Supporting Information

A one-step laser process for rapid manufacture of mesoscopic perovskite solar cells prepared under high relative humidity

Qian Chen[†], Muhamad Z. Mokhtar[†], Jack Chun-Ren Ke[‡§], Andrew G. Thomas[†‡], Aseel Hadi[†], Eric Whittaker[‡], Michele Curioni[†] and Zhu Liu[†]*

[†]School of Materials, The University of Manchester, Manchester, M13 9PL, UK

[‡]Photon Science Institute, The University of Manchester, Manchester, M13 9PL, UK.

[§]School of Physics and Astronomy, the University of Manchester, Manchester M13 9PL, UK

Corresponding Authors

Zhu Liu

Tel.: 0044 1613064845

*E-mail: zhu.liu@manchester.ac.uk

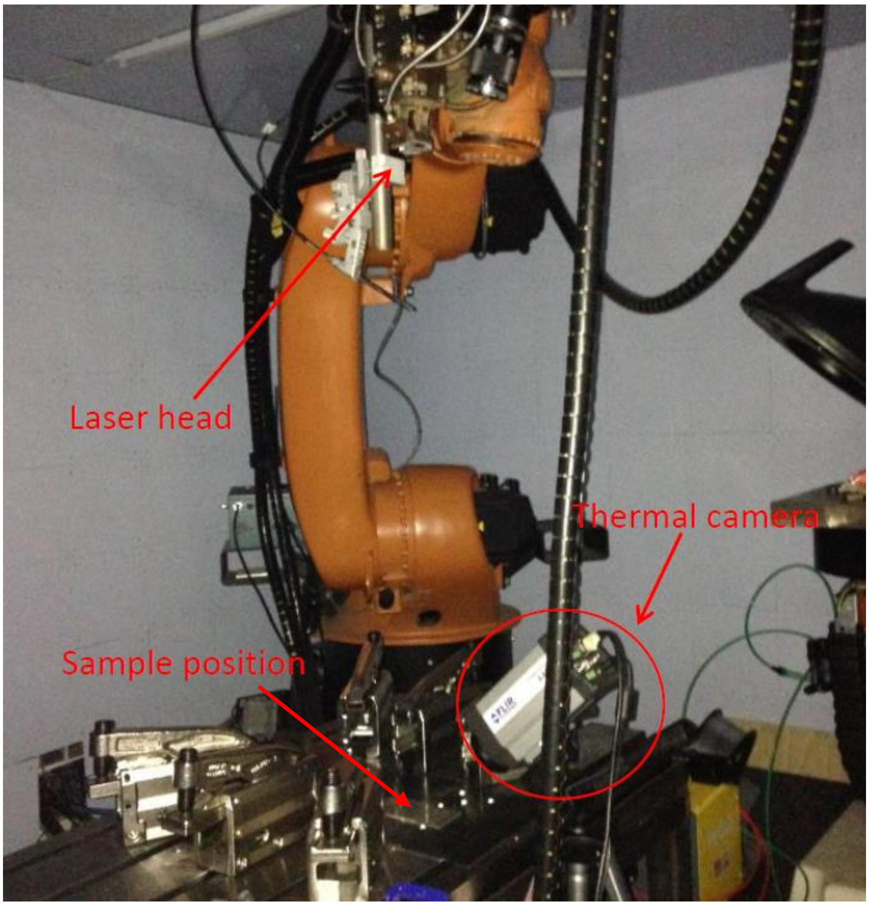

Figure S1. A photograph of the laser set-up for the rapid fabrication of both mesoporous and compact TiO_2 films.

