Supporting information

Bright and fast-response perovskite light-emitting diodes with a ICBA:modified-C_{60} nanocomposite electrical confinement layers

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General synthetic processes of 3,4-C_6Bn and 3,5-C_6Bn

1-bromohexane (60 mmol), dihydroxybenzaldehyde (10 mmol) and potassium carbonate (100 mmol) in 50-mL anhydrous acetonitrile was heated at 85 °C under protection of argon. The reaction mixture was stirred overnight. After cooling to room temperature, the solution was concentrated under reduced pressure and the residue was purified by column chromatography (CH_2Cl_2/hexane=2:1, v/v) on a silica gel to yield products.

3,4-C_6Bn

Yield: 85.1%. 1H NMR ($CDCl_3$, 300 MHz, 298 K) δ 9.88 (s, 1H), 7.30 (d, 2H), 6.91 (s, 1H), 3.89 (s, 4H), 1.71 (s, 4H),1.35 (s, 4H), 1.29 (s, 4H), 1.26 (s, 4H), 0.99 (s, 6H); 13C NMR ($CDCl_3$, 75 MHz, 298 K) δ 191.0, 129.0, 148.2, 145.6, 121.9, 116.8, 115.8, 72.5, 33.4, 31.0, 25.1, 22.3, 13.5. HRMS (m/z,MALDI) Calcd for $C_{19}H_{30}O_3$ 306.2159, found 306.2150.

3,5-C_6Bn

Yield: 90.6%.1H NMR ($CDCl_3$, 300 MHz, 298 K) δ 9.90 (s, 1H), 6.91 (d, 2H), 6.52 (s, 1H), 3.90 (s, 4H), 1.72 (s, 4H),1.33 (s, 4H) 1.29 (s, 4H), 1.24 (S, 4H), 0.95 (s, 6H); 13C NMR ($CDCl_3$, 75 MHz, 298 K) δ 192.0, 159.7,137.7, 108.2, 104.7, 72.8, 33.0, 30.4, 26.1, 23.3, 14.1. HRMS (m/z,MALDI) Calcd for $C_{19}H_{30}O_3$ 306.2159, found 306.2161.

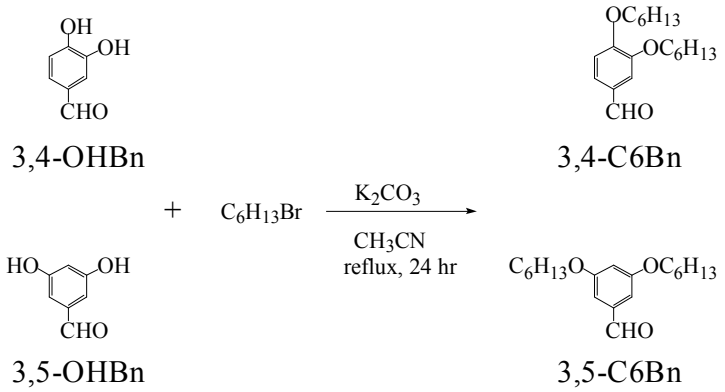

Fig. S1. Synthetic route for the **3,4C_6Bn and 3,5-C_6Bn** molecules.

General synthetic processes of 3,4-OE and 3,5-OE

1 (22 mmol), dihydroxybenzaldehyde (10 mmol) and potassium carbonate (100 mmol) in 50-mL anhydrous dimethylforamide was heated at 155 °C under protection of argon. After cooling to the room temperature, the crude compound was extracted by ethylacetate/water, then washed with brine and finally dried with an anhydrous sodium sulfate. The solution was concentrated under reduced pressure and the residue was purified by column chromatography (CH_2Cl_2/hexane =3:1, v/v) on a silica gel to yield products.

3,4-OE

Yield: 88.2%.1H NMR ($CDCl_3$, 300 MHz, 298 K) δ 9.91 (s, 1H), 7.32 (d, 1H), 7.21 (s, 1H), 6.86 (s, 1H), 4.15 (s, 12H), 3.71 (s, 12H), 3.25 (s, 6H); 13C NMR ($CDCl_3$, 75 MHz, 298 K) δ 192.0, 129.0, 149.2, 145.6, 121.1, 116.1, 115.4, 72.5, 70.4, 53.4. HRMS (m/z,MALDI) Calcd for $C_{21}H_{34}O_9$ 430.2203, found 430.2200.

