Electronic Supplementary Material (ESI) for Physical Chemistry Chemical Physics

Supporting Information

Patterned 3-Dimensional Metal Grid Electrodes as Alternative Electron Collector in Dye-sensitized Solar Cells

Julianto Chua,[a] Nripan Mathews,[a*] James R. Jennings,[b] Guangwu Yang,[b] Qing Wang[b] and Subodh G. Mhaisalkar [a,c*]

[a] School of Materials Science & Engineering, Nanyang Technological University, Singapore, email: Nripan@ntu.edu.sg; Subodh@ntu.edu.sg
[b] Department of Materials Science & Engineering, National University of Singapore, Singapore
[c] Energy Research Institute @ NTU (ERI@N), Nanyang Technological University, Singapore

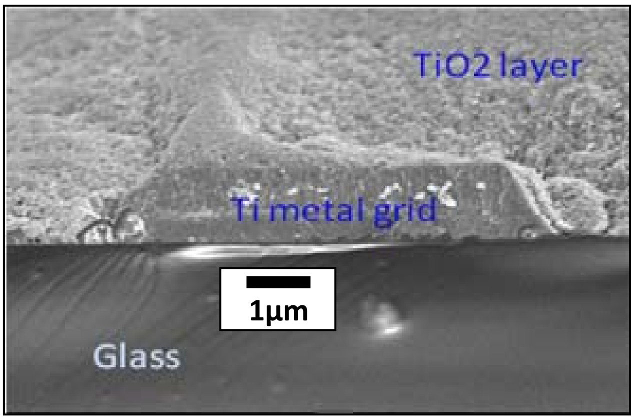

Fig S1. Cross section SEM image, showing that TiO2 film conforms well on the metal grid

Table S1. 4-point probe measurement of titanium metal and FTO layer, before and after a post processing consisting of $TiCl_4$ treatment and sintering to 500°C

Sheet resistance	Titanium metal	FTO layer
Before	1.22 Ω/sq	11.96 Ω/sq
After	4.5 Ω/sq	12.64 Ω/sq

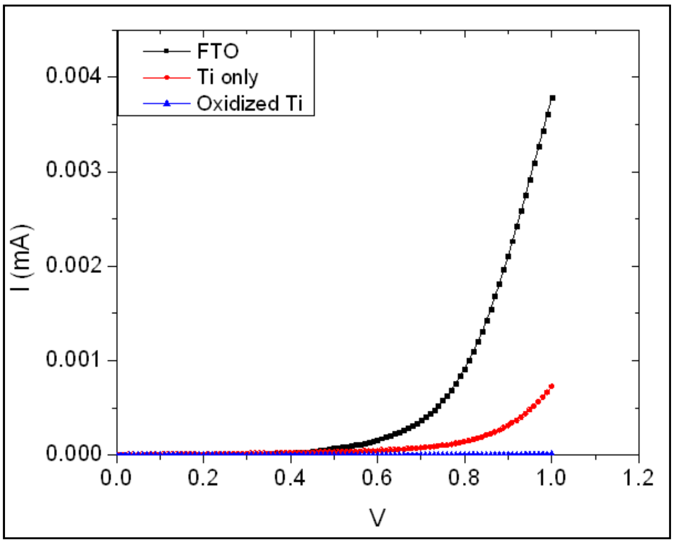

Fig S2. Leakage characteristics of FTO-electrolyte-FTO system vs FTO-electrolyte-titanium metal system

Dark currents were measured for blank cells consisting of FTO -electrolyte- FTO configuration (black curve). The replacement of one of the FTO electrodes with the metal grid electrode results in reduced current (red curve). The sintering of the metal grid further reduces the dark currents (blue curve) which is more apparent at potentials greater than 0.6V

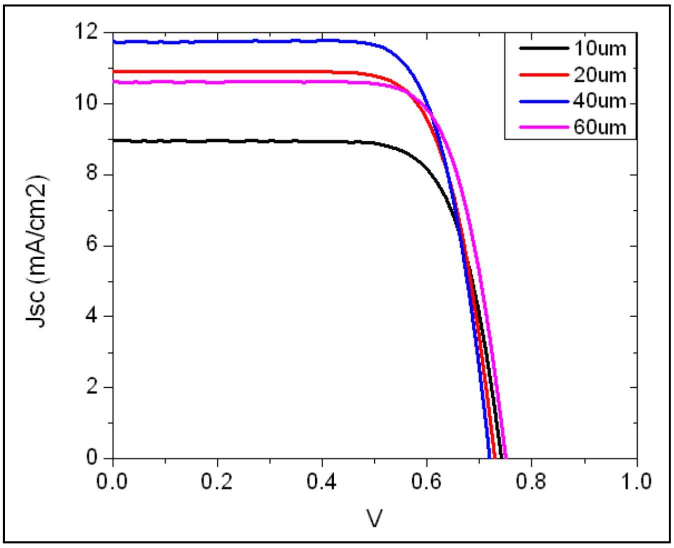

Fig S3. JV curves of various spacing MGE DSC (6um grid width)