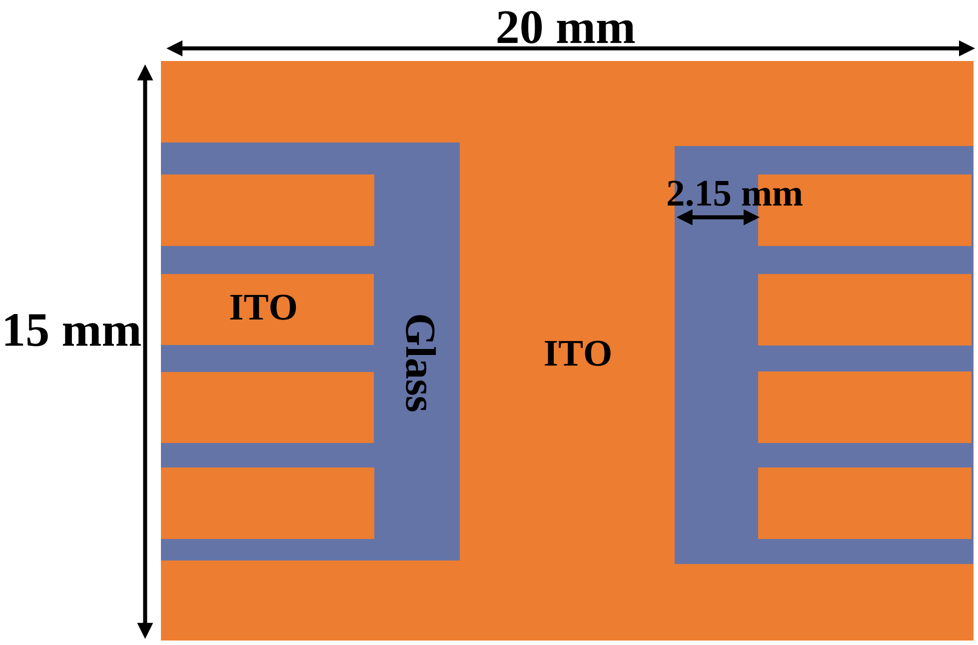

Figure S2. A schematic representation of laser-patterned ITO on glass with a laser isolation line of 2.15 mm in width.

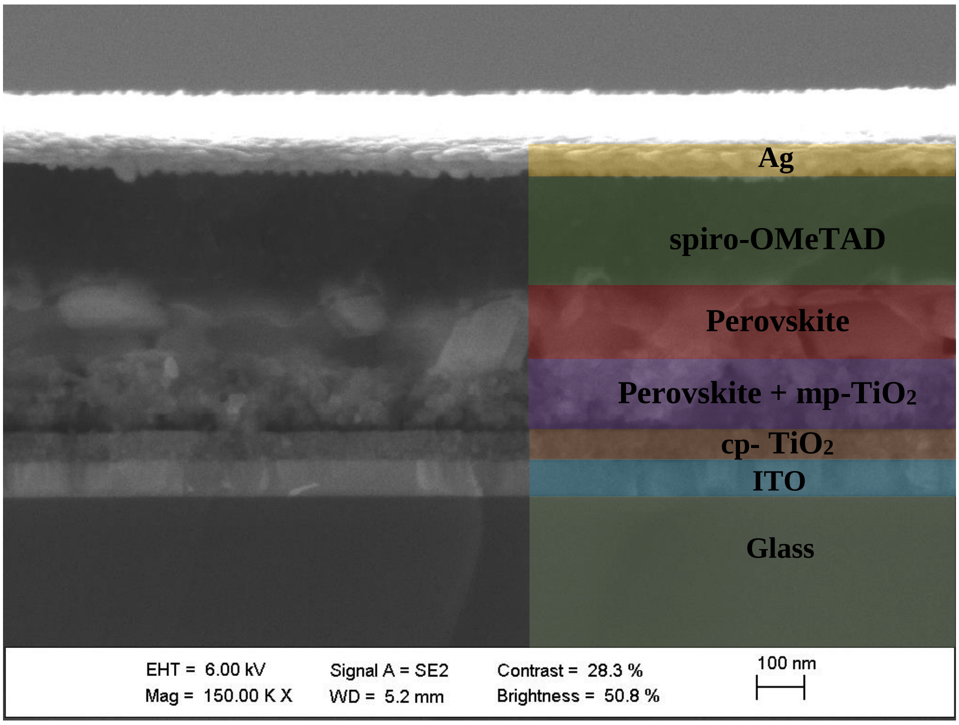

Figure S3. SEM cross-sectional view of the PSCs fabricated in an environment with a relative humidity around 60% based on a configuration of ITO/compact TiO_2/mp-TiO_2/perovskite/spiro-MeOTAD/Ag.

