Supporting Information

Highly Efficient Quasi-solid-state Dye-sensitized Solar cell using Polyethylene oxide (PEO) and Poly(methyl methacrylate) (PMMA)-based Printable Electrolytes

*Shanmuganathan Venkatesan,[a] I-Ping Liu,[a] Jian-Ci Lin,[a] Ming-Hsiang Tsai,[a] Hsisheng Teng[a] and Yuh-Lang Lee[a, b]**

[a]*Department of Chemical Engineering, National Cheng Kung University, No.1 University Road, Tainan 70101. Taiwan. E mail:yllee@mail.ncku.edu.tw*

[b]*Hierarchical Green-Energy Materials (Hi-GEM) Research Center, National Cheng Kung University, Tainan 70101, Taiwan No.1 University Road, Tainan 70101. Taiwan*

*E-mail: yllee@mail.ncku.edu.tw. Tel: +886-6-2757575 ext. 62693. Fax: +886-6-2344496.

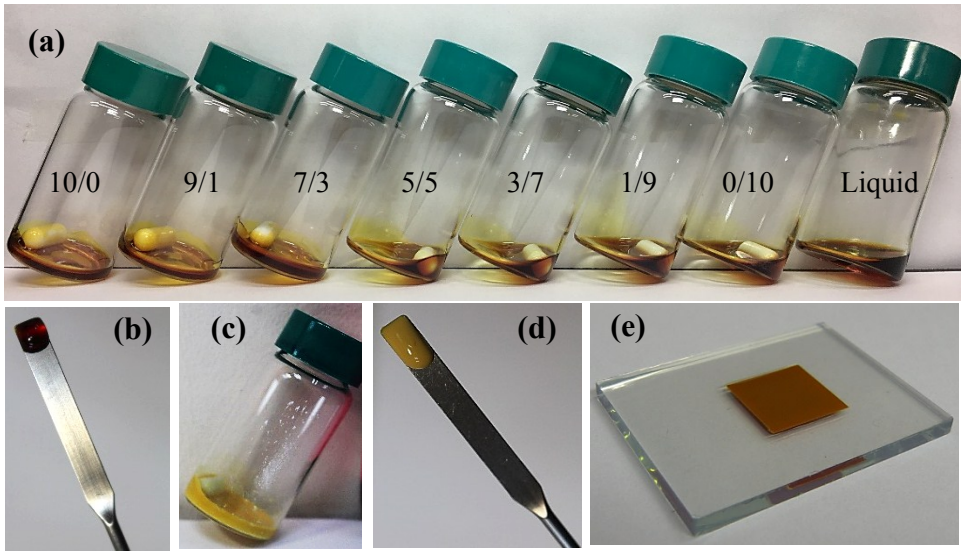

Fig. S1. (a) Preparation of printable electrolytes at different stages. The electrolytes contain 9 wt. % polymer with various compositions of PEO/PMMA in MPN-liquid electrolyte, (b) a printable electrolyte paste prepared by using PEO/PMMA (7/3), (c-d) PEO/PMMA (7/3)/TiO_2 NFs (10 wt. %) based PE paste and (d) printed electrolyte on the photoanode surface.

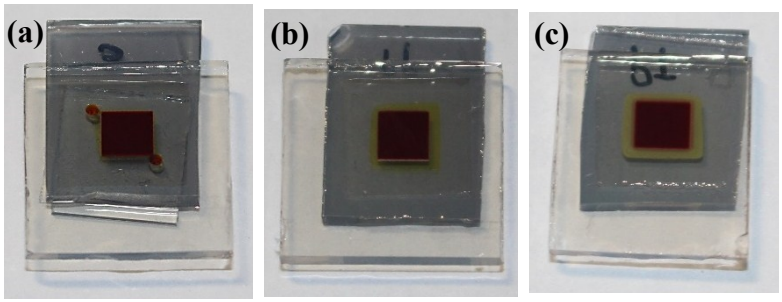

Fig. S2. DSSCs assembled with (a) liquid electrolyte, (b) PEO/PMMA (7/3) PE and (C) PEO/PMMA/TiO_2 PE.

