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SINGLE-LAYER BLUE LEDS BASED ON A PEROVSKITE–POLYMER COMPOSITE

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Abstract. A practical solution to the challenge of simple and stable blue LEDs is proposed: a solution-processed single-layer device based on a perovskite–polymer composite. Stable blue electroluminescence at low operating voltages is demonstrated, and prospects for further optimization and practical implementation are outlined.

Keywords: blue LEDs; halide perovskites; perovskite–polymer composite; single-layer architecture; electroluminescence; solution processing; implementation.

Аннотация. В работе предложено практическое решение проблемы создания технологически простых и стабильных синих светодиодов: однослойная архитектура на основе перовскит–полимерного композита, полученного растворным методом. Показана возможность устойчивой синей электролюминесценции при низких напряжениях и обозначены перспективы оптимизации для внедрения.

Ключевые слова: синие светодиоды; галогенидные перовскиты; перовскит–полимерный композит; однослойная архитектура; электролюминесценция; растворные методы; внедрение.

Annotatsiya.
Annotatsiya. Ushbu ishda texnologik jihatdan sodda va barqaror ko‘k svetodiod yaratish muammosining amaliy yechimi taklif etildi: eritma asosida olingan perovskit–polimer kompozitiga asoslangan bir qatlamli arxitektura. Past ishchi kuchlanishlarda barqaror ko‘k elektroluminessensiya ko‘rsatildi va amaliyotga joriy etish istiqbollari bayon qilindi.

Kalit so‘zlar: ko‘k svetodiod; galogenid perovskitlar; perovskit–polimer kompoziti; bir qatlamli arxitektura; elektroluminessensiya; eritma usuli; amaliyotga joriy etish.

Introduction

The practical implementation of research results in optoelectronic devices remains a key challenge in modern materials science, particularly for young scientists and doctoral researchers. Blue light-emitting diodes (LEDs) are essential components of full-color displays, solid-state lighting, and sensing systems; however, the realization of stable and low-cost blue emitters is still limited by material instability and device-architecture complexity [1,2].

Conventional high-performance LEDs are typically based on multilayer thin-film structures incorporating separate electron- and hole-transport layers. Although such architectures provide efficient charge injection and recombination, they require vacuum-based fabrication techniques, expensive materials, and strict process control, which significantly increases production costs and restricts scalability [3,4]. As a result, there remains a gap between laboratory-scale demonstrations and practical deployment of blue-emitting devices.

In this context, single-layer LED architectures fabricated via solution-based methods have attracted growing attention as a potential route toward simplified processing and cost reduction [5]. By reducing the number of functional layers and technological steps, single-layer designs are better suited for scalable manufacturing. Nevertheless, the realization of reliable single-layer blue LEDs remains challenging due to inefficient charge injection, enhanced nonradiative recombination, and degradation of the emissive layer under electrical bias [6].

Halide perovskites based on alkali metals and lead have emerged as promising optoelectronic materials owing to their strong optical absorption, narrow-band emission, and pronounced excitonic photoluminescence at room temperature [7,8]. At the same time, blue-emitting perovskite compositions are particularly sensitive to structural defects and phase instability, which negatively affects operational stability and limits their practical application [9].

A promising practical strategy to overcome these limitations involves the formation of hybrid perovskite–polymer composites. Incorporation of a polymer matrix has been shown to improve film-forming properties, restrict crystallite growth, and partially passivate defect states, thereby enhancing structural robustness and reproducibility of solution-processed devices [10-14]. In addition, polymer-assisted charge redistribution can be beneficial for simplified single-layer architectures lacking dedicated transport layers.

In this work, a solution-processed single-layer blue LED based on a hybrid perovskite–polymer composite is investigated with emphasis on electroluminescent behavior and charge-transport mechanisms. The study is focused on demonstrating a feasible and experimentally accessible pathway for translating material design into simplified device architectures, as well as outlining prospects for further optimization toward practical optoelectronic implementation.

Materials and methods

Potassium bromide (KBr) and lead bromide ($PbBr_2$) were used as inorganic precursors for the formation of the perovskite phase. Dimethyl sulfoxide (DMSO) served as the solvent, polyethylene oxide (PEO) was employed as the polymer matrix, and oleic acid (OA) together with OAc were used as stabilizing and defect-passivating additives. All reagents were of analytical grade and were used as received.

The precursor solution for the emissive layer was prepared by dissolving KBr and $PbBr_2$ in a molar ratio of 1:1 in DMSO under continuous stirring until a homogeneous and transparent solution was obtained. After complete dissolution of the inorganic components, PEO was added to form a polymer-assisted system, followed by the introduction of organic additives to stabilize the perovskite phase. The resulting mixture was stirred until full homogenization, yielding a hybrid perovskite–polymer composite suitable for thin-film deposition.

