Electronic Supplementary Material (ESI) for RSC Advances.

Supporting Information

Charge Balance Control of Quantum Dot Light Emitting Diodes with Atomic layer Deposited Aluminum Oxide Interlayers

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Materials

Cadmium acetate ($Cd(acet)_2$, 99.9%), zinc oxide (ZnO, 99.99%), zinc acetate ($Zn(acet)_2$), sulfur (S, 99.9%), selenium (Se, 99.9%), oleic acid (OA, 90%), 1-octadecene (ODE, 90%), zinc acetate dihydrate and tetramethyl ammonium hydroxide pentahydrate (TMAH) were purchased from Sigma-Aldrich. Anhydrous hexane, octane (98%), ethanol (94-96%), dimethyl sulfoxide (DMSO, 99.9%) and trioctylphosphine (90%) were purchased from Alfa Aesar. Anhydrous ethanol (99.5%) and acetone (99.5%) was purchased from Daejung Chemical and Metals Co., Ltd.

Synthesis of CdSe@ZnS/ZnS quantum dots

For a synthesis of green QDs with alloyed structure, a mixture of 0.14 mmol of $Cd(acet)_2$ powder, 3.14 mmol of ZnO powder, 7 mL of OA, and 15 mL ODE were stirred by a magnetic bar in a 50mL 3-neck flask under vacuum state for 1 h at 120 ˚C. After 1 h for degassing, the temperature was raised to 290 ˚C under a flow of nitrogen gas. A 1^{st} stock solution of Se (2 mmol) and S (2 mmol) in TOP (2 mL) was injected into the reaction mixture at 290 ˚C. The reaction temperature was raised to 310 ˚C and kept for 12 min to form the CdSe@ZnS alloyed core/shell QDs. Following the addition of 1^{st} stock solution, 2^{nd} stock solution of S (1.6 mmol) in ODE (2.4 mL) was injected at 310 ˚C and kept for 10 min. After 10 min of reaction, Zn acetate solution dissolved in OA and ODE was injected into the reaction mixture to form outer shell and kept for 10 min. After the reaction temperature was lowered to 270 ˚C, 10 mmol of S in TOP (5 mL) was added dropwise for 10 min and maintained for 20 min. Solution was diluted with hexane and excess anhydrous ethanol to remove excess ligands and precursors by centrifugation. Then, the precipitate was dispersed in hexane and octane.

Synthesis of ZnO nanoparticles

For a synthesis of ZnO NPs, 10 mmol of TMAH in ethanol (10 mL) was added dropwise for 20 min into 10 mmol of zinc acetate dihydrate in DMSO (40 mL) and maintained for 40 min at 5 ˚C. Then, solution was diluted with excess acetone to precipitate pure ZnO NPs by centrifugation. The precipitate was dispersed in ethanol.

