*§Electronic Supplemental data*

**Non-Doped and Unsorted Single-Walled Carbon Nanotubes as Carrier-Selective, Transparent and Conductive Electrode for Perovskite Solar Cells**

Takahiro Sakaguchi,a,† Il Jeon,a,† Takaaki Chiba,a Ahmed Shawky,a,b Rong Xiang,a Shohei Chiashi,a Esko I. Kauppinen,c Nam-Gyu Park,d,\* Yutaka Matsuo,a,e,\* Shigeo Maruyamaa,f,\*

a Department of Mechanical Engineering, School of Engineering, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8565, Japan

b Nanomaterials and Nanotechnology Department, Advanced Materials Division, Central Metallurgical Research and Development Institute (CMRDI), P. O. Box 87, Helwan 11421, Cairo, Egypt

c Department of Applied Physics, School of Science, Aalto University 15100, FI-00076 Aalto, Finland

d School of Chemical Engineering and Department of Energy Science, Sungkyunkwan University, Suwon 440-746, Korea

e Hefei National Laboratory for Physical Sciences at Microscale, University of Science and Technology of China, 96 Jinzhai Road, Hefei, Anhui 230026, China

f Energy NanoEngineering Laboratory, National Institute of Advanced Industrial Science and Technology (AIST), 1-2-1 Namiki, Tsukuba 205-8564, Japan

§ Electronic Supplementary Information (ESI) available: [details of any supplementary information available should be included here]. See DOI: 10.1039/x0xx00000x

† These authors contributed equally (T.S. and I.J.). The authors declare no competing financial interests.

\* E-mail: npark@skku.edu (N.P.); matsuo@photon.t.u-tokyo.ac.jp (Y.M.); maruyama@photon.t.u-tokyo.ac.jp (S.M.)

**Contents:**

**1. WVTR Test Results**

**2. IPCE and UV-Vis Spectroscopy**

**3. Nyquist Plot of Impedance Measurement**

**4. Four-Probe Measurement**

**5. Photoelectron Yield Spectroscopy**

**6. Vis-NIR Spectroscopy**

**1. WVTR Test Results**

|  |  |
| --- | --- |
| **Samples** | **WVTR (g/m2d)** |
| CNT | 34000 |
| CNT+PMMA | 1500 |



**Figure S1.** Schematic diagram of WVTR equipment (left) and WVTR test results (right).

**2. IPCE and UV-Vis Spectroscopy**

**Figure S2.** (a) IPCE measurement of SWNT film-laminated PSCs (Integrated *J*SC = 17.78 mA/cm2) with and without PMMA (Integrated *J*SC = 15.00 mA/cm2). (b) Transmittance measurement of SWNT film-laminated PSCs with and without PMMA when light was shone from the FTO side.

**3. Nyquist Plot of Impedance Measurement**

**Figure S3.** The PSC circuit model and Nyquist plots from the impedance measurement.

**4. Four-Probe Measurement**

****

**Figure S4.** Four-probe sheet resistance measurement of a SWNT film before and after the PMMA application.

**5. Photoelectron Yield Spectroscopy**

****

**Figure S5.** PYS measurements of (a) a pristine SWNT film and (b) a PMMA-applied SWNT film.

**6. Vis-NIR Spectroscopy**



**Figure S6.** Absorption spectroscopy of the PSC device with PMMA and without PMMA.