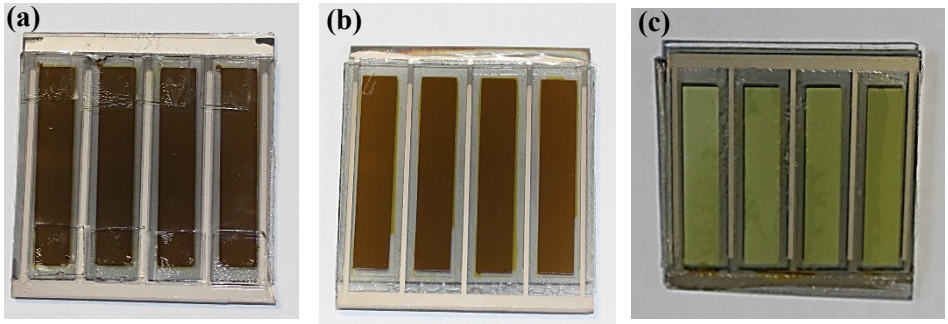

Fig. S3. Sub-module DSSCs assembled with (a) liquid electrolyte, (b) PEO/PMMA (7/3) PE and (C) PEO/PMMA/TiO_2 PE.

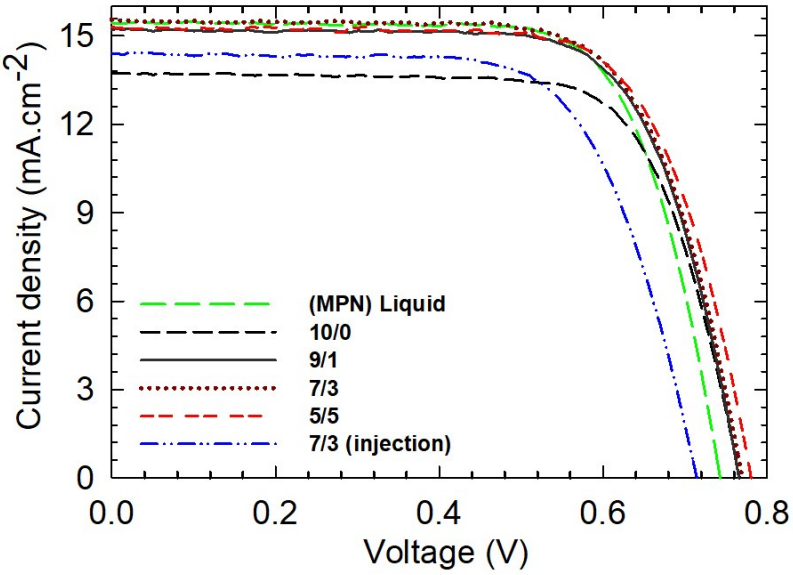

Fig. S4. J-V curves measured for the DSSCs using liquid electrolyte and printable electrolyte systems. The PEs contains 9 wt. % polymer and the PEO/PMMA is 7/3. These curves were measured under a one-sun condition with the intensity of 100 mW cm^{-2}.

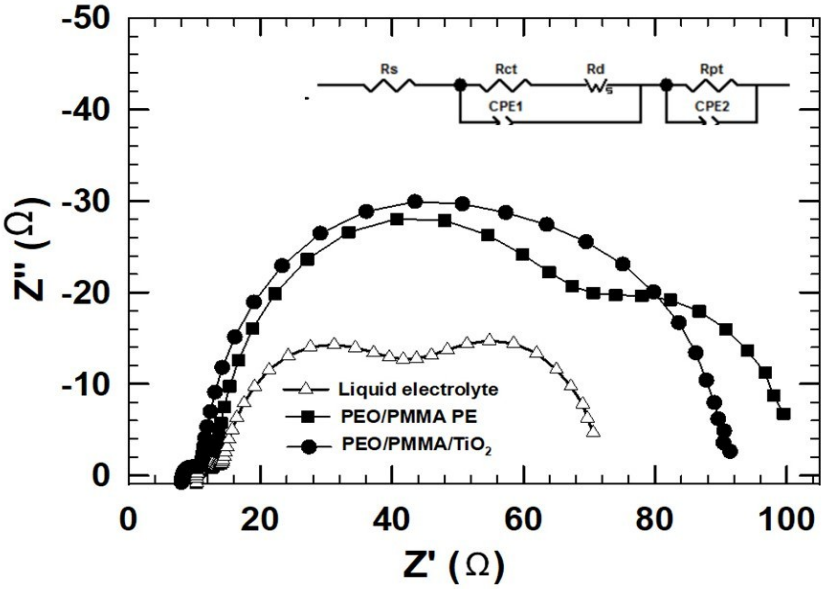

Fig. S5. Nyquist plots of the EIS spectra measured at 0.75 V under dark conditions for the liquid-state cell and QS-DSSCs with and without 10 wt. % TiO_2 NFs.

Description: The EIS spectra in Fig S5 show the three semi-circles for the cells using liquid-electrolyte and PEO/PMMA PE. These circles are corresponding to the R_{pt} (high frequency region), the R_{ct} (middle frequency region), and Nernstian diffusion (R_w) (low frequency region) within the electrolytes. For the cell using PEO/PMMA/TiO_2 NFs, only two semicircles are observed because of overlaps occurred between middle and low frequency circles.

