Supplementary Information

$CsPbBr_3$ nanowire polarized light-emitting diodes through mechanical rubbing

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Experimental details:

Chemicals:

Cesium carbonate (Cs_2CO_3, 99.995%, Aldrich), lead(II) bromine ($PbBr_2$, 99.999%, Aldrich), oleic acid (OA, 90%, Aldrich), oleylamine (OAm, 70%, Aldrich), octylamine (OCT, 99%, Aldrich), octadecene (ODE, 90%, Aldrich), and hexane (> 99.7%, Sinopharm Chemical), molecular sieves, (4 Å, aladdin). OA, OCT, OAm and hexane were dehydrated using molecular sieves before use. Other chemicals were used as received without further purification.

Synthesis of $CsPbBr_3$ nanowires

A Cs–oleate solution was prepared via a reported approach developed by Protesescu et al [1] with slight revision here. In brief, 0.2 g Cs_2CO_3 mixed with 625 μl OA and 7.5 ml ODE was loaded into a round-bottom flask (volume 50 ml), degassed and dried under vacuum at 120 °C (all of the temperatures mentioned in the article refer to the temperature of the oil bath) for at least 1 hour to ensure that Cs_2CO_3 was fully reacted with the OA. The yellowish Cs-oleate will precipitate out after cooling, and was heated to 100 °C before use.

5 mL ODE and 0.2 mmol $PbBr_2$ were loaded into a 3-neck flask and degassed under vacuum for 20 min at 120 °C. Then OCT (0.8 mL) was added in N_2 atmosphere, and the solution would become milky white. Next, the solution changed to be temporarily transparent (then milky white) after OAm (0.8 mL) was put in. The mixture was heated to 135 °C for 20 minutes. Finally, the dissolved Cs-oleate (0.7 mL) was rapidly injected into the reaction system and the reaction mixture was cooled with cold water after 40-60 minutes. The NWs were isolated by centrifugation at 6000 rpm for 5 mins and washed once with hexane.

Dried toluene (5 mL), $PbBr_2$ (0.188 mmol), OAm (0.65 mL) and OA (0.5 mL), were added to a scintillation vial all within a nitrogen inert atmosphere glovebox. The solution was stirred at 100 °C within the glovebox until the $PbBr_2$ salt completely dissolves, which may take at least 1 hour. The cleaned NW dispersion was then mixed with the above solution and was stirred at 85 °C until the solution changed from orange yellow to slightly green. The NWs were isolated by centrifugation at 6000 rpm for 5 mins and re-dispersed in dried hexane for further use.

Materials characterizations:

The scanning electron microscope (SEM) images were obtained on ZEISS Auriga electron microscope operating at an accelerating voltage of 30 kV. Transmission electron microscope (TEM) characterizations were carried out on a Philips Tecnai-G20 microscope operating at an accelerating voltage of 200 kV. Atomic force microscope (AFM) were obtained on Shimadzu, SPM-9700 microscope. X-ray diffraction (XRD) patterns were measured by a Rigaku Smartlab diffractometer with Cu Kα radiation. Photoluminescence (PL) spectra were recorded using a Horiba FluoroMax-4 spectrofluorometer. The absorbance spectra were recorded using a UV–visible spectrophotometer (Shimadzu-UV2550).

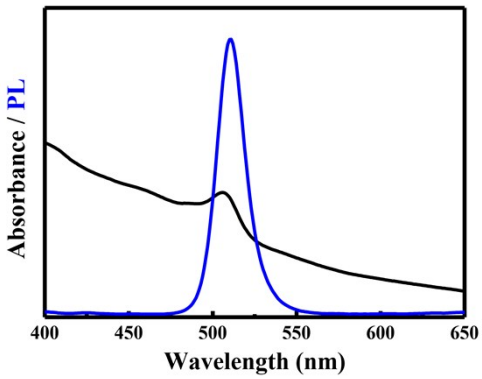

Fig. S1 Typical optical absorption and PL spectrum for $CsPbBr_3$ NWs.

