All solute PEDOT:PSS mixtures were prepared by mixing a 500µL solution of pristine PEDOT:PSS (Heraeus Clevios PH 1000) with Triton surfactants (Sigma Aldrich) and different amounts of ethanol and IPA (Fujifilm Wako Pure Chemical Co.) using different volume ratios: 1:3, 1:7, and 1:11, where PEDOT:PSS is the lesser volume component of the solution. The obtained solutions were sonicated for 24 hours at room temperature before thin film preparation. The glass substrates (1.5×1.5 $cm^2$) were cleaned by acetone, ethanol and DI water under sonification for 15 min. And then, they were annealed at 170 °C for 20 min before spin-coating process. The ethanol/ IPA solute PEDOT:PSS was spun onto glass slides at 6000 rpm for 60 s, followed by annealing at 170 °C in air for 20 min. Silver paste was applied at four corners of each solute PEDOT:PSS thin film for Hall measurement (Ecopia HMS-3000) using the Van der Pauw method. The thickness of solute PEDOT:PSS on glass was evaluated using the spectroscopic ellipsometry (J. A. Woollam Co.).
After cleaning with acetone, ethanol, and deionized water, and removing the native silicon oxide by 5 % HF etching, both sides of polished n-type Czochralski Si (100) substrates (300 µm, 1–5 Ω•cm) were coated with solute PEDOT:PSS [Fig. 1(a)]. To evaluate the passivation of ethanol or IPA solute PEDOT:PSS, effective carrier lifetime measurement of c-Si substrate was carried out using the microwave photo-conductivity decay (µPCD) under an injection level of $1\times10^{14}$ $cm^{-3}$ (KOBELCO, LTA1512EP). Furthermore, quasi-steady state photoconductivity (QSSPC) (Sinton Instruments WCT120) was applied for **conductive PEDOT:PSS/c-Si** and **PEDOT:PSS/ c-Si/ solute PEDOT:PSS** to characterize the potential of hybrid c-Si solar cells using ethanol / IPA solute PEDOT:PSS at the backside [Fig. 1(b) and 1(c)]. Herein, the conductive PEDOT:PSS was formed by mixing it with small amount of Ethylene Glycol (Wako, 058-00986) and it possesses high conductivity of 850 S/cm with the thickness of 35 nm. The $J_o$, implied $V_{OC}$ and effective carrier lifetime were extracted using injection level of $1\times10^{15}$ $cm^{-3}$. Fabrication of c-Si solar cells were completed with thermal evaporation of 200-nm-thick Al film and 300-nm-thick Ag onto backside and front side of Si solar cells (ULVAC Kiko, Inc VPC-260F), respectively. Current density-voltage (J-V) characteristics were measured by a JASCO YQ-250BX solar simulator under 1-sun illumination, which was also integrated with a monochromator, power meter and Keithley source meter for external quantum efficiency (EQE) measurements.

**Table S1:** *Chemical structure and physical properties of organic solvents, methanol, ethanol and isopropanol.*

| **Name** | **Chemical structure** | **Dielectric constant[a]** | **Absolute viscosity/cp[b]** |
|---|---|---|---|
| Methanol | $CH_3OH$ | 32.6 | 0.59 |
| Ethanol | $CH_3CH_2OH$ | 22.4 | 1.2 |
| Isopropanol | $CH_3CH_2CH_2OH$ | 18.3 | 1.77 |

[a, b]The dielectric constant values and absolute viscosity of neat solvents obtained from ref. 1 and ref. 2

