal, S., & Dhaka, M. S., 2022). The most popular methods for synthesizing perovskite quantum dots include the hot injection method and the room temperature ligand-assisted redeposition method (Gielen, D., Boshell, F., Saygin, D., Bazilian, M. D., Wagner, N., & Gorini, R., 2019). One of these two methods, the ligand-assisted redeposition method (LARP), has the great advantage of not requiring an inert atmosphere and high temperature. This method is widely used in the production of perovskite-structured materials containing bromide ions. However, perovskite-structured materials containing iodide ions can also be synthesized by selecting appro-

priate ligands, antisolvents, and solvents (Vighnesh, K., Wang, S., Liu, H., & Rogach, A. L., 2022; Tong, Y., Bladt, E., Aygüler, M. F., Manzi, A., Milowska, K. Z., Hintermayr, V. A., & Feldmann, J., 2016; Zhang, D., Yu, M., Xu, Y., Li, D., Huang, Y., Yu, C., & Lin, J., 2022; Pan, H., Xu, X., Liu, J., Li, X., Zhang, H., Huang, A., & Xiao, Z., 2021).

The synthesis of perovskite nanocrystals using hot injection (HI) is one of the most common methods to obtain high quality luminescent materials, and is a method for producing nanocrystals in a high temperature and inert environment. The hot injection method was first used in the synthesis of cadmium chalcogenide (CdS, CdSe, CdTe) nanocrystals. Then this method began to be widely used in the synthesis of nanomaterials with other compositions (Zhong, Q., Cao, M., Xu, Y., Li, P., Zhang, Y., Hu, H., & Zhang, Q., 2019). In addition, it is also widely used in the processes of obtaining perovskite-structured quantum dots. The synthesis of perovskite quantum dots with a $CsPbBr_3$ composition by the LARP method is described in another literature. For this, CsBr and $PbBr_2$ were first dissolved separately in equal molar ratios in ethanol and dimethylformamide (DMF), respectively. 10 ml of hexane and the corresponding ligands were added to a three-necked flask and mixed at room temperature on a magnetic stirrer. After a certain time, lead and cesium precursors were added to a three-neck flask in precise amounts, forming a yellow precipitate. The quantum dots were separated from this solution by centrifugation and remelted to form bright fluorescent perovskite quantum dots (Chun, F., Zhang, B., Li, Y., Li, W., Xie, M., Peng, X., & Yang, W., 2020).

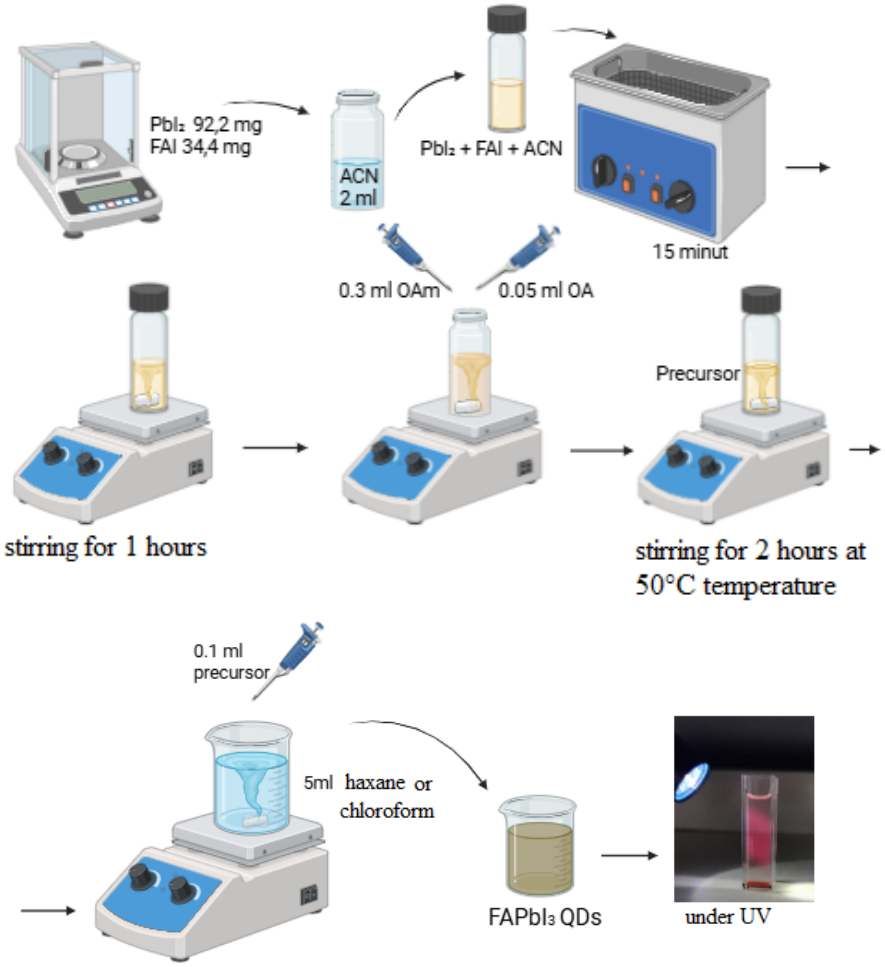
Another study used DMF as a solvent in the synthesis of $MAPbI_3$ quantum dots based on the LARP method. In this process, it was also noted that the stability of quantum dots depends on the amount of DMF. That is, changes in the stability of $MAPbI_3$ quantum dots were observed by using high and less DMF. It was observed that when less DMF was used as a solvent, the quantum dots did not lose their bright fluorescence for up to 12 hours. It was studied that the use of more DMF led to the degradation of bright red fluorescence for up to 1 minute. The use of less solvent also leads to fewer crystal defects. In a similar process, DMF was used as a solvent and chloroform as an antisolvent in the synthesis of $MAPbI_3$ quantum dots using the LARP method. Oleic acid (OAc) and oleylamine (OAm) were used for surface passivation. The use of chloroform as an antisolvent helps to increase the stability of perovskites containing iodide ions (Tashpulatov, K., Norboev, K., Toshpulatov, D., Magdiev, S., Nasimov, A., Mirzaev, S., & Yakubov, B., 2025).