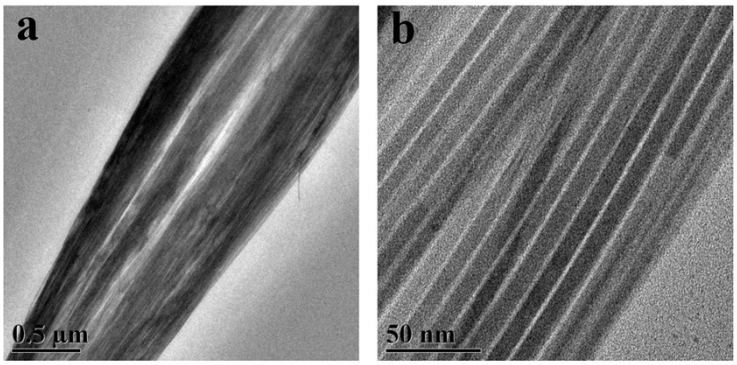

Fig. S2 (a) TEM images of $CsPbBr_3$ NW, which is a nanobeam formed by newly synthesized NWs. (b) $CsPbBr_3$ NWs show the arrangement in magnifications.

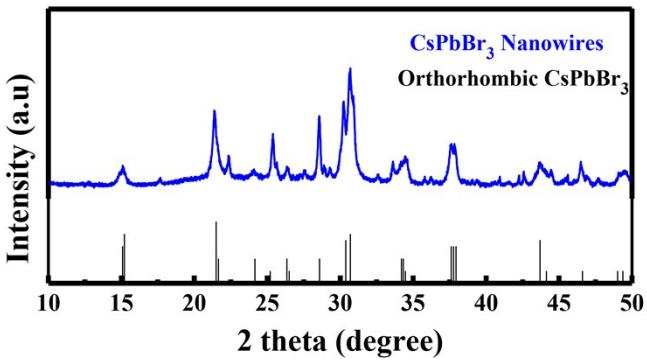

Fig. S3 XRD of $CsPbBr_3$ NWs indicating the crystallographic features.

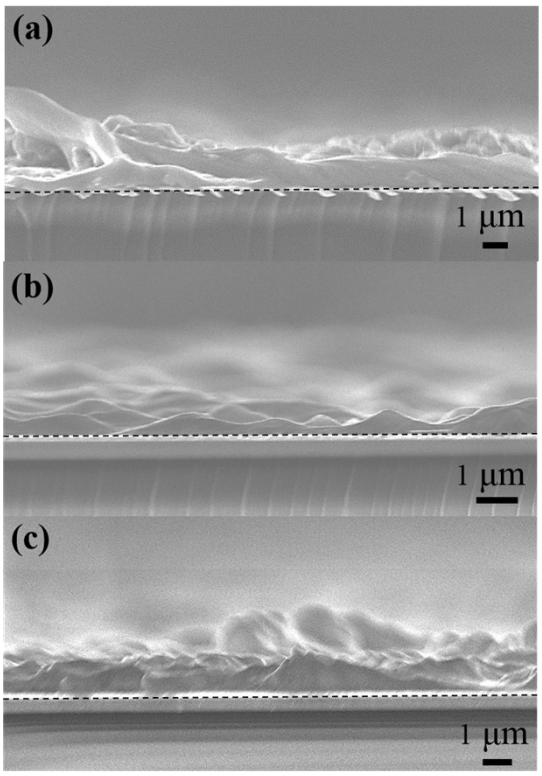

Fig. S4 The crossing section SEM images of drop-casted $CsPbBr_3$ NW films without rubbing (a) and after mechnical wet rubbing (b) or mechnical dry rubbing (c). The dotted line represents the base.