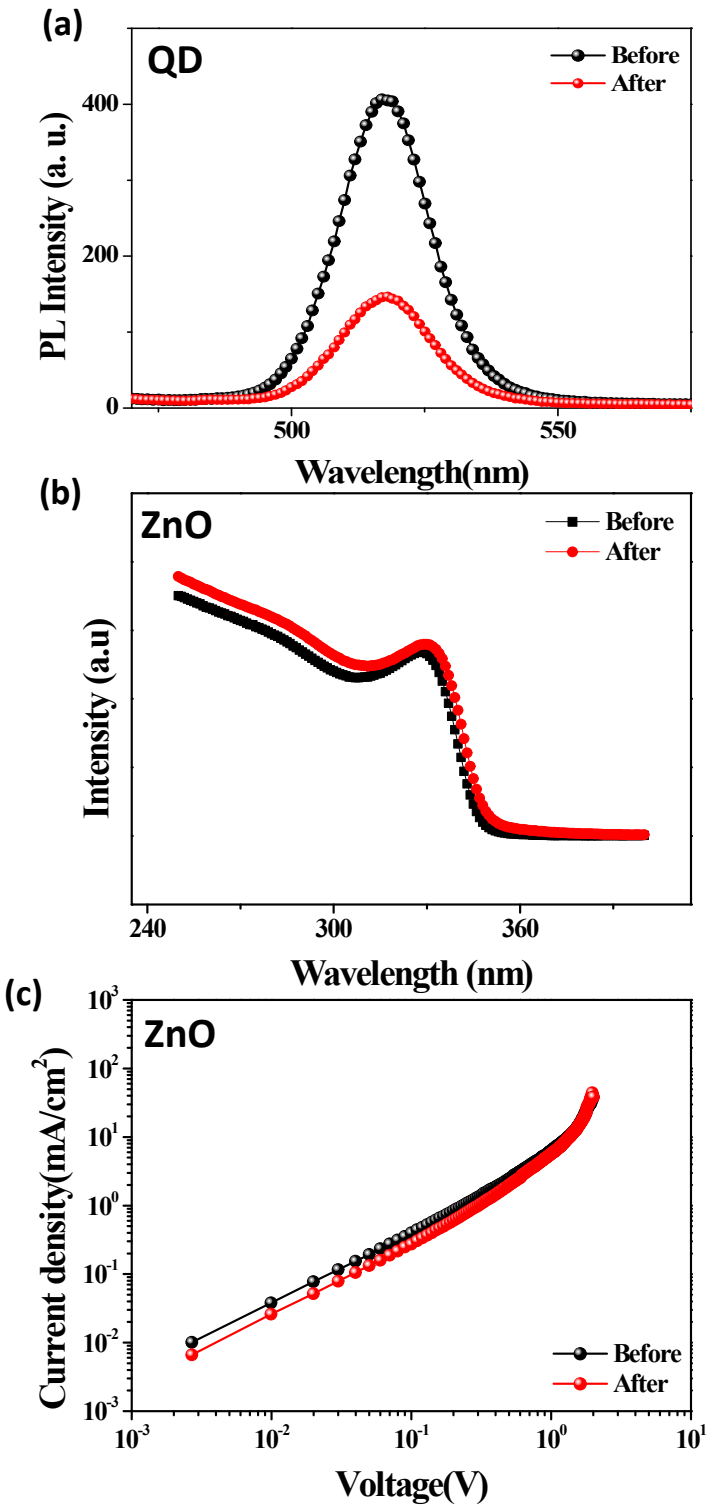

Fig. S1. Before and after plasma treatment of (a) PL spectra of QDs, (b) UV/vis absorption spectra of ZnO and (c) current densities from EOD