The aim of this work is to synthesize $FAPbBI_3$ perovskite dots using various antisolvents and study their spectral properties. We utilize modern characterization method to study prepared nanocrystals.

Method of research

Synthesis of perovskite quantum dots with FAPbI3 composition. Using acetonitrile (ACN) instead of DMF as a good solvent, $FAPbI_3$ perovskite quantum dots were synthesized by the LARP method at room temperature. For this, FAI and PbI_2 salts were initially weighed on an analytical balance in a 1:1 molar ratio. The measured salts were dissolved in 2 ml of acetonitrile and kept in an ultrasonic bath for 15 minutes. The resulting mixture was formed in a yellowish paste. That is, these salts were observed to have limited solubility in acetonitrile. The resulting mixture was stirred for 1 hour on a magnetic stirrer and ligands such as OAm and OAc were added in a volume ratio of 0.5:3. After the ligands were added, the yellowish paste slowly began to dissolve and a dark mass was formed at the bottom of the vessel and a bright yellow homogeneous solution was formed at the top. The solution was stirred at a constant speed on a magnetic stirrer for two hours at a temperature of 50 °C. After 2 hours, 0.1 ml of the resulting precursor was added to 5 ml of antisolvent hexane, which was stirred vigorously on a magnetic stirrer. As a result, the formation of colloidal $FAPbI_3$-containing perovskite quantum dots with clear bright red fluorescence was observed (Figure 1). When 0.1 ml of the same precursor was added to chloroform, which was stirred vigorously on a magnetic stirrer, the formation of quantum dots was also observed.

Figure 1. *Scheme of room temperature synthesis of $FAPbI_3$ quantum dots based on acetonitrile (good solvent) and hexane/chloroform (antisolvent)*



Research results

$FAPbI_3$ perovskite quantum dots belong to the type of inorganic-organic perovskite quantum dots. The difference from inorganic perovskites is that inorganic-organic perovskite quantum dots contain organic cations (such as MA^+, FA^+) as cations. In the synthesis of such perovskites, it is also important to choose "good" and "bad" solvents. "Good" and "bad" solvents for FAI and PbI2 salts are listed in Table 1 below.

Table 1. *Properties of solvents used in the LARP method and the solubility of salts in them*

"Good" solvent	b.p. (°C)	Relative permittivity	FAI solubility	PbI_2 solubility	"Bad" solvent
DMSO	189	46.7	Good	Good	Toluene
DMF	153	36.7	Good	Good	Toluene
ACN	82	37.5	Poor	Poor	Toluene
DMSO	189	46.7	Good	Good	Chloroform
DMF	153	36.7	Good	Good	Chloroform
ACN	82	37.5	Poor	Poor	Chloroform
DMSO	189	46.7	Good	Good	Hexane

"Good" solvent	b.p. (°C)	Relative permittivity	FAI solubility	PbI_2 solubility	"Bad" solvent
DMF	153	36.7	Good	Good	Hexane
ACN	82	37.5	Poor	Poor	Hexane

Solvents such as DMF and ACN have been widely used in the synthesis of $FAPbI_3$ quantum dots. The fact that FAI and PbI_2 salts dissolve well in the "good" solvent DMF makes it convenient to prepare precursors. The salts were poorly soluble in acetonitrile. However, the solubility improved with the addition of ligands and the effect of temperature

$$FAI_{(ACN)} + PbI_{2(ACN)} \rightarrow FAPbI_{3(ACN)}$$

The absorption spectra of $FAPbI_3$ quantum dots synthesized in acetonitrile/chloroform ("good"/"bad" solvents) is unique, with a broad range between 400 and 700 nm. It was found that the broad absorption band and the absorption edge characteristic of quantum dots are at 700 nm (Figure 2). The emission spectrum of the same $FAPbI_3$ perovskite quantum dots has a unique spectrum, with a maximum emission at around 760 nm, indicating that they have red emission (Figure 3).