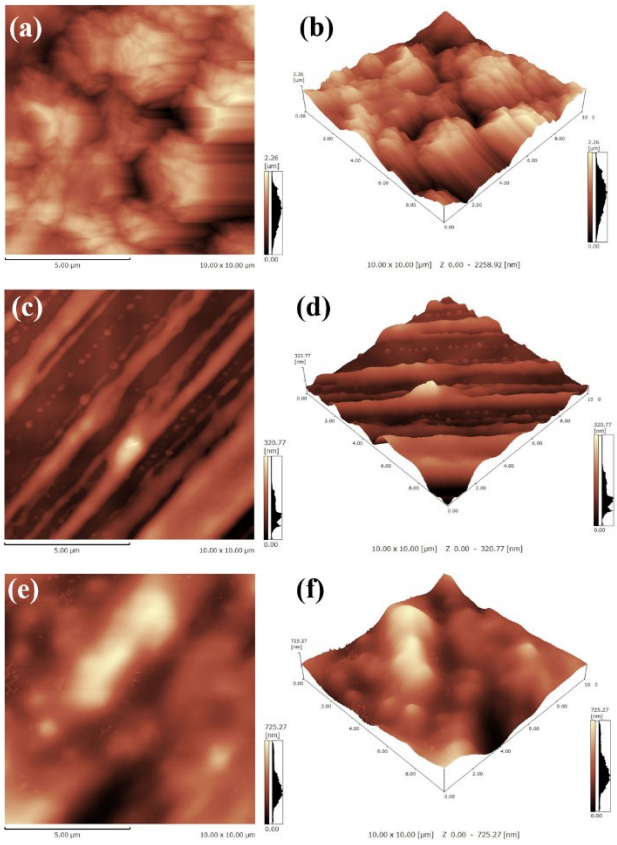

Fig. S5 AFM measurements of a 10×10 μm drop-casted $CsPbBr_3$ NW films (a) without rubbing and a 3D representation (b), and after mechnical wet rubbing (c) and a 3D representation (d), or after mechnical dry rubbing (e) and a 3D representation (f).

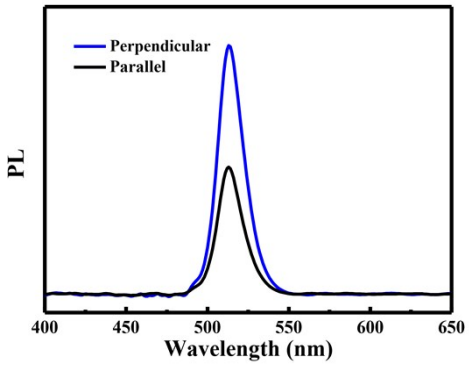

Fig. S6 The PL spectra of drop-casted $CsPbBr_3$ NW films without rubbing for two orthogonal directions.

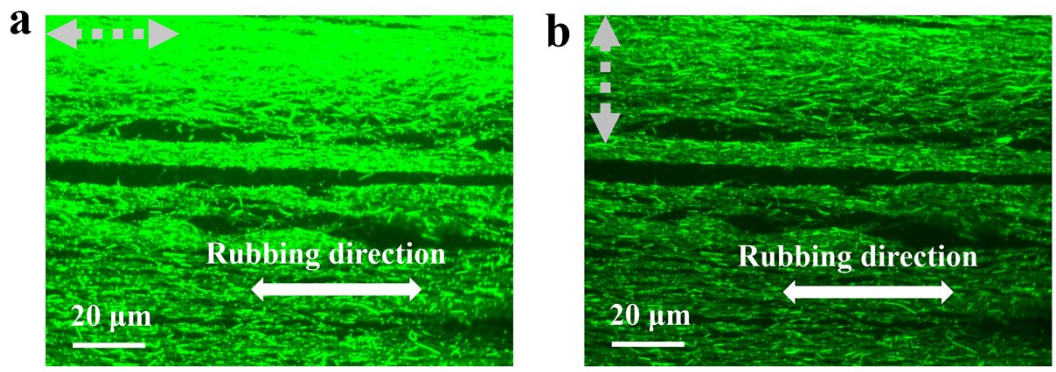

Fig. S7 Luminescence photos for the anisotropic $CsPbBr_3$ NW films with different polarizer directions. (a) Parallel. (b) Perpendicular.

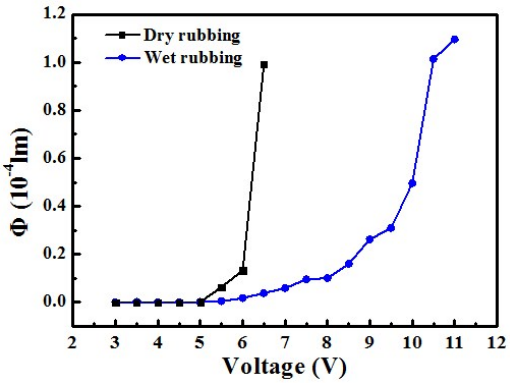

Fig. S8 Light-out power of wet-rubbed and dry-rubbed $CsPbBr_3$ NW LEDs.

[1] Protesescu, L.; Yakunin, S.; Bodnarchuk, M. I.; Krieg, F.; Caputo, R.; Hendon, C. H.; Yang, R. X.; Walsh, A.; Kovalenko, M. V. Nano Lett. 2015, 15, 3692.