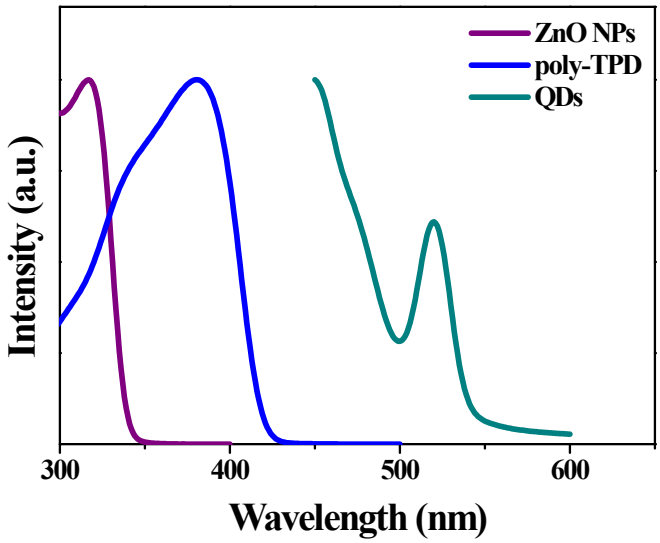

Fig. S2. UV/vis absorption spectra of ZnO NPs, poly-TPD and QDs

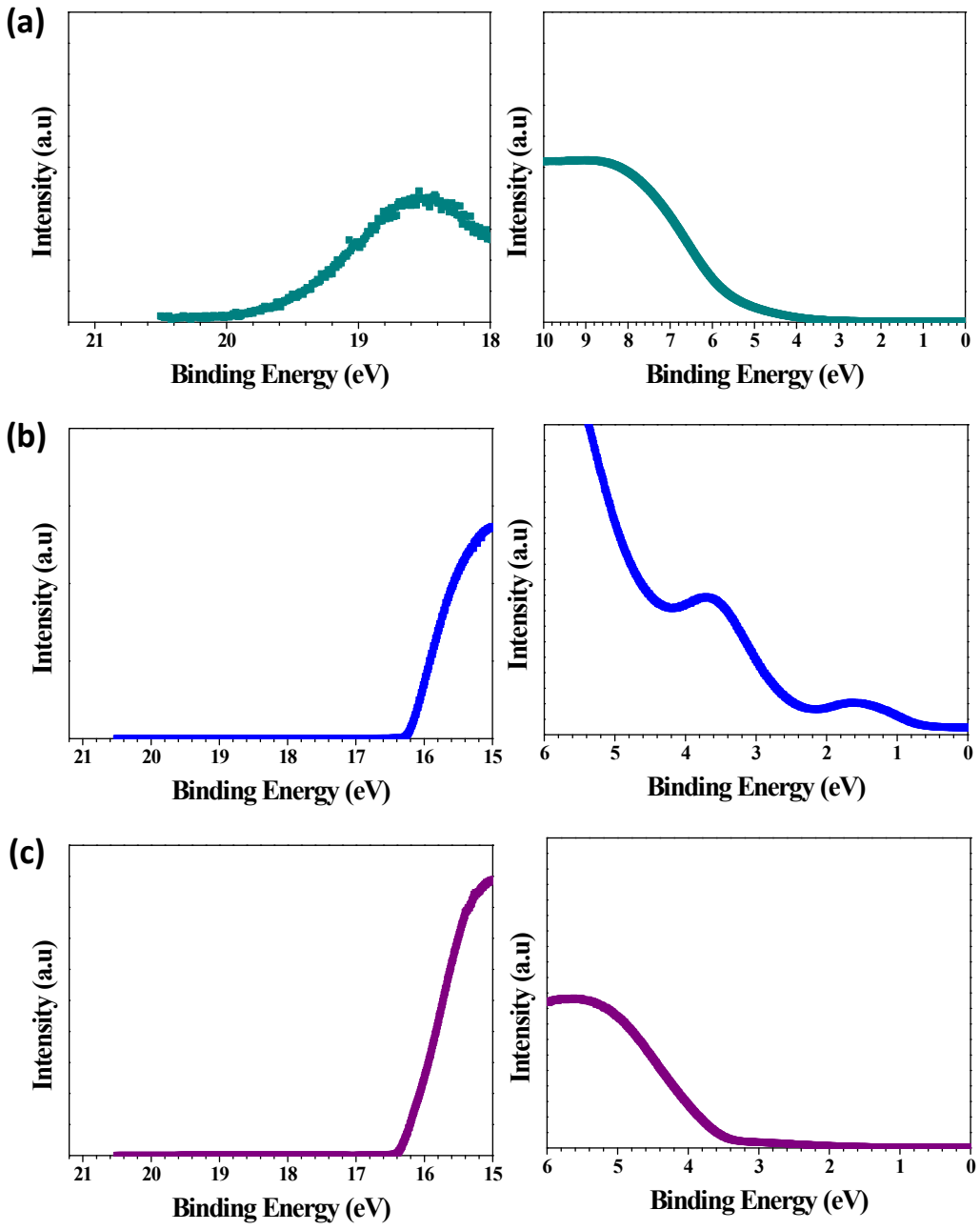

Fig. S3. Ultraviolet photoelectron spectra of (a) QDs, (b) poly-TPD and (c) ZnO NPs