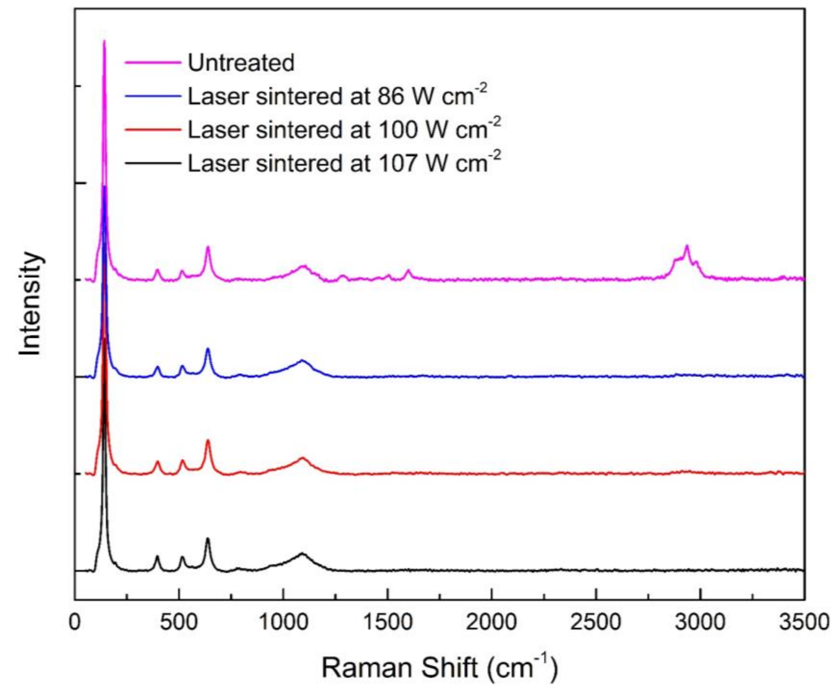

Figure S4. Raman spectra of untreated and laser sintered TiO_2 mesoporous structures at 86, 100 and 107 W cm^{-2}.

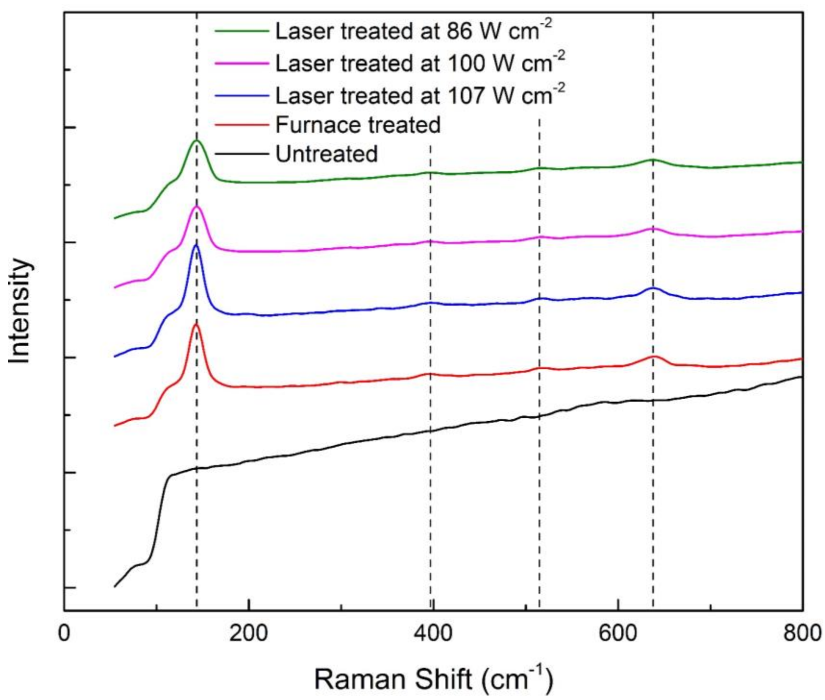

Figure S5. Raman spectra of untreated, furnace and laser treated compact TiO_2 films at 86, 100 and 107 W cm^{-2}.

