Electronic Supplementary Material (ESI) for Energy & Environmental Science.

Environmentally-responsible fabrication of efficient perovskite solar cells from recycled car batteries

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Movie S1 Synthetic process of lead iodide perovskite materials from a lead-acid battery. The movie demonstrates the synthetic process of lead iodide perovskite from a lead-acid battery, including three steps: (1) harvesting material from the anodes and cathodes of car battery; (2) synthesizing PbI_2 from the collected materials; (3) depositing lead iodide perovskite nanocrystals. Also, an economic analysis is also provided, and one car battery enables the fabrication of ~709.0 m^2 PSCs. If the device performance achieves ~15%, the total energy generated from resulting solar panels meets the electricity usage for ~30.2 US residential units in Las Vegas, Nevada. It demonstrates that spent car batteries can serve as sufficient lead sources for the environmentally-responsible fabrication of lead-based PSCs.

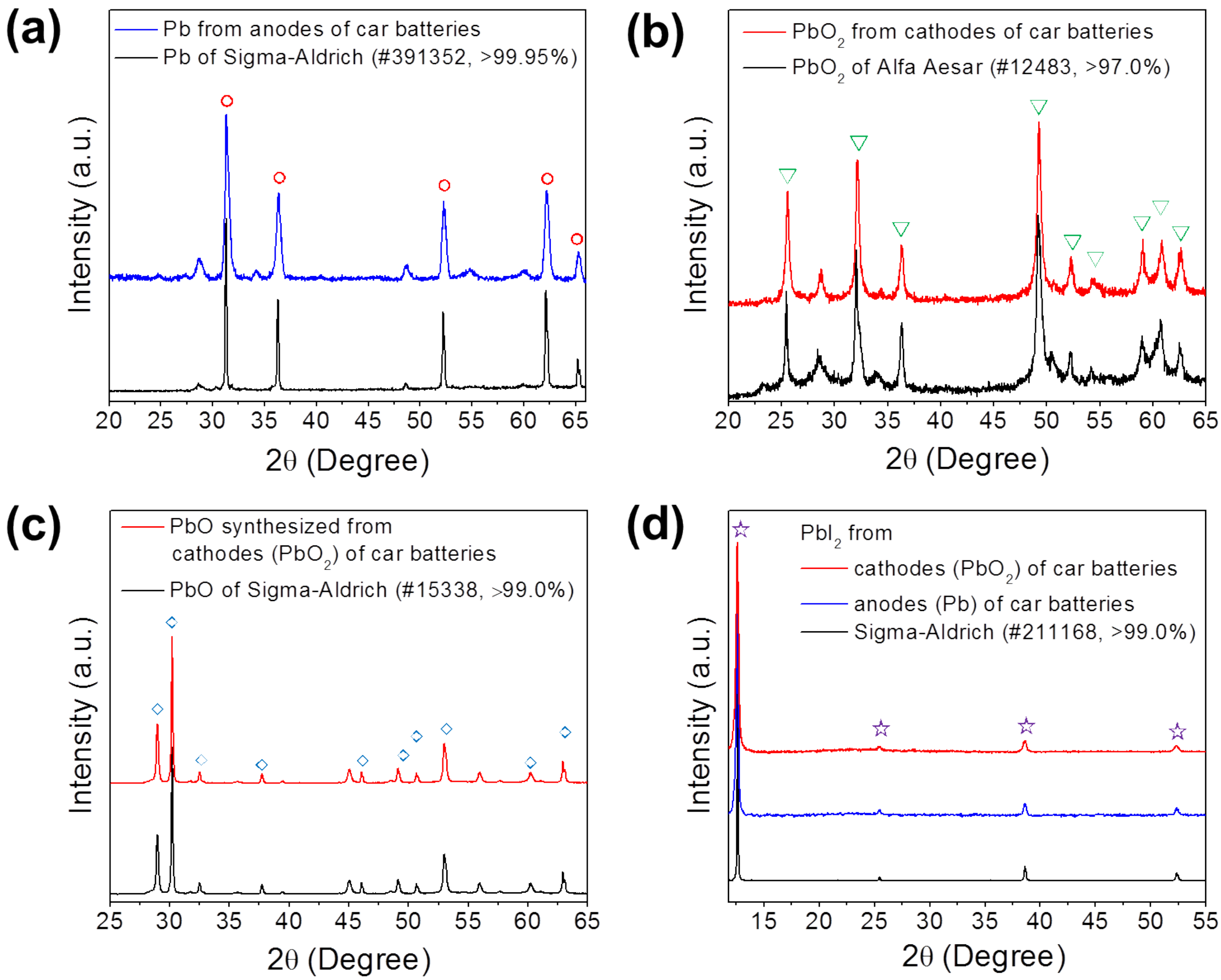