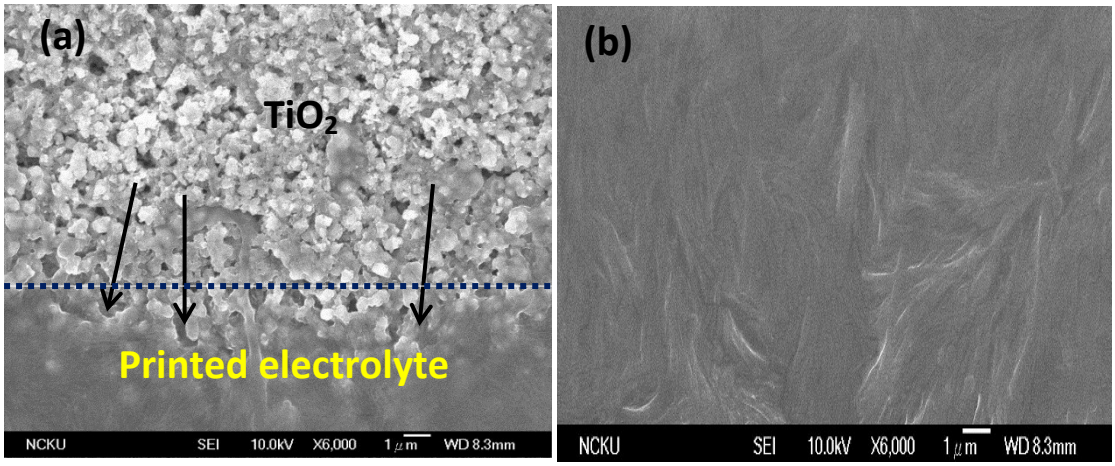

Fig. S6. (a) SEM image of the partially printed electrolyte on the photoanode. The arrow marks on the image indicate a strong penetration of the PE into the nanopores of the TiO_2. (b) The surface of the photoelectrode after completely covered with printed electrolyte.

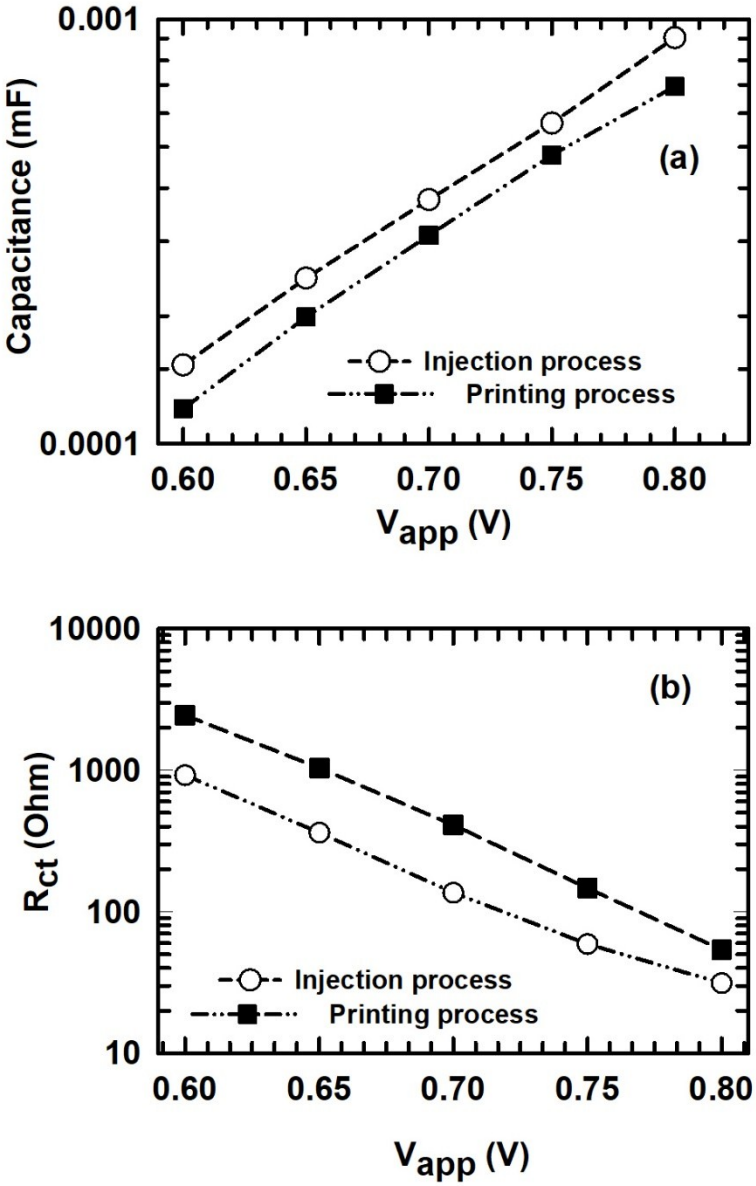

Fig. S7. Comparison between the injection and printing process for the PEO/PMMA electrolyte based on the (a) capacitance and (b) R_{ct}.