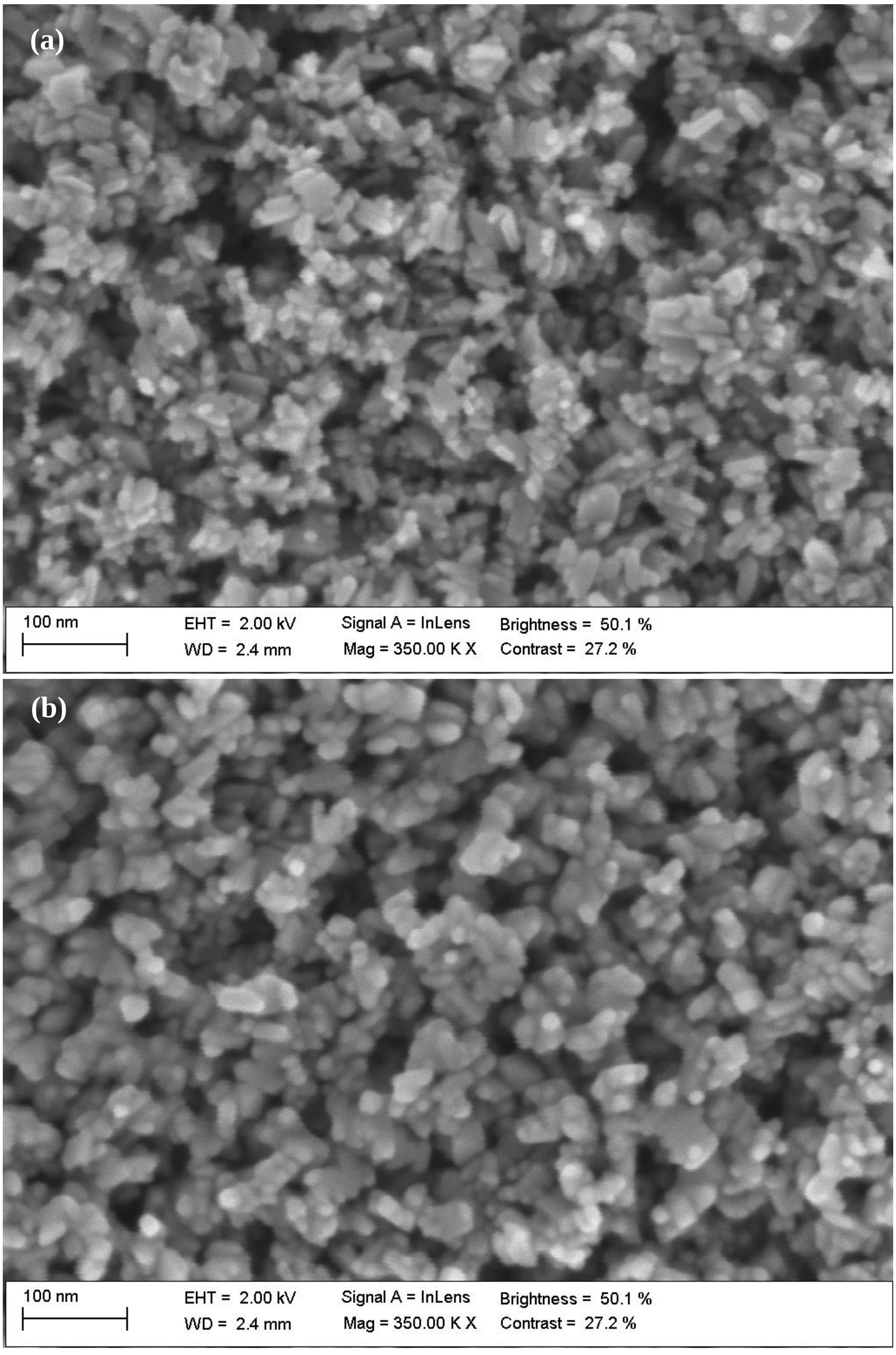

Figure S6. SEM images of top views of laser treated TiO_2 mesoporous structures at (a) 86 and (b) 107 W cm^{-2}.