Thin films were deposited onto glass substrates coated with a transparent conductive indium tin oxide (ITO) layer using a spin-coating technique. After deposition, the films were thermally annealed to remove residual solvent and promote crystallization of the perovskite phase. Based on the prepared films, single-layer light-emitting diode structures with a simplified architecture of ITO / perovskite–PEO / top contact were fabricated.

Electroluminescence measurements were performed at room temperature in the visible spectral range using a Shimadzu RF-6000 spectrofluorimeter under an applied bias voltage. Electrical characterization was carried out using a source-measure unit to record current–voltage (J–V) characteristics and determine current density. Device operation and emission uniformity were additionally evaluated by visual inspection and digital photography.

Results and discussion

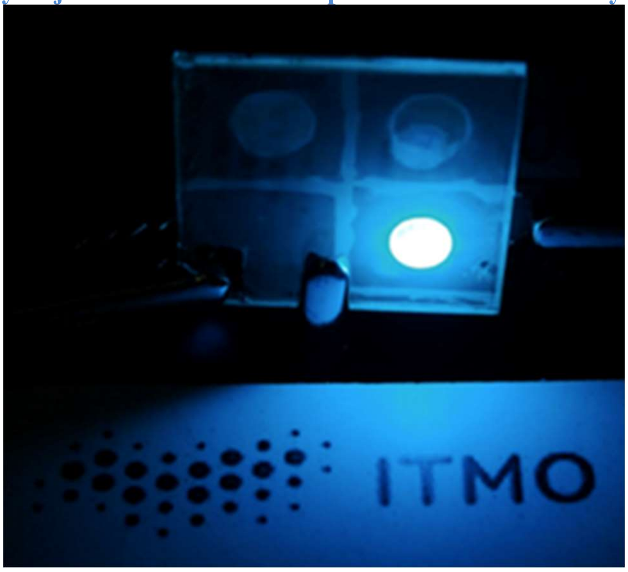

Figure 1. Photograph of a single-layer blue perovskite–polymer LED under electrical bias.

To provide a physical description of charge transport in the simplified structure, the current density can be interpreted using the space-charge-limited current (SCLC) framework, which is commonly applied to hybrid semiconductor layers under injection-dominated conditions. In the SCLC regime, the current density JJJ is expressed by **Equation (1):**

$$J = \frac{9}{8}\varepsilon_0 \varepsilon_r \mu \frac{V^2}{L^3} \qquad (1)$$

where ε_0 is the vacuum permittivity, ε_r is the relative dielectric constant of the active layer, μ is the effective charge carrier mobility, V is the applied voltage, and L is the thickness of the emissive layer.

Acording to Equation (1), injection-driven transport in the perovskite–polymer layer can lead to a rapid increase of current density with applied voltage, consistent with carrier accumulation and enhanced radiative recombination under bias. This interpretation supports the experimentally observed electroluminescence in Figure 1 and provides a concise physical basis for understanding device operation in a low-complexity, solution-processed architecture.

Overall, the results demonstrate that a perovskite–polymer composite can enable blue electroluminescence in a single-layer LED design, offering a practical route toward simplified and potentially scalable light-emitting devices aligned with low-cost manufacturing concepts.

Conclusions

In this work, a practical approach to addressing the challenge of implementing optoelectronic research into simplified device architectures has been demonstrated using the example of blue light-emitting diodes. The study focused on a single-layer LED design based on a hybrid perovskite–polymer composite fabricated via solution processing, which directly responds to the need for technologically simple and scalable optoelectronic systems.

The results confirm that the incorporation of a polymer matrix into a bromide-based perovskite system enables stable blue electroluminescence in a device architecture that does not require dedicated charge-transport layers. This approach effectively reduces structural complexity and fabrication steps, thereby lowering barriers to practical implementation and widening the accessibility of such technologies for young researchers and doctoral students.

Qualitative analysis of electroluminescent behavior and charge-transport mechanisms indicates that the hybrid perovskite–polymer active layer supports efficient charge injection and radiative recombination under electrical bias. The observed performance can be consistently interpreted within a space-charge-limited current framework, providing a physically grounded explanation of device operation without reliance on complex numerical modeling.

From the perspective of the conference theme, the proposed single-layer perovskite–polymer LED represents a viable solution to the problem of translating laboratory-scale material research into application-oriented optoelectronic devices. The simplicity of the solution-based fabrication route and the reduced device architecture highlight clear prospects for further optimization, scaling, and practical deployment in low-cost light-emitting applications.

Overall, this work demonstrates that hybrid perovskite–polymer systems offer an effective platform for bridging the gap between fundamental research and practical implementation, and outlines promising directions for future studies aimed at improving stability, reproducibility, and application readiness of perovskite-based optoelectronic devices.

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