Figure 2. *Absorption spectrum of $FAPbI_3$ perovskite quantum dots dispersed in chloroform*

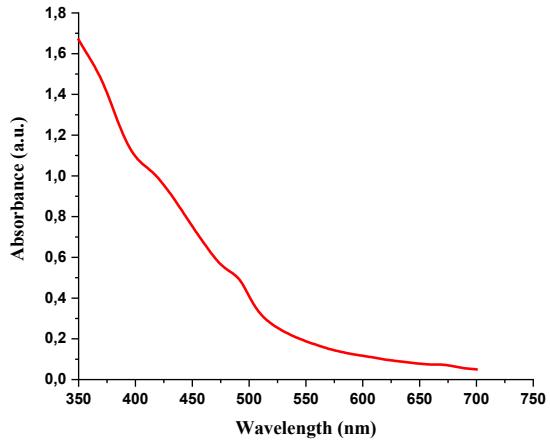


Figure 3. *Emission spectrum of $FAPbI_3$ perovskite quantum dots*

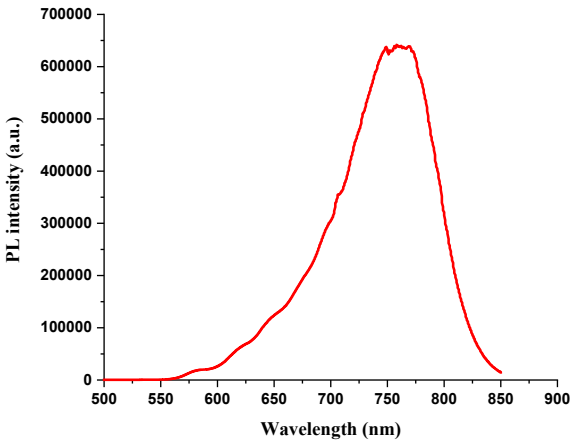
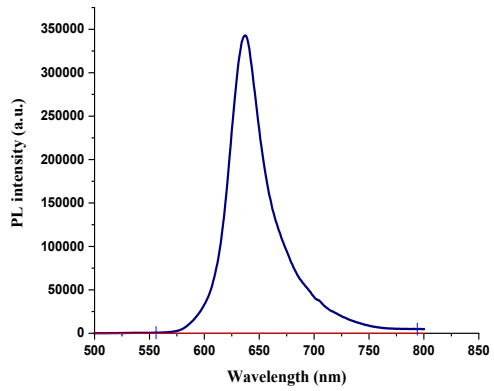
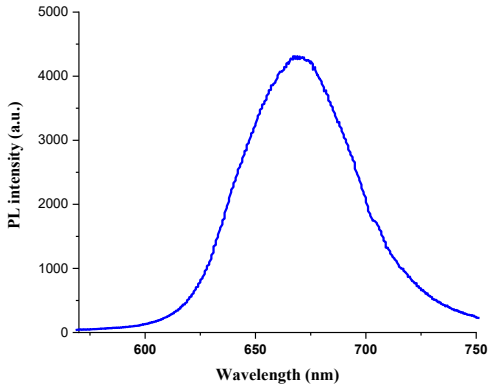


Figure 4. *Emission spectra of $FAPbI_3$ perovskite quantum dots prepared using DMF/chloroform and DMF/hexane pair*





Based on the spectra above, it can be said that the ACN/chloroform pair is consistent with each other and the obtained quantum dots are relatively monodisperse. However, the emission spectra of $FAPbI_3$ perovskite synthesized based on the DMF/chloroform and DMF/hexane solvent pairs are also depicted in Figure 4. The emission spectrum of

$FAPbI_3$ perovskite quantum dots synthesized based on the DMF/chloroform solvent pair has orange color with the emission maximum at 640 nm. The emission spectrum of $FAPbI_3$ perovskite synthesized in the DMF/hexane pair was also found to be unique and has a red emission at 670 nm.

Based on the spectrum of the perovskite quantum dots obtained based on the DMF/chloroform pair, it can be said that the perovskite quantum dots obtained based on the DMF/chloroform pair are also monodisperse. It was observed that the solution of $FAPbI_3$ quantum dots synthesized based on the DMF/hexane was transparent and very homogeneous and had a red emission under a UV lamp. However, it can be observed that $FAPbI_3$ quantum dots synthesized based on the DMF/chloroform pair are more stable and intense than quantum dots obtained based on the DMF/hexane pair (Figure 4).