Fig. S1 Materials characterizations. (a) XRD analysis on the high-purity lead powder (Sigma-Aldrich, #391352, >99.95%) and the lead particles from anodes of car batteries. (b) XRD analysis on the high-purity PbO_2 powder (Alfa Aesar, #12483, >97.0%) and the PbO_2 particles from cathodes of car batteries. (c) XRD analysis on the high-purity PbO powder (Sigma-Aldrich, #15338, >99.0%) and the PbO particles after the annealing of PbO_2 particles for 5 hours. (d) XRD analysis on the high-purity PbI_2 powder (Sigma-

Aldrich, #211168, >99.0%) and the PbI_2 powders synthesized from the cathodes and anodes of car batteries.

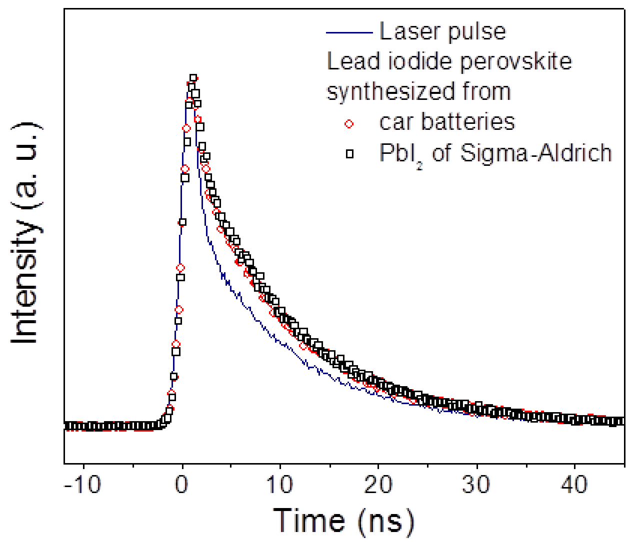

Fig. S2 PL response of perovskite films. Normalized time resolved photoluminescence intensity from the lead iodide perovskite films synthesized from car batteries and commercial PbI_2 powder (Sigma-Aldrich, #211168, >99.0%). The excitation laser pulse profile is shown in solid blue line. All samples exhibit a single exponential relaxation process with the same lifetime of 1.00 ± 0.09 ns.

