

Tunable electroluminescence from n-ZnO/p-GaN heterojunction with CsPbBr₃ interlayer grown by Pulse-Laser Deposition

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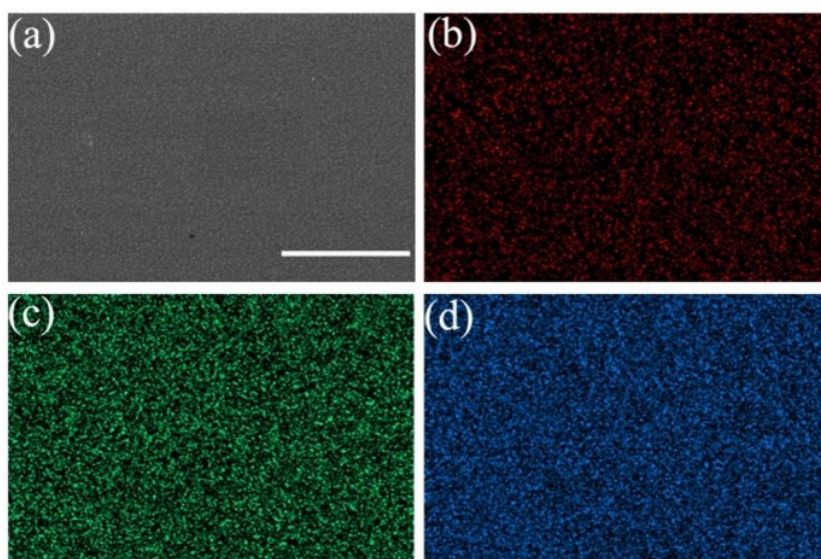


Figure. S1. EDS mapping of the CsPbBr₃ thin film (a) surface, (b) Cs, (c) Pb (d) Br, and. Scale bars in SEM images are 25 μm .