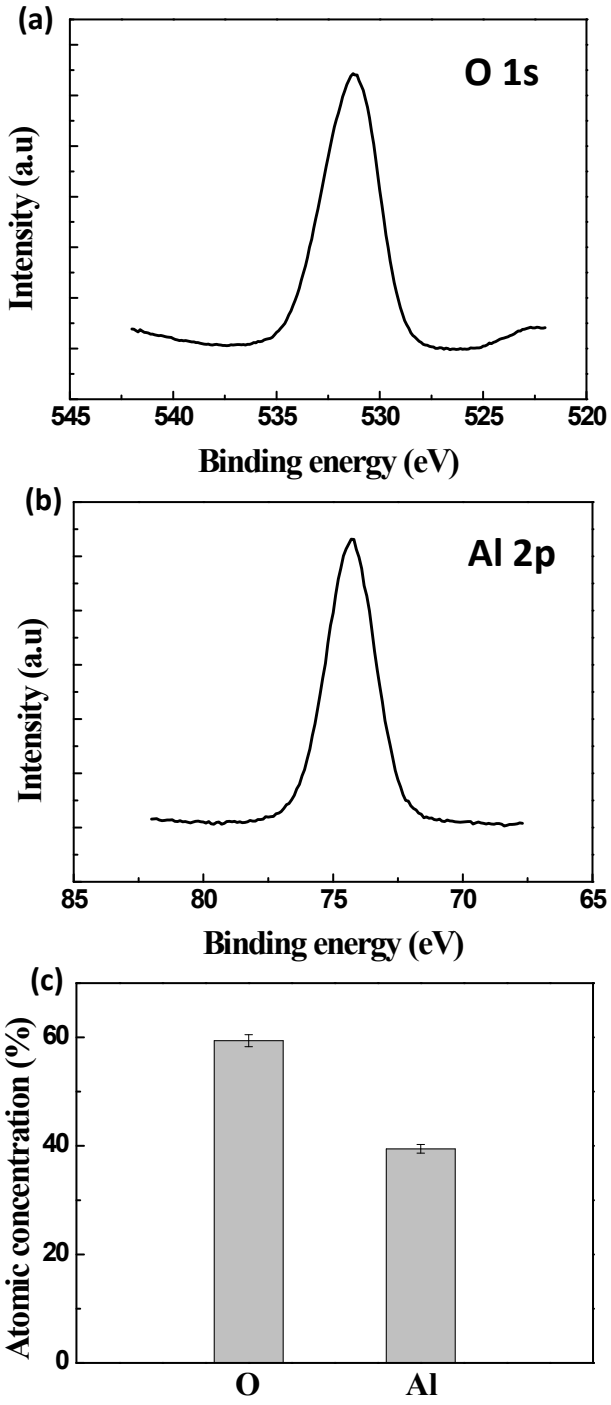

Figure S4. XPS data of Al2O3 interlayer (a) binding energy of O 1s and (b) Al 2p, (c) atomic concentration of Al_2O_3 interlayer