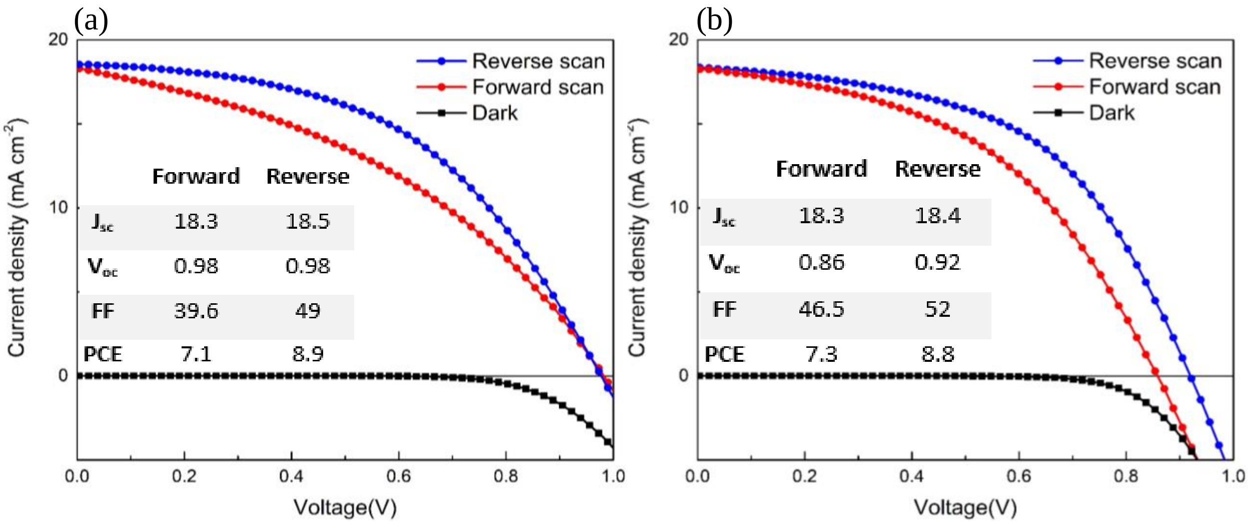

Figure S7. Current density-voltage (J-V) curves of perovskite solar cells produced by (a) 2 h furnace treatment and (b) laser treated for 1 min at 107 W cm^{-2} densities under standard AM 1.5G condition with a relative humidity at 60%.

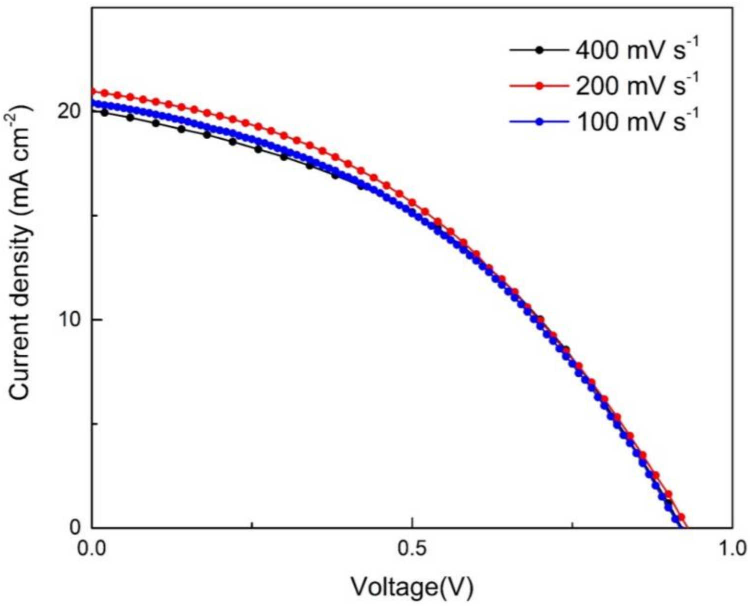

Figure S8. Current density-voltage (J-V) curves of perovskite solar cells produced by different scan rates under standard AM 1.5G condition with a relative humidity at 60%.

Table S1. Summary of photovoltaic parameters of the perovskite solar cells produced in our work at relative humidity around 60% with a one-step deposition method compared to several recent works.