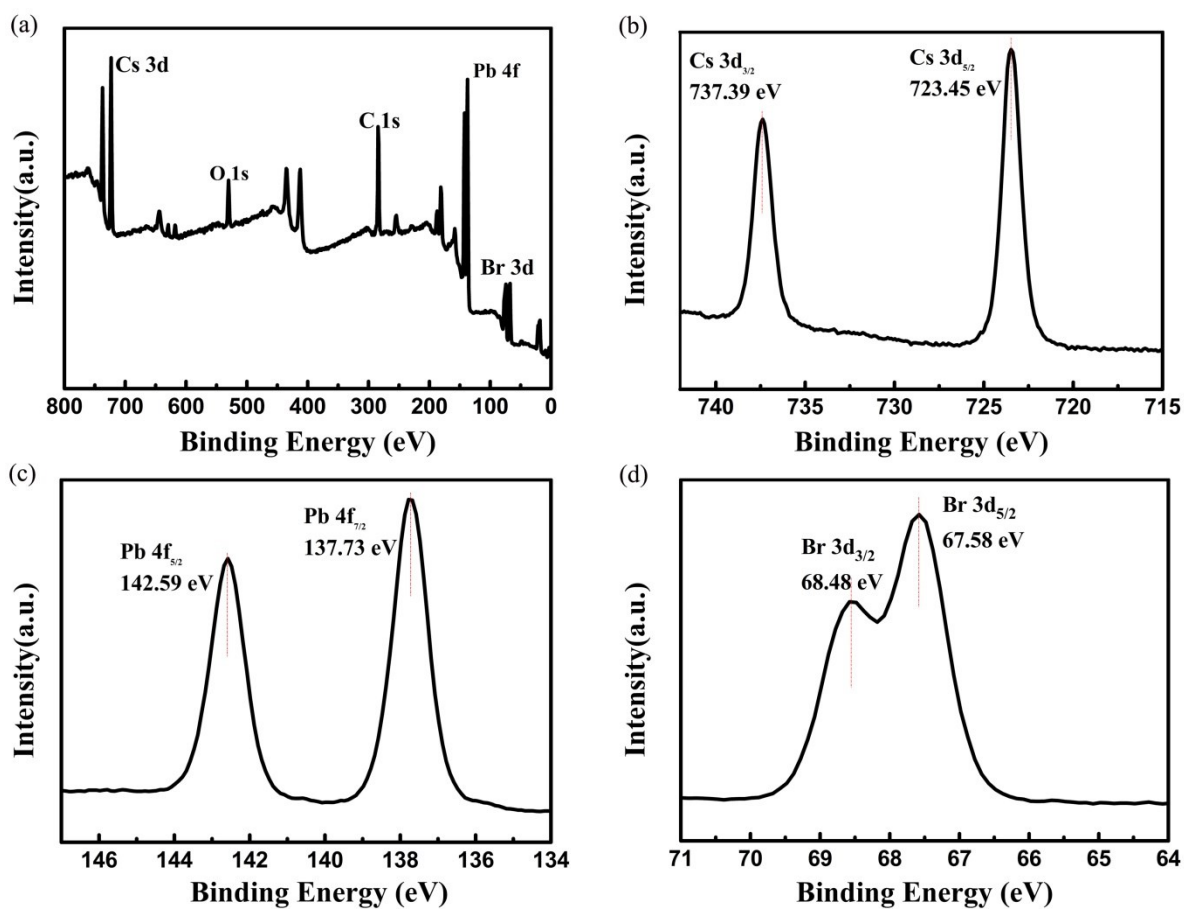


Figure S2: XPS spectra of the CsPbBr₃ thin film: (a) total spectrum (b) Cs 3d (c) Pb 4f (d) Br 3d. X-ray photoelectron spectroscopy (XPS) was employed to qualitatively analyze the chemical state and structural properties. Because of adventitious carbon is so ubiquitous, its C 1s peak position is often used as a reference and is assumed to be 284.6 eV.^{1,2} And the binding energy profile is smoothed using the mode of Wiener Filter.