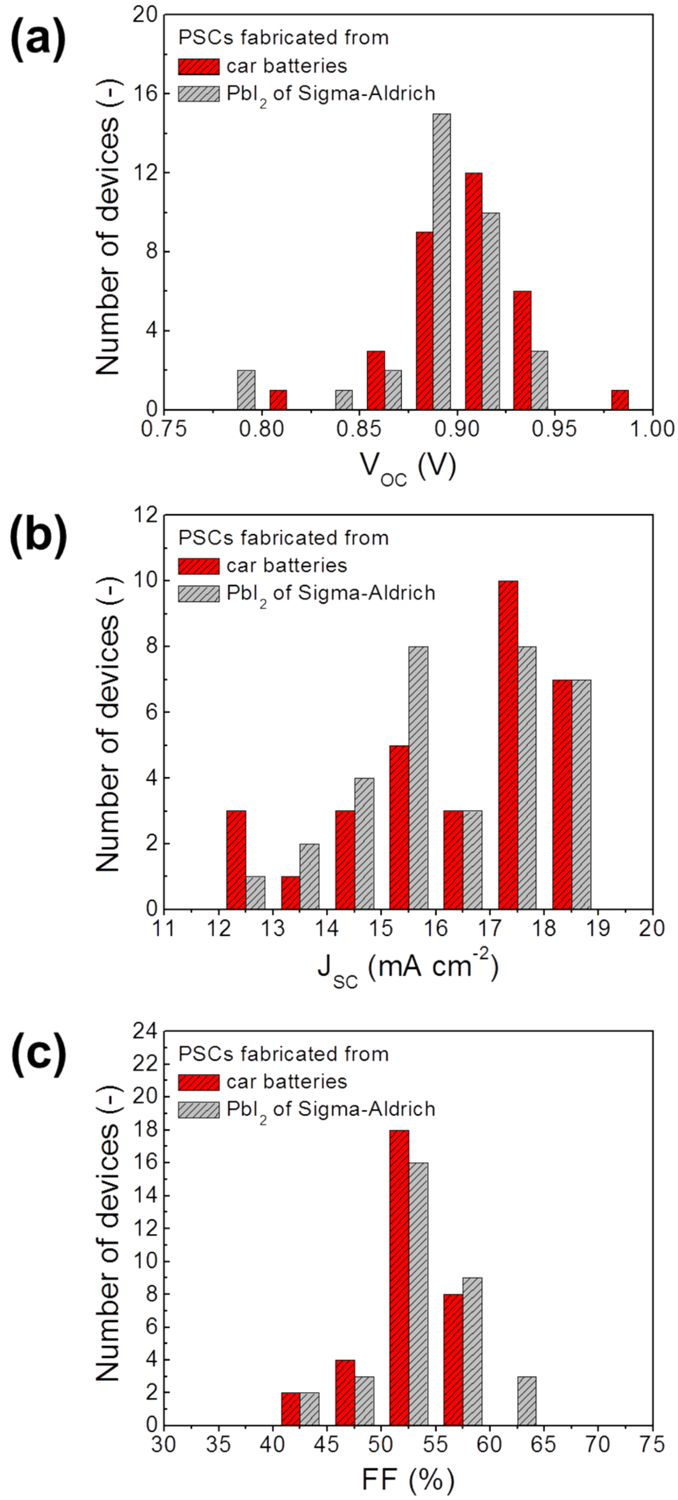
(a)
PSCs fabricated from
car batteries
PbI2 of Sigma-Aldrich
Number of devices (-)
V OC (V)
(b)
PSCs fabricated from
car batteries
PbI2 of Sigma-Aldrich
Number of devices (-)
J SC (mA cm-2)
(c)
PSCs fabricated from
car batteries
PbI2 of Sigma-Aldrich
Number of devices (-)
FF (%)

Fig. S3 Static data of photovoltaic performance of PSCs fabricated from car batteries and high-purity PbI_2. Histogram plots of solar cell performance parameters: (a) V_{OC}, (b) J_{SC}, and (c) FF from multiple batches of $CH_3NH_3PbI_3$-sensitized TiO_2 photovoltaic devices (total of 65 devices).