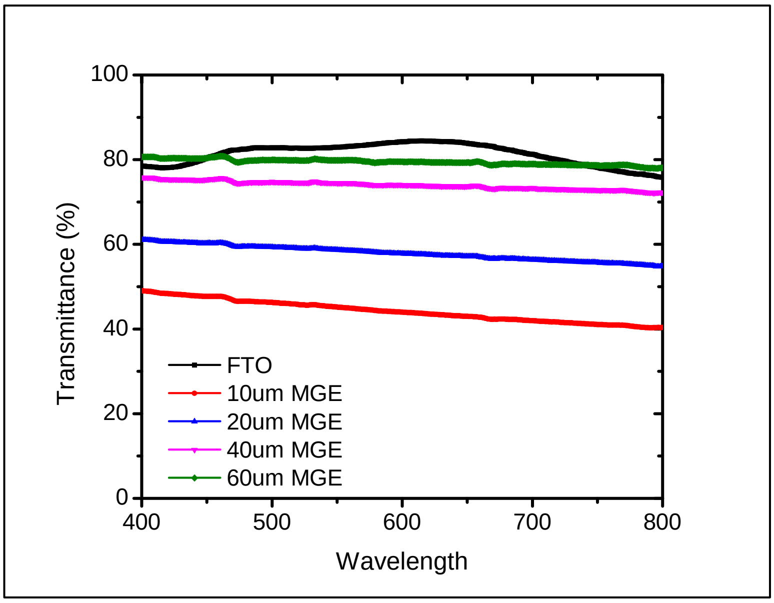

Fig S4. Transparency of various spacing MGE substrate (6um grid width, referenced to air)

S6. Normalized Photocurrent measurements for front and back illumination

All the MGE substrates in this experiment are patterned with 8um grid width (as compared to 6um grid width for the devices mentioned in the main article). Device fabrication follows the exact process and materials as mentioned in the main article.

Table S2. Performance of the various spacing MGE DSCs and normalized J_{SC} (for transparency) for front electrode (FE) illumination

	Voc (V)	Jsc (mA/cm^2)	FF (%)	η (%)	Transparency (%)	Normalized Jsc (mA/cm^2)
Standard cell	0.743	12.11	73.41	6.60	81.30	14.90
10um MGE DSC	0.717	6.74	75.23	3.64	38.03	17.72
20um MGE DSC	0.734	8.49	74.22	4.63	58.70	14.46
40um MGE DSC	0.745	9.43	74.46	5.23	68.64	13.74
60um MGE DSC	0.724	8.53	76.19	4.70	75.49	11.30

Table S3. Performance of the various spacing MGE DSCs and ratio of Jsc over transparency for counter electrode (CE) illumination

	Voc (V)	Jsc (mA/cm^2)	FF (%)	η (%)	Transparency (%)	Normalized Jsc (mA/cm^2)
Standard cell	0.709	7.84	75.14	4.18	73.19	10.71
10um MGE DSC	0.707	7.82	74.22	4.11	71.01	11.01
20um MGE DSC	0.702	6.80	74.17	3.54	66.83	10.17
40um MGE DSC	0.734	7.12	76.41	3.99	71.82	9.91
60um MGE DSC	0.713	6.52	77.36	3.60	68.80	9.48

S6. Conclusion: Results shown in *Table S2* and *Table S3* show that the best Jsc-to-transparency ratio (normalized Jsc) is actually exhibited by the 10um spaced MGE DSC. We attribute this to its shortest electron transport distance, which is approximately ~5um (half its spacing between grids). As expected, normalized Jsc of the 20um spaced MGE DSC is very close to that of standard cell, because its electron transport distance (~10um) is similar to that of standard cell (~10um, which is the thickness of TiO_2 photoanode). Generally, the normalized Jsc of MGE DSCs reduces with increasing spacing; indicating that electron loss due to recombination is more pronounced when the electron has to travel further.

As the experiments described above indicate, transparency is not the only issue limiting the photocurrent within our devices. The larger grid spacings which necessitate a large electron transport length in our devices, also contributes to the photocurrent reduction. This is in agreement with previous studies on the maximum thickness of TiO_2 photoelectrode that can be utilized in a DSC before recombination losses become dominant.[1]

1. Halme, J., et al., *Spectral Characteristics of Light Harvesting, Electron Injection, and Steady-State Charge Collection in Pressed TiO2 Dye Solar Cells.* The Journal of Physical Chemistry C, 2008. **112**(14): p. 5623-5637.