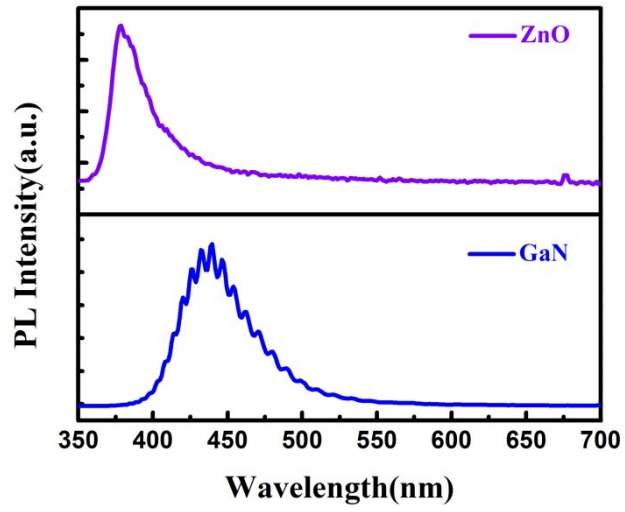


Figure S3. PL spectra of the ZnO film, GaN substrate

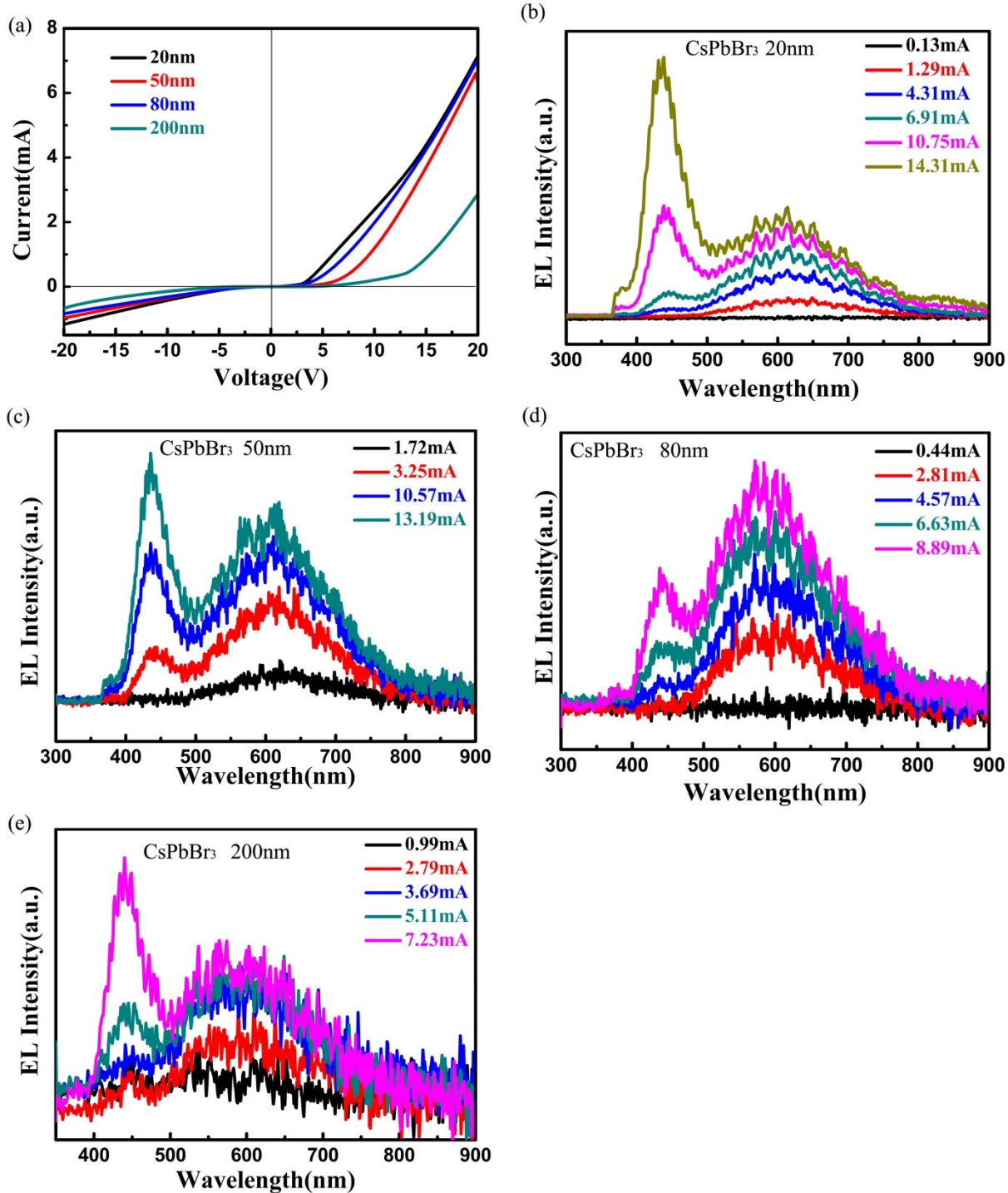


Figure S4. (a) I-V curves of the n-ZnO/i-CsPbBr₃/p-GaN heterojunction LED, EL spectrum of the n-ZnO/i-CsPbBr₃/p-GaN heterojunction LED with different CsPbBr₃ film thickness (b) 20 nm, (c) 50 nm, (d) 80 nm, (e) 100 nm.

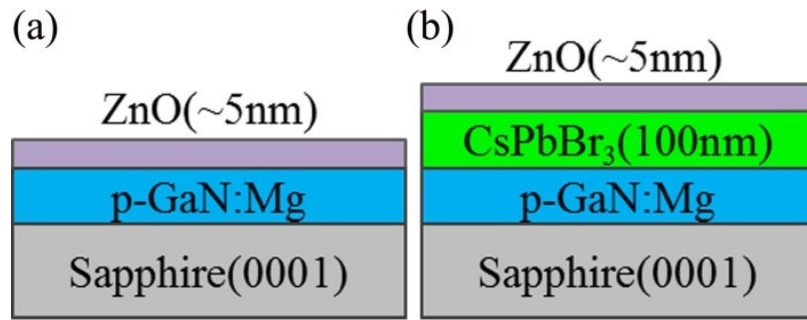


Figure S5. Samples (a)-(b) are prepared for measuring the oxygen vacancy of ZnO film: (a) ZnO/GaN, (c) ZnO/CsPbBr₃/GaN