**Figure S1:** *Digital images of different solute PEDOT:PSS on glass*

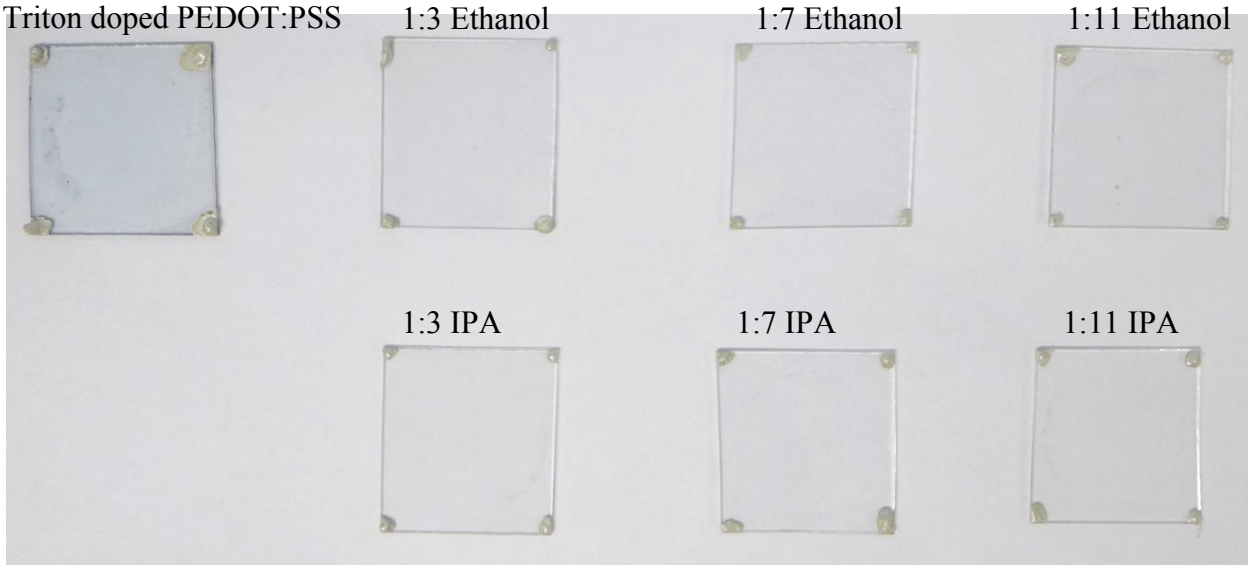


**Table S2:** *Thickness, sheet resistance and conductivity of ethanol and IPA solute PEDOT:PSS with volume ratio of 1:3, 1:7 and 1:11.*

| | **Ethanol solute PEDOT:PSS** | | | **IPA solute PEDOT:PSS** | | |
|---|---|---|---|---|---|---|
| Volume ratio | **1:3** | **1:7** | **1:11** | **1:3** | **1:7** | **1:11** |
| S (S/cm) | 2.1 | 0.024 | 0.018 | 2.25 | 0.42 | 0.075 |
| R (MΩ/□) | 3.0 | 64 | 70 | 0.97 | 3.3 | 13 |
| Thickness (nm) | 15.2 | 8.42 | 5.79 | 9.16 | 7.15 | 5.32 |

**Figure S2:** *Transmittance of ethanol/ IPA solute PEDOT:PSS on glass with volume ratio of 1:3, 1:7 and 1:11.*

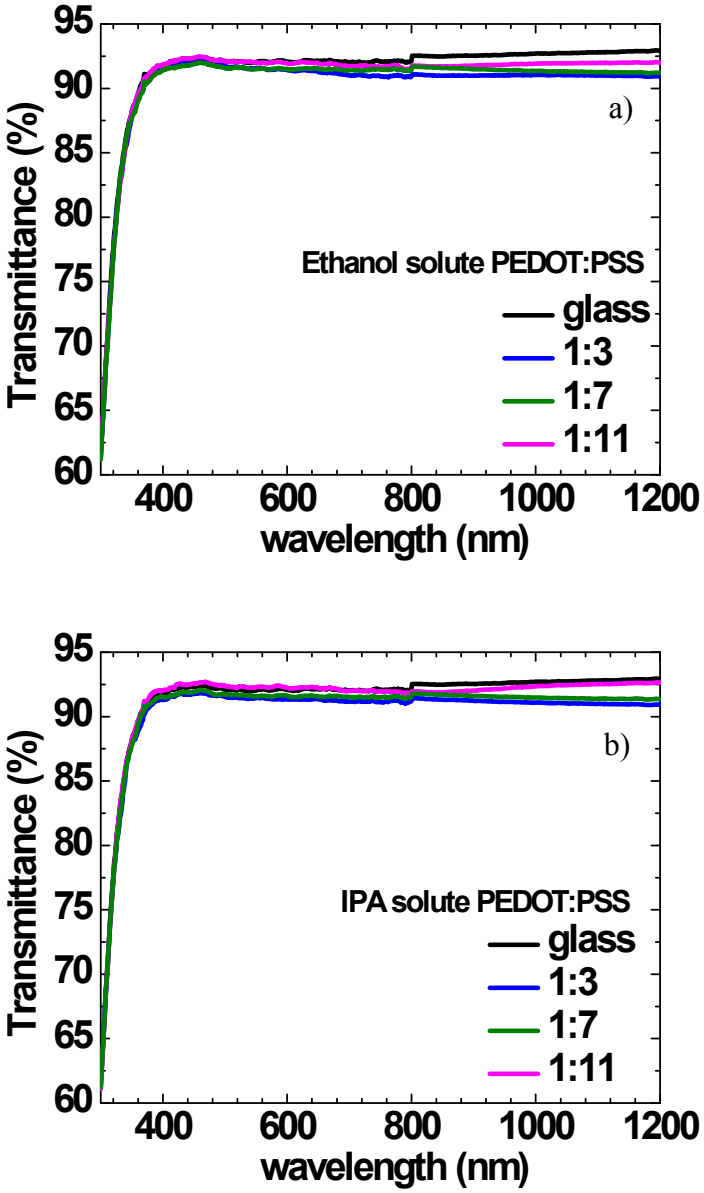

**Table S3:** *Effective carrier lifetimes in average and in maximum extracted from c-Si passivated by ethanol/ IPA solute PEDOT:PSS.*

| | **Ethanol soluting PEDOT:PSS** | | | **IPA soluting PEDOT:PSS** | | |
|---|---|---|---|---|---|---|
| Volume ratio | **1:3** | **1:7** | **1:11** | **1:3** | **1:7** | **1:11** |
| Highest LT (µs) | **1096** | **956** | 576 | 622 | **1072** | 504 |
| Average LT (µs) | 657 | 630 | 324 | 390 | 718 | 312 |