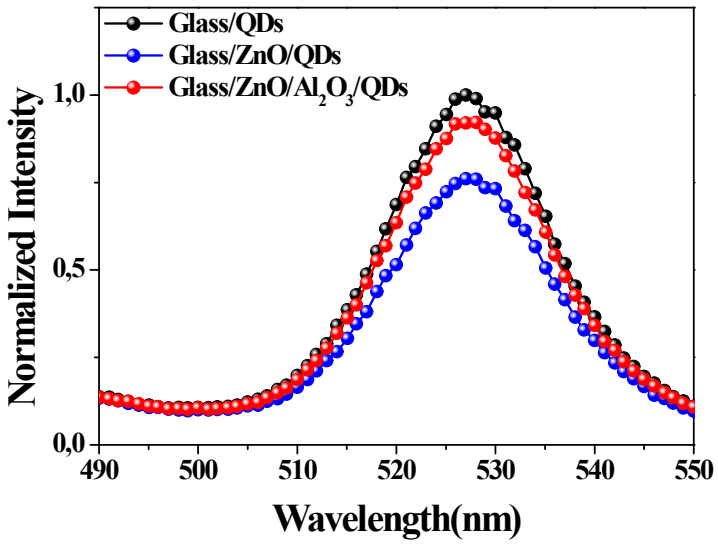

Fig. S5. Stable-state PL spectra of QDs, ZnO/QDs, and ZnO/Al_2O_3/QDs

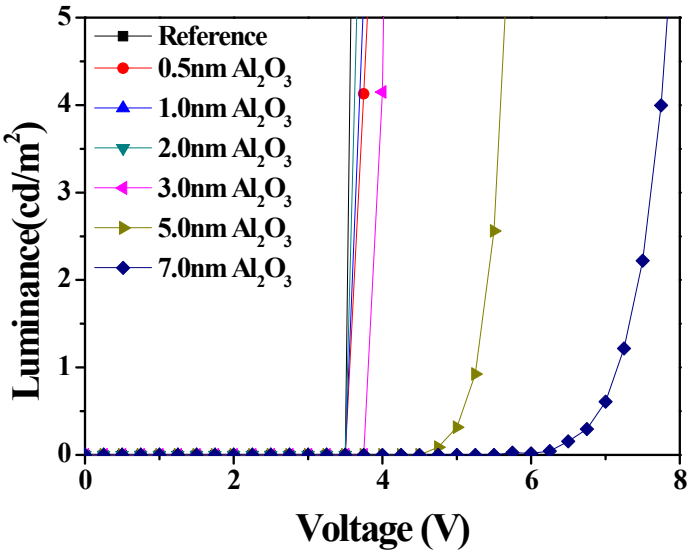

Fig. S6. Luminance-voltage curves of inverted QLEDs depending on the thickness of Al_2O_3 interlayers to define the threshold voltage at a luminance of 1 cd/m2