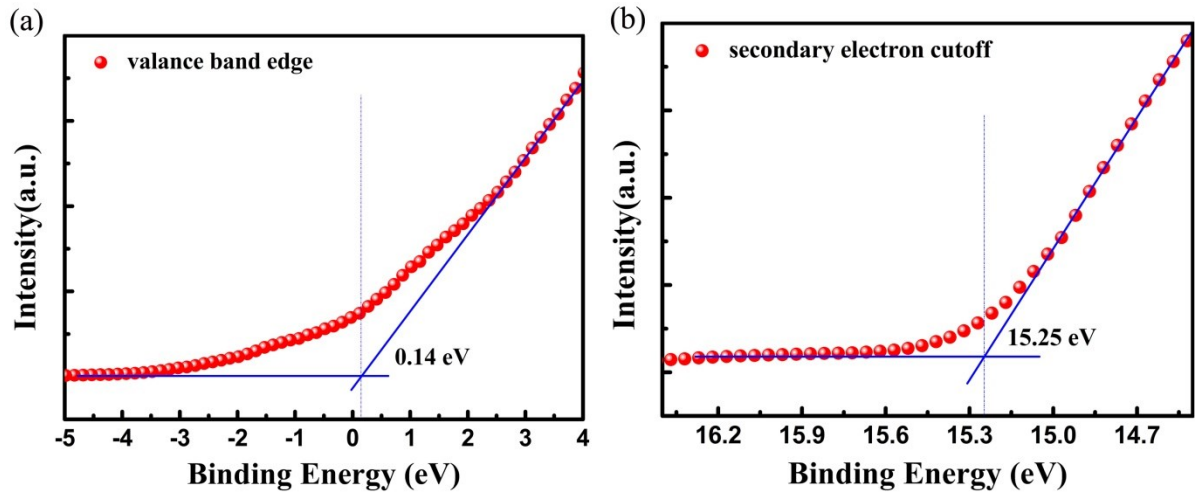


Figure S6. UPS spectra of CsPbBr₃ thin films, (a) Valence band edge, (b) secondary electron cutoff.

The valence band maximum (VBM) is estimated according to equation³⁻⁶:

$$E_V = h\nu + E_{cutoff} - E_{Feimi}$$

where $h\nu$ is the ultraviolet radiation energy (21.2 eV). Figure S6 shows the E_{cutoff} and E_{Feimi} are 0.14 eV, and 15.25 eV, respectively. Thus, the E_V of CsPbBr₃ is calculated to be 6.09 eV. Combined with the absorbance spectrum of the CsPbBr₃ (Figure 2c), the E_g is measured to be 2.33 eV. Finally, the E_C of the CsPbBr₃ is estimated to be 3.76 eV

Table S1. The high-resolution XPS spectra of the elements Cs, Pb, and Br by different prepared method.

| Method (film) | Cs 3d _{5/2} (eV) | Cs 3d _{3/2} (eV) | Pb 4f _{7/2} (eV) | Pb 4f _{5/2} (eV) | Br 3d _{5/2} (eV) | Br 3d _{3/2} (eV) | Ref. |
|------------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|--------------|
| Solution-processed | 724.55 | 738.54 | 138.56 | 143.44 | 68.52 | 69.85 | 7 |
| Evaporated | 724.70 | 738.68 | 138.66 | 143.56 | 68.60 | 69.95 | 7 |
| Chemical Vapor deposition (CVD) | \ | \ | 135.00 | 139.80 | 65.00 | 66.00 | 8 |
| Pulse laser deposition (PLD) | 723.45 | 737.39 | 137.73 | 142.59 | 67.58 | 68.48 | This work |

Table S2. Color coordinates of the ZnO/GaN heterojunction LED and ZnO/CsPbBr₃/GaN heterojunction LED

| | | | | | | |
|-------------------------------------|---------|---------|---------|---------|---------|---------|
| ZnO/GaN LED | 3.91 mA | 6.22 mA | 9.89 mA | 13.5 mA | 17.1 mA | / |
| CIE X | 0.3453 | 0.2920 | 0.2541 | 0.2396 | 0.2355 | / |
| CIE Y | 0.2889 | 0.2296 | 0.1814 | 0.1675 | 0.1629 | / |
| ZnO/CsPbBr ₃ /GaN LED | 0.77mA | 2.11 mA | 5.81 mA | 10.1 mA | 14.8 mA | 20.1 mA |
| CIE X | 0.4250 | 0.4647 | 0.4691 | 0.4554 | 0.4429 | 0.4356 |
| CIE Y | 0.4228 | 0.4553 | 0.4671 | 0.4658 | 0.4518 | 0.4511 |

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