The full-with at half maximum (FWHM) value of the $FAPbI_3$ perovskite quantum dots synthesized based on the DMF/hexane pair was found to be larger than that of the sample synthesized based on the DMF/chloroform pair. Therefore, it can be proposed that the monodispersity is lower than that of the particles synthesized based on the DMF/chloroform pair. When the FWHM value of the $FAPbI_3$ perovskite quantum dots synthesized based on the DMF/chloroform pair was calculated based on the emission spectrum, it was found that the monodispersity is lower than that of acetonitrile/chloroform. This is because the emission spectrum of the perovskite synthesized based on the DMF/chloroform pair has a smaller amount of red shift and a wider shift towards the emission side.

Conclusions

$FAPbI_3$ perovskite quantum dots were synthesized at room temperature by the ligand-involved redeposition method in various “good” and “bad” solvents. According to the results of spectral analysis, it was found that the effect of solvents and ligands is an important factor in the formation of quantum dots. During the experiments, relatively stable $FAPbI_3$ perovskite quantum dots were observed in samples synthesized in the presence of DMF/chloroform and ACN/chloroform pairs. It was observed that the formation and stability of quantum dots were ensured when the volume ratios of ligands were added in the case of 0.5:3 (oleylamine: oleic acid).

References

Zhang, Y. (2026). Solar PV in the 21st century: Aligning technological growth with sustainability. Next Energy, 10, 100499. URL: https://doi.org/10.1016/j.nxener.2025.100499

Sharma, R., Sharma, A., Agarwal, S., & Dhaka, M. S. (2022). Stability and efficiency issues, solutions and advancements in perovskite solar cells: A review. Solar Energy, – 244. – P. 516–535. URL: https://doi.org/10.1016/j.solener.2022.08.001

Gielen, D., Boshell, F., Saygin, D., Bazilian, M. D., Wagner, N., & Gorini, R. (2019). The role of renewable energy in the global energy transformation. Energy strategy reviews, – 24. – P. 38–50. URL: https://doi.org/10.1016/j.esr.2019.01.006

Vighnesh, K., Wang, S., Liu, H., & Rogach, A. L. (2022). Hot-injection synthesis protocol for green-emitting cesium lead bromide perovskite nanocrystals. URL: https://doi.org/10.1021/acsnano.2c11689

Tong, Y., Bladt, E., Aygüler, M. F., Manzi, A., Milowska, K. Z., Hintermayr, V. A., & Feldmann, J. (2016). Highly luminescent cesium lead halide perovskite nanocrystals with tunable composition and thickness by ultrasonication. Angewandte Chemie International Edition, – 55(44). – P. 13887–13892. URL: https://doi.org/10.1002/anie.201605909

Zhang, D., Yu, M., Xu, Y., Li, D., Huang, Y., Yu, C., ... & Lin, J. (2022). Solvothermal synthesis of perovskite $CsPbCl_3$ nanoplates and improved photoluminescence performance through postsynthetic treatment. Optical Materials, – 127. – 112257 p. URL: https://doi.org/10.1016/j.optmat.2022.112257

Pan, H., Xu, X., Liu, J., Li, X., Zhang, H., Huang, A., & Xiao, Z. (2021). Microwave-assisted synthesis of blue-emitting cesium bismuth bromine perovskite nanocrystals without

polar solvent. Journal of Alloys and Compounds, – 886. – 161248 p. URL: https://doi.org/10.1016/j.jallcom.2021.161248

Zhong, Q., Cao, M., Xu, Y., Li, P., Zhang, Y., Hu, H. & Zhang, Q. (2019). L-type ligand-assisted acid-free synthesis of $CsPbBr_3$ nanocrystals with near-unity photoluminescence quantum yield and high stability. Nano Letters, – 19(6). – P. 4151–4157. URL: https://doi.org/10.1021/acs.nanolett.9b01666

Chun, F., Zhang, B., Li, Y., Li, W., Xie, M., Peng, X., ... & Yang, W. (2020). Internally-externally defects-tailored $MAPbI_3$ perovskites with highly enhanced air stability and quantum yield. Chemical Engineering Journal, – 399. – 125715 p. URL: https://doi.org/10.1016/j.cej.2020.125715

Tashpulatov, K., Norboev, K., Toshpulatov, D., Magdiev, S., Nasimov, A., Mirzaev, S., & Yakubov, B. (2025). Facile Synthesis of Stable and Highly Luminescent $MAPbI_3$ Perovskite Quantum Dots. Journal of Fluorescence, – 35(10). – P. 9553–9557. URL: https://doi.org/10.1007/s10895-025-04258-2

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