3,5-OE

Yield: 89.4%.1H NMR ($CDCl_3$, 300 MHz, 298 K) δ 9.88 (s, 1H), 6.87 (d, 2H), 6.61 (s, 1H), 4.15 (s, 4H), 3.73 (s, 4H), 3.53 (m, 20H), 3.22 (s, 6H); 13C NMR ($CDCl_3$, 75

MHz, 298 K) δ 190.2, 160.0, 137.5, 107.2, 105.7, 73.1, 70.9, 70.1, 53.1.HRMS(m/z,MALDI) Calcd for $C_{21}H_{34}O_9$ 430.2203, found 430.2210.

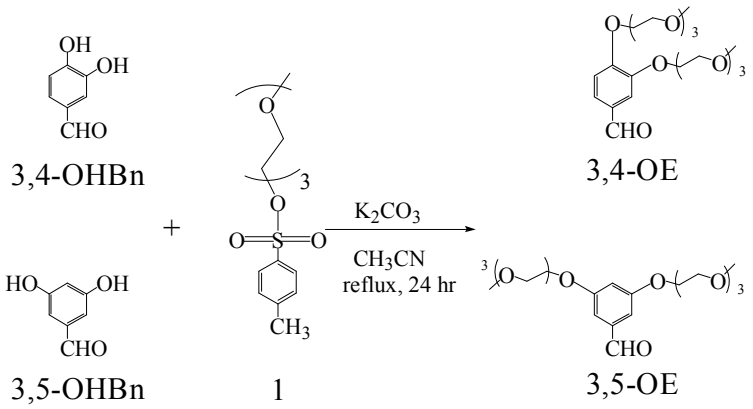

Fig. S2. Synthetic route for the **3,4-OE and 3,5-OE** molecules.

General synthetic processes of 3,4-C_6BnC_{60}, 3,5-C_6BnC_{60}, 3,4-OEC_{60} and 3,5-OEC_{60}

Benzadehyde derivatives (0.6 mmol), C_{60} (0.4 mmol) and *N*-methyl glucine (0.88 mmol) in 40-mL anhydrous chlorobenzene was heated at 140 °C under protection of argon. After cooling to the room temperature, the crude compound was washed by methanol. Then, the precipitate was filtered and purified by silica-gelcolumn chromatography using toluene as the eluent to afford compound.

3,4-C_6BnC_{60}

Yield: 53.2%. 1H NMR ($CDCl_3$, 300 MHz, 298 K) δ 6.64 (d, 1H), 6.57 (d, 1H), 6.50 (s, 1H), 3.90 (s, 4H), 3.52 (s, 1H),2.29 (s, 3H), 2.19 (s, 2H), 1.73 (s, 4H),1.32 (s, 4H), 1.28 (m, 8H), 0.93 (s, 6H); 13C NMR ($CDCl_3$, 75 MHz, 298 K) multiple signals from 145.0 to 114.0 and 75.0 to 15.0 ppm. HRMS (m/z,MALDI) Calcd for $C_{79}H_{30}O_3$ 1026.2159, found 1026.2152.

3,5-C_6BnC_{60}

Yield: 45.6%.1H NMR ($CDCl_3$, 300 MHz, 298 K)δ6.30 (s, 2H), 6.15 (s, 1H), 3.96 (s, 4H), 3.52 (s, 1H),2.30 (s, 3H), 2.15 (s, 2H), 1.73 (s, 4H),1.33 (s, 4H), 1.29 (m, 8H), 0.93 (s, 6H); 13C NMR ($CDCl_3$, 75 MHz, 298 K) multiple signals from 150.0 to 114.0 and 70.0 to 15.0 ppm. HRMS (m/z,MALDI) Calcd for $C_{79}H_{30}O_3$ 1026.2159, found 1026.2165.