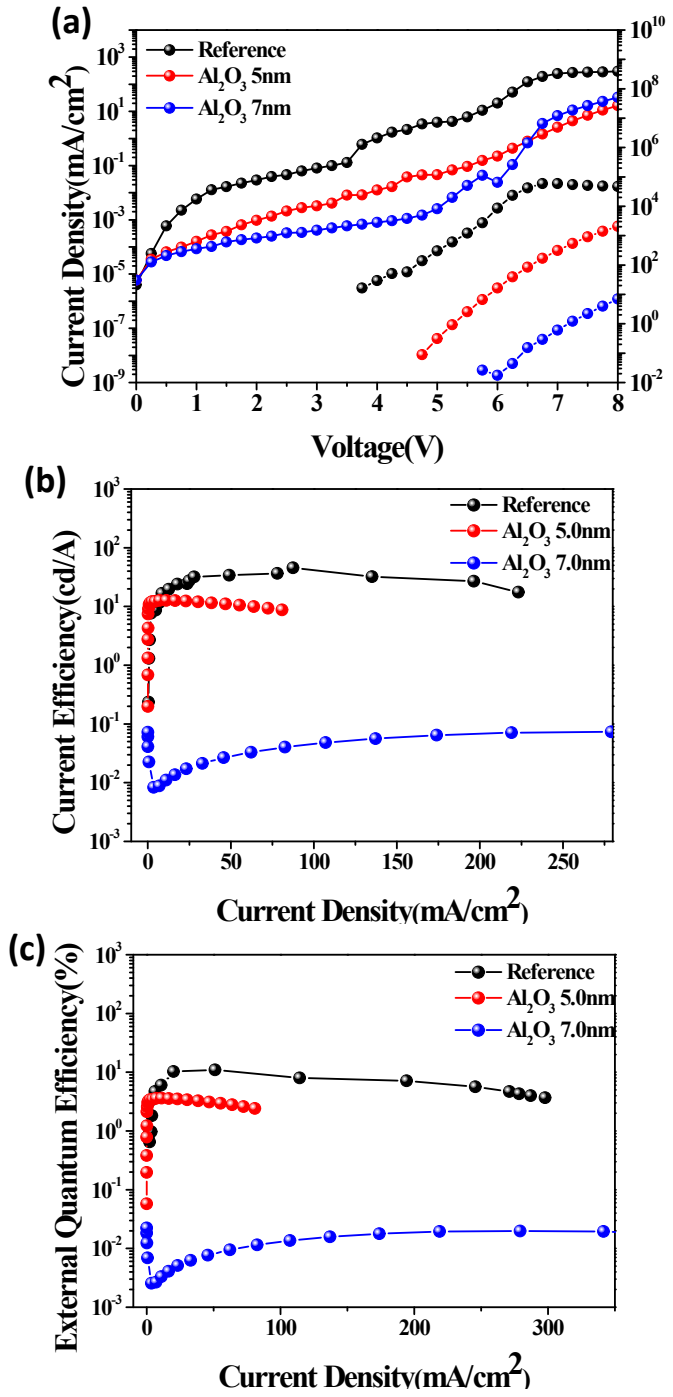

Fig. S7. Optical and electrical properties of QLEDs (a) current density-voltage and luminance-voltage (b) current efficiency-current density (c) external quantum efficiency-current density

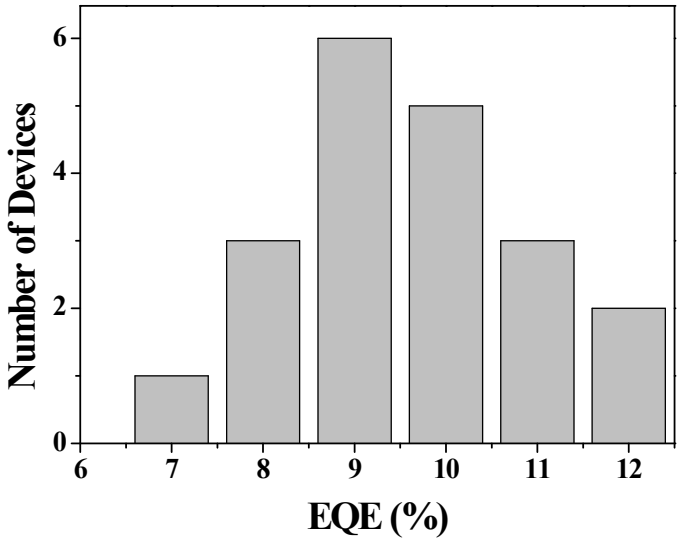

Fig. S8. Histogram of the maximum EQEs of 20 unencapsulated QLEDs with Al_2O_3 interlayers

