Annealing-Temperature Dependent Carrier-Transportation in ZnO/PbS Quantum Dot Solar Cells Fabricated Using Liquid-Phase Ligand Exchange Methods

Akihiro Takahashi [1], Haibin Wang [2], Takeshi Fukuda [1], Norihiko Kamata [1], Takaya Kubo [2,*] and Hiroshi Segawa [2,3,*]

[1] Department of Functional Materials Science, Saitama University, 255 Shimo-Okubo, Sakura-ku, Saitama 338-8570, Japan; warudaw@gmail.com (A.T.); takeshi.fukuda@sekisui.com (T.F.); kamata@fms.saitama-u.ac.jp (N.K.)

[2] Research Center for Advanced Science and Technology, The University of Tokyo, 4-6-1 Komaba, Meguro-ku, Tokyo 153-8904, Japan; wanghb@dsc.rcast.u-tokyo.ac.jp

[3] Department of General Systems Studies, Graduate School of Arts and Sciences, The University of Tokyo, 3-8-1 Komaba, Meguro-ku, Tokyo 153-8902, Japan

* Correspondence: ukubo@mail.ecc.u-tokyo.ac.jp (T.K.); csegawa@mail.ecc.u-tokyo.ac.jp (H.S.); Tel.: +81-3-5452-5297 (H.S.)

Supplementary Materials

Table S1. Solar cell performance parameters obtained from PbS QD solar cells treated with different annealing temperatures.

Annealing temperature	Jsc[a] (EQE)	Jsc	Voc	FF	PCE
(^{o}C)	(mA/cm^2)	(mA/cm^2)	(V)	(%)	(%)
20	24.30	25.4 ± 1.1	0.562 ± 0.03	46.9 ± 2.5	6.71 ± 0.7 (7.4)
60	26.70	26.9 ± 1.0	0.591 ± 0.003	60.9 ± 2.5	9.68 ± 0.6 (10.3)
80	28.15	27.4 ± 1.2	0.609 ± 0.007	61.4 ± 3.2	10.24 ± 0.5 (10.8)
100	27.95	28.7 ± 0.5	0.601 ± 0.01	57.5 ± 2.5	9.93 ± 0.7 (10.7)
120	27.40	27.8 ± 1.5	0.584 ± 0.02	58.1 ± 3.8	9.44 ± 0.8 (10.2)
140	27.64	28.0 ± 2.3	0.505 ± 0.02	50.2 ± 3.2	7.10 ± 1.0 (8.1)

[a]The J_{sc} values predicted from the EQE spectra show good agreement with the experiment values.

[b]The PCEs in brackets represent the values obtained for the best-PCE cells. The performance parameters statistic of six devices are shown in the table.
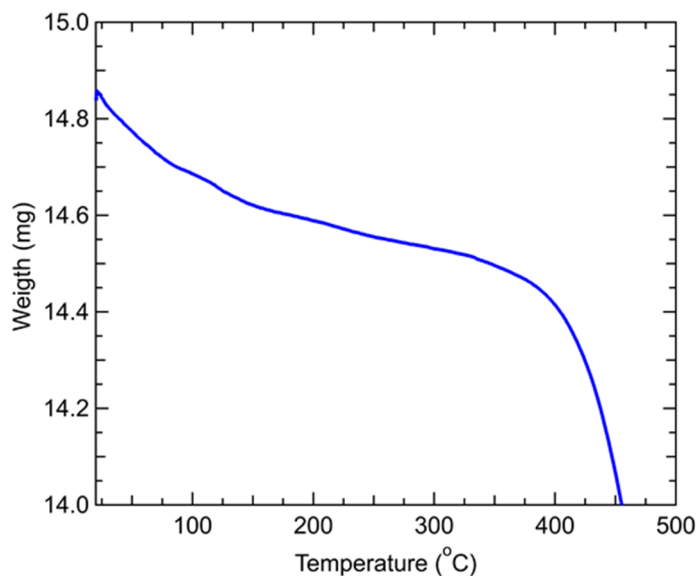
Figure S1. TGA curve obtained on PbS QD pieces scratched off from an as-prepared PbS QD film formed on a glass substrate.
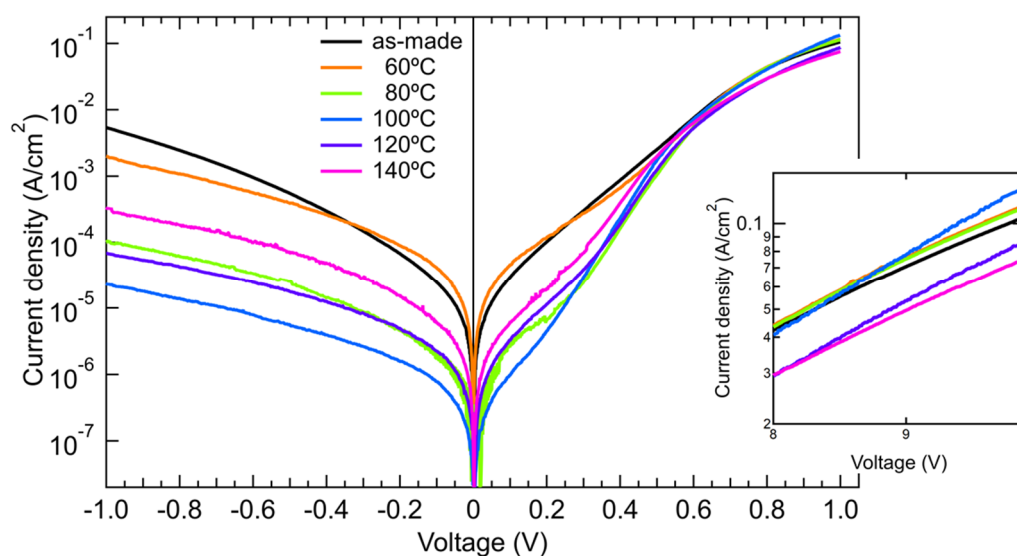