**Table S4:** *Key parameters of **PEDOT:PSS/ c-Si/ solute PEDOT:PSS** extracted from QSSPC measurements.*

| | **ref** | **Ethanol solute PEDOT:PSS** | | **IPA solute PEDOT:PSS** | |
|---|---|---|---|---|---|
| Volume ratio | | **1:7** | **1:11** | **1:7** | **1:11** |
| $\tau_{eff}$ (µs) at injection level of $1x10^{15}$ $cm^{-3}$ | 18.68 | 99.30 | 40.63 | 103.15 | 37.79 |
| $J_0$ ($A/cm^2$)$x10^{-12}$ | 1.06 | 0.303 | 0.665 | 0.255 | 0.952 |
| Implied $V_{OC}$ (mV) | 547 | 597 | 564 | 599 | 564 |

**Figure S3:** *a) J-V curves; b) External quantum efficiency of PEDOT:PSS/ Si substrate/ solute PEDOT:PSS on the backside.*

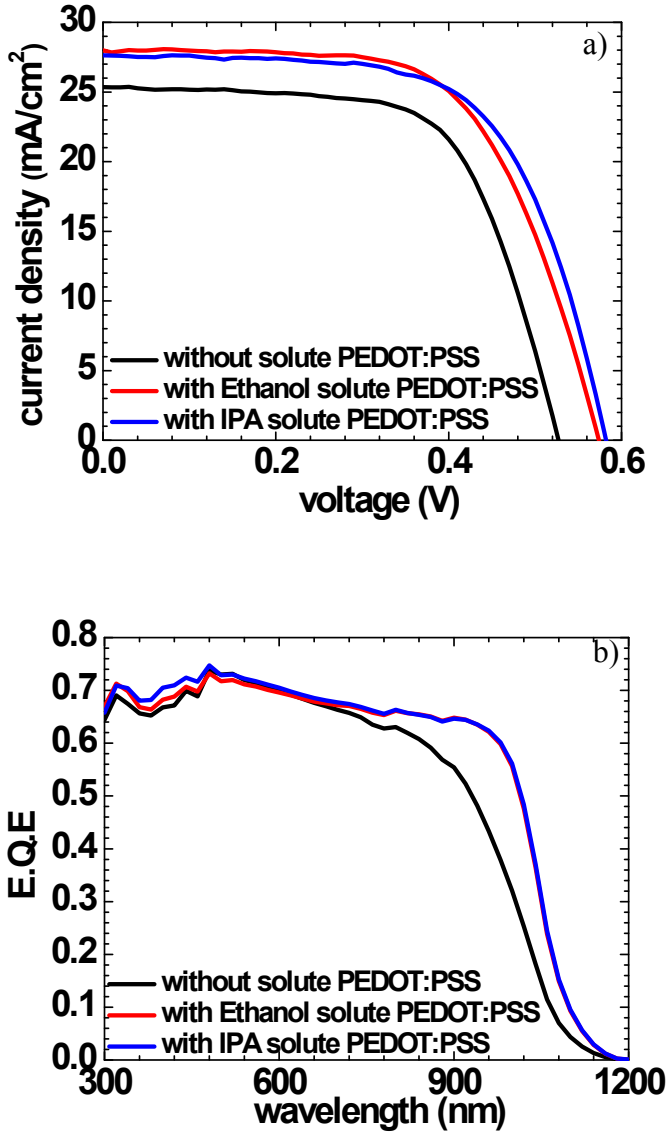


**Table S5:** *Key J-V parameters of PEDOT:PSS/ c-Si/ solute PEDOT:PSS*

| | $J_{SC}$ (mA/cm$^2$) | $V_{OC}$ (V) | FF | *Eff* |
|---|---|---|---|---|
| **Without solute PEDOT:PSS** | 25.35 | 0.527 | 0.65 | 8.69 |
| **With ethanol solute PEDOT:PSS** | 27.99 | 0.574 | 0.62 | 10.03 |
| **With IPA solute PEDOT:PSS** | 27.63 | 0.582 | 0.64 | 10.26 |

Reference:


a. https://en.wikipedia.org/wiki/Main_Page
b. Y. Xia and J. Ouyang, *Journal of Materials Chemistry*, 2011, **21**, 4927–4936.