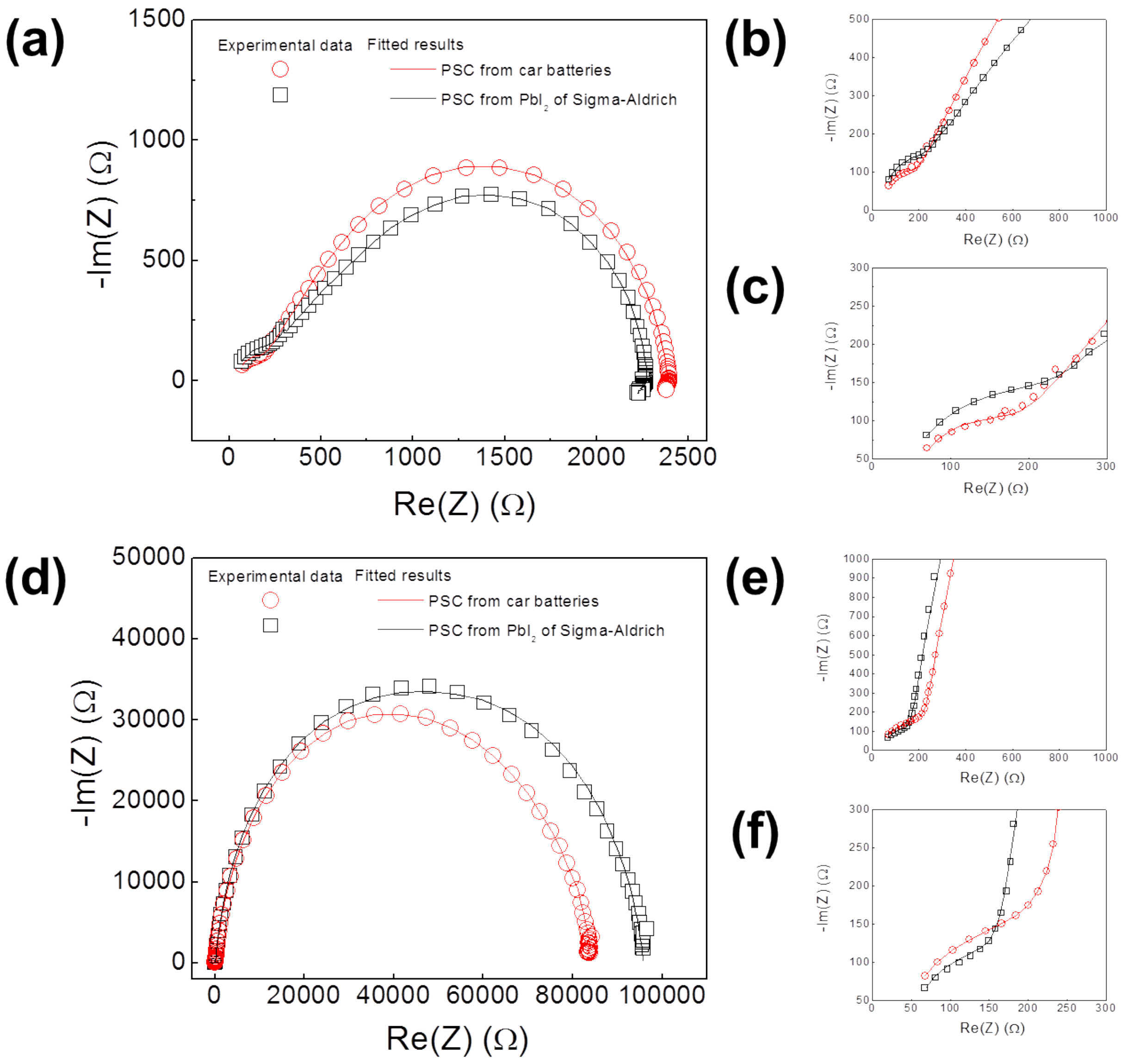

Fig. S4 Nyquist diagrams of PSCs fabricated from car batteries and high-purity commercial PbI_2. (a)-(c) and (d)-(e) are the Nyquist diagrams corresponding to the impedance spectra under dark conditions in the applied voltages at 800 mV and 550 mV, respectively. Transmission line behaviors are clear visible in (b) and (e). The arcs in (c) and (f) represent the impedance responses from the gold/hole-transporting material interface. The transmission lines merge into the semicircles representing the recombination resistance at lower frequency. The solid lines are the fits by the reported models previously used in Ref. 23, 24, 25 and 29 for solid-state DSCs and PSCs.