Year	Perovskite type	Average PCE	Deposition method	Humidity	Reference
Our work	$CH_3NH_3PbI_3$ with 5% $Pb(SCN)_2$	8.2	One-step	60	_
2017	$CH_3NH_3PbI_3$	6.68	One-step	40	[1]
2017	$CH_3NH_3PbI_{3-x}Cl_x$	6.3	One-step	20	[2]
2017	$CH_3NH_3PbI_3$	10.0	One-step	70	[3]
2016	$CH_3NH_3PbI_{3-x}Cl_x$	7.63	One-step	50	[4]
2017	$CH_3NH_3PbI_3$	12	One-step	75	[5]
2016	$CH_3NH_3PbI_{3-x}Cl_x$	8.3	Spay-cast	55	[6]
2017	$CH_3NH_3PbI_3$	7.19	Two-step	60-70	[7]
2016	$CH_3NH_3PbI_3$	6.16	Two-step	50	[8]
2017	$CH_3NH_3PbI_3$	10.88	Two-step	50-60	[9]
2016	$CH_3NH_3PbI_3$	8.3	Two-step	60	[10]
2017	$CH_3NH_3PbI_3$	8.0	Two-step	_	[11]
2016	$CH_3NH_3PbI_3$	8.2	Two-step	60	[12]

Reference

[1] S. Prathapani, V. More, S. Bohm, P. Bhargava, A. Yella, and S. Mallick, "TiO 2 colloid-based compact layers for hybrid lead halide perovskite solar cells," *Appl. Mater. Today*, 2017, 7, 112–119.

[2] H. M. Cronin, K. D. G. I. Jayawardena, Z. Stoeva, M. Shkunov, and S. R. P. Silva, "Effects of ambient humidity on the optimum annealing time of mixed-halide Perovskite solar cells," *Nanotechnology*, 2017, 28, 114004.

[3] J. Ciro, R. Betancur, S. Mesa, and F. Jaramillo, "High performance perovskite solar cells fabricated under high relative humidity conditions," *Sol. Energy Mater. Sol. Cells*, 2017, 163, 38–42.

[4] G. Wang *et al.*, "Efficient perovskite solar cell fabricated in ambient air using one-step spin-coating," *RSC Adv.*, 2016,6, 43299-43303.

[5] J. Troughton, K. Hooper, and T. M. Watson, "Humidity resistant fabrication of CH3NH3PbI3 perovskite solar cells and modules," *Nano Energy*, 2017, 39, 60–68.

[6] D. K. Mohamad, J. Griffin, C. Bracher, A. T. Barrows, and D. G. Lidzey, "Spray-Cast Multilayer Organometal Perovskite Solar Cells Fabricated in Air," *Adv. Energy Mater.*, 2016, 6, 1600994.

[7] N. Islavath *et al.*, "Effect of hole-transporting materials on the photovoltaic performance and stability of all-ambient-processed perovskite solar cells," *J. Energy Chem.*, vol. 26, no. 3, pp. 584–591, 2017.

[8] Z. Liu, T. Shi, Z. Tang, B. Sun, and G. Liao, "Using a low-temperature carbon electrode for preparing hole-conductor-free perovskite heterojunction solar cells under high relative humidity," *Nanoscale*, vol. 8, no. 13, pp. 7017–7023, 2016.

[9] C. Liu *et al.*, "Efficient and Stable Perovskite Solar Cells Prepared in Ambient Air Based on Surface-Modified Perovskite Layer," *J. Phys. Chem. C*, vol. 121, no. 12, pp. 6546–6553, 2017.

[10] G. Murugadoss *et al.*, "An efficient electron transport material of tin oxide for planar structure perovskite solar cells," *J. Power Sources*, vol. 307, pp. 891–897, 2016.

[11] S. Rahmany, M. Layani, S. Magdassi, and L. Etgar, "Fully functional semi-transparent perovskite solar cell fabricated in ambient air," *Sustain. Energy Fuels*, 2017, 1, 2120-2127.

[12] M. K. Gangishetty, R. W. J. Scott, and T. L. Kelly, "Effect of relative humidity on crystal growth, device performance and hysteresis in planar heterojunction perovskite solar cells," *Nanoscale*, vol. 8, no. 12, pp. 6300–6307, 2016.