3,4-OEC$_{60}$

Yield: 50.2%. 1H NMR ($CDCl_3$, 300 MHz, 298 K) δ, 6.80 (d, 2H), 6.48 (s, 1H), 4.15 (s, 12H),3.71 (s, 12H), 3.51 (s, 1H),3.25 (s, 6H), 2.33 (s, 3H), 2.19 (s, 2H); 13C NMR ($CDCl_3$, 75 MHz, 298 K) multiple signals from 148.0 to 111.0 and 76.0 to 13.0 ppm. HRMS (m/z,MALDI) Calcd for $C_{81}H_{34}O_9$ 1150.2203, found 1150.2210.

3,5-OEC$_{60}$

Yield: 44.4%. 1H NMR ($CDCl_3$, 300 MHz, 298 K) δ 6.30 (s, 1H), 6.21 (s, 1H), 6.01 (s, 1H), 4.15 (s, 4H), 3.73 (s, 4H), 3.58 (s, 2H), 3.51 (m, 20H), 3.22 (s, 6H),2.30 (s, 3H), 2.10 (s, 2H); 13C NMR ($CDCl_3$, 75 MHz, 298 K) multiple signals from 148.0 to 115.0 and 72.0 to 15.0 ppm. HRMS (m/z,MALDI) Calcd for $C_{81}H_{34}O_9$ 1150.2203, found 1150.2201..

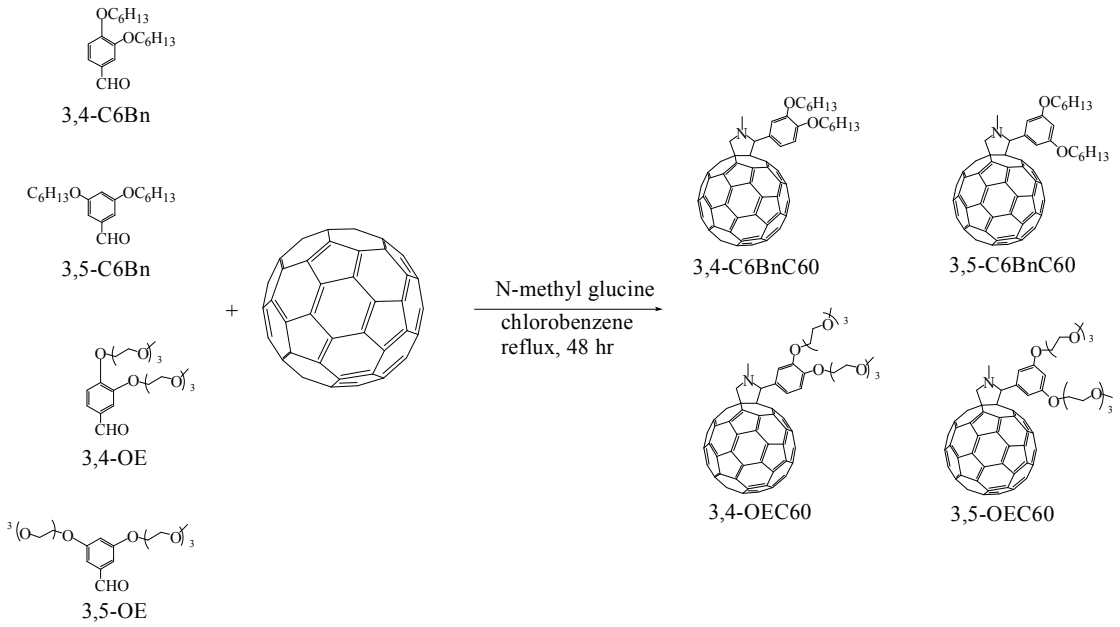

Fig. S3. Synthetic route for the **3,4-C$_6$BnC$_{60}$, 3,5-C$_6$BnC$_{60}$, 3,4-OEC$_{60}$ and 3,5-OEC$_{60}$** molecules.