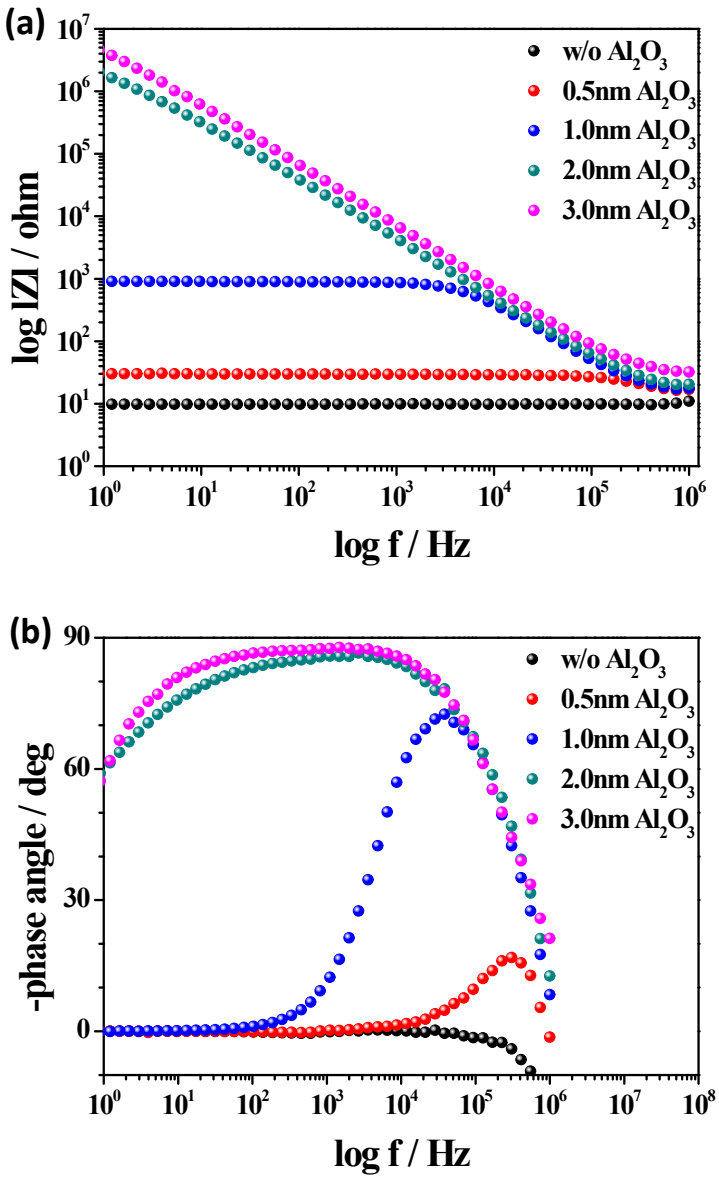

Fig. S9. Bode plots of impedance spectra with the different thickness of Al_2O_3 interlayers (a) log Z vs. log f (b) phase angle vs. log f

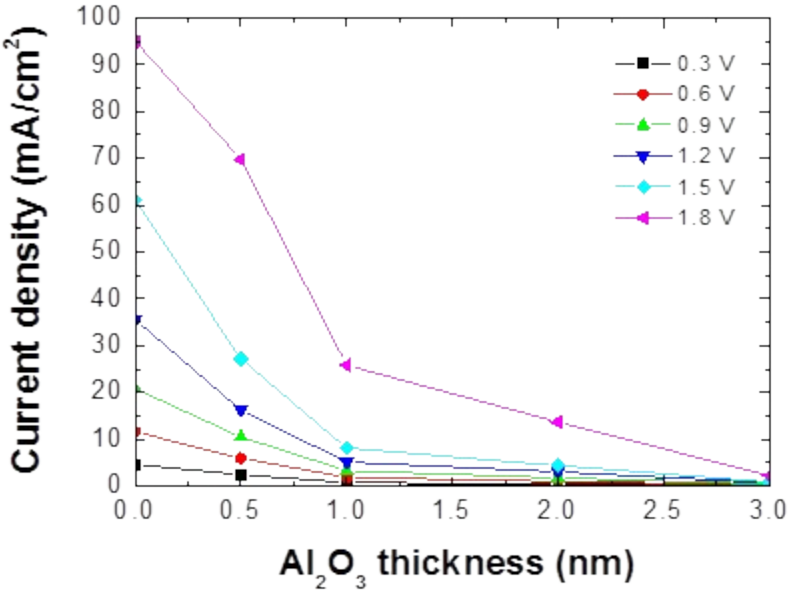

Fig. S10. Current density vs. thickness of Al_2O_3 interlayers with various applied voltage.