Approaches to enhance electroluminescent efficiency of light-emitting diodes based on quasi-two-dimensional perovskite

Yanbing Hou, Wentao Bi, Bo Song, Pengcheng Jia, Junhan Guo, Zixiao Chen, Qiuhong Cui, Yufeng Hu, Zhidong Lou, Feng Teng
Institute of optoelectronic technology, Beijing JiaoTong University, Beijing 100044, China

1. Introduction

Quasi-two-dimensional (quasi-2D) perovskites with $(A_1)_2(A_2)_{n-1}Pb_nX_{3n+1}$ multi-quantum well structures are considered as the potential electroluminescence (EL) materials due to their controllable quantum confine effect which would lead a high EL efficiency. However, the quasi-2D perovskite films fabricated with solution processing technologies consist of different *n* phases and orientated layers, which limits the performance of quasi-2D perovskite light-emitting diodes (PeLEDs). To improve the performance of PeLEDs, it is essential to obtain perovskite thin films with both large exciton binding energy, complete surface coverage and suitable morphology. Here some approaches are developed to improve the performance of quasi-2D PeLEDs.

2. Experiments and results

2.1 Poly(ethylene oxide) passivated quasi-2D perovskite

In this part of work, the enhanced optical and electrical properties of quasi-2D perovskite achieved by poly(ethylene oxide) (PEO) passivation. The introduction of PEO can not only passivate the surface defects of $(PEA)_2MA_{n-1}Pb_nBr_{3n+1}$ films, but also suppress the formation of low luminous efficient *n*=1 single-layered quasi-2D perovskite phase. The photoluminescence quantum yields (PLQY) of the composite film has been approximately increased by 350% compared with pure quasi-2D perovskite film. The EL devices based on emitting layer (EML) of PEO:quasi-2D perovskite composite film have achieved a brightness of up to 41800 cd/m^2 and a maximal current efficiency of 25.1 cd/A. The EL intensity of the device with PEO passivation dropped to 70% of the initial value after around 7 hours under a constant current density of 10 mA/cm^2, which indicates the excellent operation stability. The composite film of quasi-2D perovskite and PEO would serve as promising materials for LED application.

2.2 Improved multi-quantum well structure

The morphology of quasi-2D perovskite film is not *controlled* easily for solution processing, which leads to low optical and electrical properties. A post-treatment method is used to change the vertical phase distribution of quasi-2D perovskite films. After this phenylethylammonium bromide (PEABr) surface post-treatment, phase purity of quasi-2D perovskite $(PEA)_2FA_2Pb_3Br_{10}$ film is obviously enhanced, which helps to improve multiple quantum wells structures and reduce the electric field induced dissociation of excitons at perovskite EML/electron transporting layer (ETL) interface. The PeLEDs based on $(PEA)_2FA_2Pb_3Br_{10}$ EML with PEABr surface post-treatment method achieve a current efficiency of 45.9 cd/A and T_{50} lifetime as high as 9.2 h, which is enhanced by approximately 150% and 400%, respectively.

2.3 Reduction in electric-field induced deactivation

An important weakness remains unsolved to the efficiency roll-off of PeLEDs with increasing brightness or drive voltage. Comparing the difference in quenching factors calculated from electric-field modulated PL and electric-filed depended lifetime of excited state of quasi-2D perovskite films, we found that the major electric-filed induced deactivation happens in funnel energy transfer process that is one of key factors to result in efficiency roll-off at high drive voltage of quasi-2D PeLEDs. The detrimental effect can be improved by doping cesium (Cs) cation in quasi-2D perovskite, which can improve the surface morphology and suppress the electric field induced dissociation of exciton for the PeLEDs. The prepared quasi-2D perovskite $(PEA)_2FA_2Pb_3Br_{10}$ film with Cs doping exhibits a remarkable PLQY up to 74%. The PeLEDs based on $(PEA)_2FA_{1.8}Cs_{0.2}Pb_3Br_{10}$ EML shows low efficiency roll-off green emission with maximum current efficiency of 55 cd/A.

3. Conclusion

Quasi-2D perovskite is one kind of the most potential EL materials. The suitable approaches and optimization for quasi-2D perovskite can make it serve as distinct and promising materials for efficient and stable LED application.

4. Acknowledgements

This work was supported by Natural Science Foundation of China (Grant Nos.61775011, 61735004, 61674012, and 61675018).