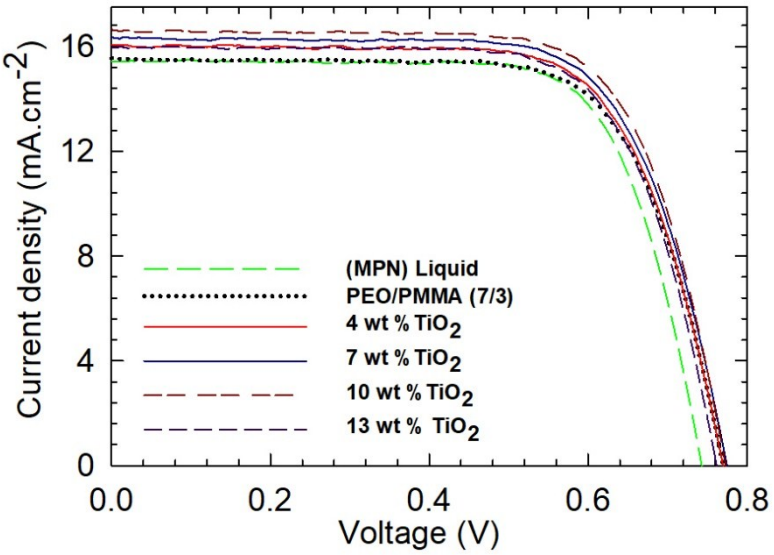

Fig. S8. J-V curves measured for the QS-DSSCs using the printable electrolyte with TiO_2 NFs. The compositions of TiO_2 NFs are 4-13 wt.%. These curves were measured under a one-sun condition with the intensity of 100 mW cm^{-2}.

Table S1. Comparison among the characteristics of PEO/PMMA-based electrolytes (PGEs and PEs) and corresponding performance of QS-DSSCs reported in the literature.

References	**Polymer utilized**	**Electrolyte**	**σ x 10^{-3} (S cm^{-1})**	**R_{pt}**	**R_{ct}**	**J_{sc} (mA cm^{-2})**	**V_{oc} (V)**	**FF**	**η (%)**
Shi et al 2009		EC/PC (8/2)-liquid							
(ref. 36)	PMA/PEG (65/35, 27 wt %)	PGE (PMA)	1.90			7.5	0.640	0.66	3.17
		PGE (PMA/PEG)	2.10			9.3	0.687	0.59	4.71
Wang et al		MPN-liquid	3.40		41.01	17.40	0.74	0.71	9.14
2013 (ref. 25)	[P(VA-co-MMA)] (20 wt %)	PE	2.60		36.31	17.32	0.71	0.70	8.61
		PE/TiO_2	2.62		38.09	17.58	0.73	0.70	8.98
Theerthagiri et		ACN-liquid							
al 2015 (ref. 37)	PMMA-PEO	PGE (PEO-PMMA)	4.18			5.54	0.69	0.59	2.20
		PGE (PEO-PMMA-2-MCP)	15.5			6.06	0.73	0.69	3.00
Aram et al 2015		EC/PC/DMC (4/2/1)-liquid				12.86	0.68	0.59	5.15
(ref. 35)	PEO	PGE (PEO)	2.20	High		5.89	0.74	0.472	2.06
	PEO/PMMA (10/90)	PGE (PEO/PMMA)	7.00	low		11.11	0.76	0.58	4.90
Mohan et al		ACN/NMP (8/2) liquid		1.47	7.35	12.87	0.734	0.630	5.96
2017 (ref. 38)	PMMA	PGE (PMMA)	0.987	7.73	29.34	4.15	0.794	0.841	2.77
		PGE/CB (0.57 wt %)	3.32	3.48	12.99	12.43	0.766	0.580	5.52
		MPN	1.95	1.31	Low	15.47	0.743	0.726	8.34
Present Study		PE (PEO)	1.28	2.54		13.75	0.767	0.725	7.65
	PEO/PMMA (7/3, 9 wt%)	PE (PEO/PMMA)	1.40	1.84	Middle	15.56	0.770	0.708	8.50
		PE/TiO_2	1.29	1.20	high	16.64	0.773	0.709	9.12