論文 / 著書情報
Article / Book Information

題目(和文)	
Title(English)	Enhancement of EL performance and flexibility of Perovskite-light emitting diodes
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出典(和文)	学位:博士(工学), 学位授与機関:東京工業大学, 報告番号:甲第12202号, 授与年月日:2022年9月22日, 学位の種別:課程博士, 審査員:細野 秀雄,真島 豊,平松 秀典,松石 聡,北野 政明,片瀬 貴義
Citation(English)	Degree:Doctor (Engineering), Conferring organization: Tokyo Institute of Technology, Report number:甲第12202号, Conferred date:2022/9/22, Degree Type:Course doctor, Examiner:,,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

系・コース： Department of, Graduate major in	材料 系 材料 コース	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of	（工学，Egineering）
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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

Perovskite light-emitting diodes (PeLEDs) have emerged as promising candidates for next generation display due to their intrinsically excellent photophysical properties such as high color purity arisen from very narrow full width at half maximum (FWHM). Low-temperature solution processing capability is also one of the merits for fabricating flexible electronics on plastic substrates. Nevertheless, it is quite challenging to realize both high electroluminescence (EL) performance and excellent flexibility, which are required for next generation display. Generally, EL devices consist of 7 different layers for effective charge injection to determine EL performance. Conversely, this complex structure makes it difficult to achieve high flexibility in ELs because all the 7 layers and of which 6 interfaces must be robust to mechanical stress. In order to resolve this issue, I propose an amorphous oxide semiconductor (AOS) as an electron transport layer (ETL) in PeLEDs. It is well known that AOSs are suitable as TFT channels for next generation display due to their excellent electrical properties and low-temperature fabrication processability. Moreover, conduction band minimum (E_{CBM}) level and conductivity are widely tunable by varying the composition in AOSs. These properties are unique advantages to modulate energy level alignment and charge balance in LEDs. In this thesis, I propose amorphous zinc silicate (a-ZSO) as an ETL to realize high EL performance and the flexibility of PeLED. The contents in this thesis are listed below:

In Chapter 1, the background, technical issue, and objectives of this thesis were described.

In Chapter 2, it was revealed that the PL property of 3D materials is significantly governed by adjacent charge transport layer owing to non-radiative recombination arisen from small exciton binding energy. Thus, I propose a novel device structure using a-ZSO ETL, in order to not only confine excitons but also realize effective charge injection into EML. This strategy demonstrates the significance of high charge transport property of the 3D perovskite for highly efficient PeLED. Thanks to the synergy effect of a-ZSO ETL and 3D perovskite EML for green emission, very low operating voltage of 2.9 V at 10,000 cd/m^2 and high efficiency of 35 lm/W were achieved for the green PeLED. The obtained high brightness of ~500,000 cd/m^2 at 5V also exhibited the validity of the proposed strategy.

Based on the results of Chapter 2, an extended study was conducted to realize PeLED with high

efficiency and excellent mechanical robustness. In Chapter 3, I proposed a simplified device structure by applying the concept of core-shell structure into transparent conductive electrode (TCE) and perovskite EML. For the TCE, tri-layer structure of ZSO/Ag/ZSO is adopted to utilize the intrinsic characteristics of a-ZSO ETL such as good charge transport property and ohmic contact with Ag layer. Moreover, Ag layer is fully embedded by ZSO layers. Thus, this edgeless structure not only prevents the degradation of Ag layer from precursor solution but also solves the issue of weak adhesion of Ag to oxide. On the other hand, mesh-like perovskite EML is fabricated by adding poly ethylene oxide (PEO) into perovskite precursor. Furthermore, leakage current in the area w/o EML is suppressed using large energy barrier (PN junction) formed at ETL/HTL interface. Thus, core shell structured EML can realize both high EL performance and excellent flexibility. Consequently, PeLED comprised by only 4 layers and fabricated on 50 um thick plastic substrate attains highly stable performance for 100,000 times bending stress at 4 mm bending radius, demonstrating the validity of our strategy.

In Chapters 2 and 3, I confirmed that oxide ETL, a-ZSO with superior electrical property, exhibits high compatibility with 3D perovskite EML. Thus, various applications of oxide ETL in perovskite optoelectronics are expected by combining with 3D organic–inorganic hybrid perovskites. However, a technical issue for the wide utilization of oxide ETL was found. In Chapter 4, we revealed that mutual chemical reaction occurs between hybrid perovskite/a-ZSO ETL. Chemical reactions leading to formation of Si rich layer in a-ZSO and PEA_2ZnBr_4 in perovskite layer degrade the LED performance. To solve this issue, small molecule 18-crown 6-ether (18C6) additives is incorporated in the precursor solution. It is demonstrated that 18C6 additives achieve the suppression of chemical reaction and a very low operating voltage resulted from efficient charge injection (3.2 V at 10,000 cd/m^2).

In chapter 5, I summarized the major conclusions obtained in this thesis and provided some suggestions for future research. Enhanced EL performance and flexibility of PeLED demonstrate great potential of amorphous oxide semiconductor. Therefore, I believe that this thesis will offer new insight to practical use of perovskite optoelectronics in the future.