Atomic-force microscopic image

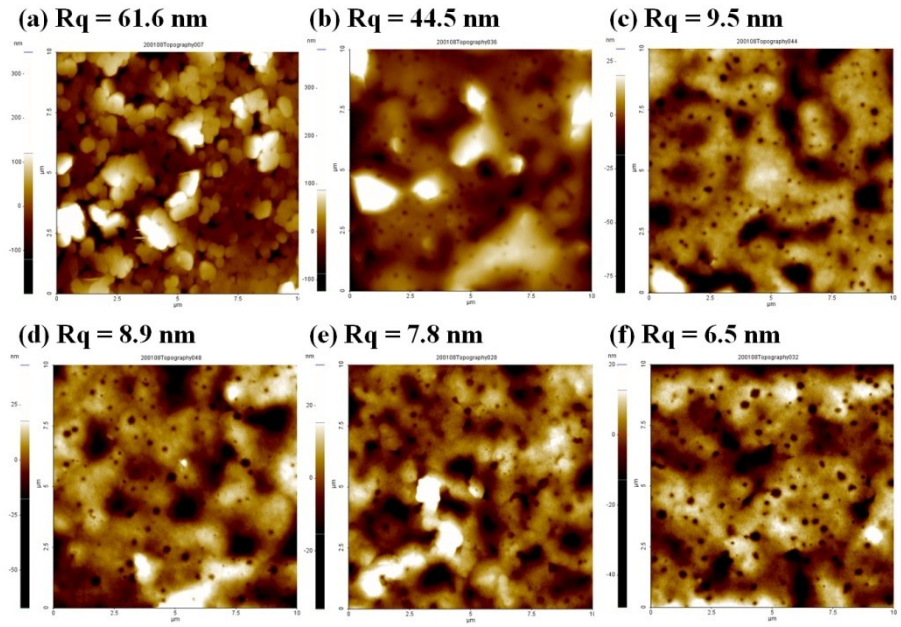

Fig. S4. Atomic-force microscopic images of the $MAPbBr_3$/glass samples without ETL and with the different ETLs. ETL: electron transport layer. (a) without ETL; (b) with ICBA; (c) with ICBA:3,4C_6BnC_{60}; (d) with ICBA:3,5C_6BnC_{60}; (e) with ICBA:3,4OEC_{60}; (f) with ICBA:3,5OEC_{60}.

Time-resolved photoluminescence

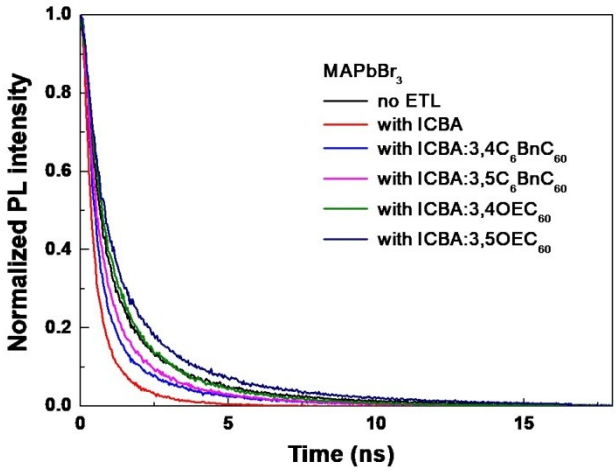

Fig. S5. Time-resolved photoluminescence (TRPL) curves of the $MAPbBr_3$/glass

samples without ETL and with the different ETLs. ETL: electron transport layer.

Voltage-current efficiency (CE) of PeLEDs

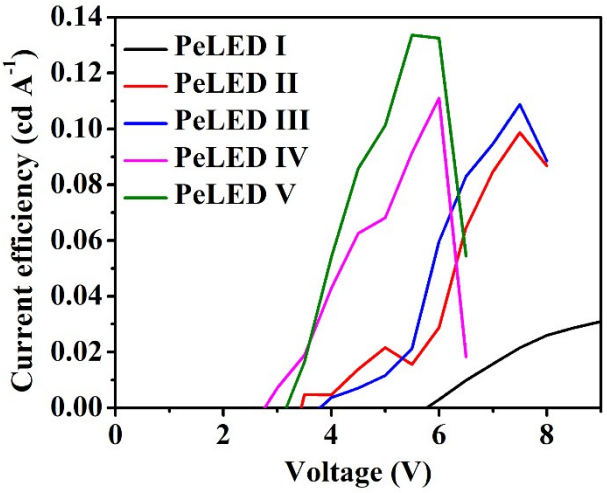

Fig. S6. Voltage-current efficiency (CE) curves of PeLEDs.