Figure S2. J-V characteristics in the dark condition of pristine and annealed solar cells.

The inset figure line indicates SCLC regime following Mott-Gurney's low (J~ V^2). The Equation. (1) is used to calculate the mobility (μ_e):

$$J_{SCLC} = \frac{9}{8}\varepsilon\varepsilon_0\mu_e\frac{V^2}{L^3} \tag{1}$$

where ε and ε_0 are relative and vacuum dielectric permittivities, respectively, V is the applied voltage, l is the QD film thickness.

With the carrier lifetime and the carrier diffusion coefficient values defined as D = (k_bT/q)μ_e, the carrier diffusion length L (~ (Dτ)$^{1/2}$) was estimated.
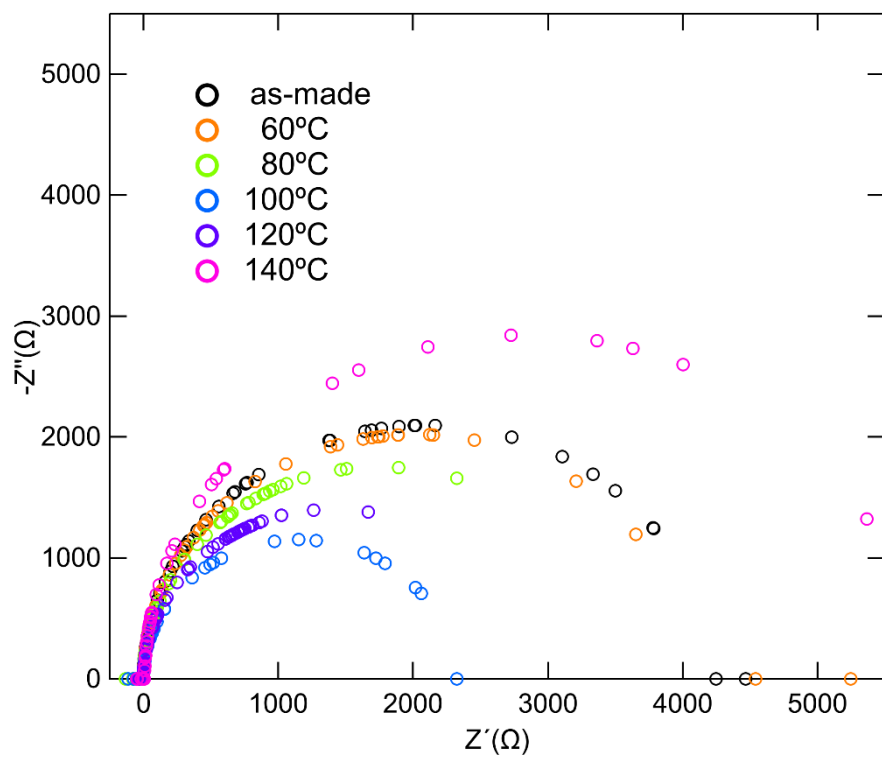
Figure S3. Impedance spectroscopy spectra. Typical Nyquist plots obtained on the ZnO/PbS QD solar cells.