Supplementary Information

Large Work Function Difference Driven Electron Transfer from Electrides to Single-walled Carbon Nanotubes

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Acronym	Description
HSWNT	HiPco SWNT (Diameter: 0.7-1.2 nm, Length: 400-700 nm)[S1]
PSWNT	Purified plasma SWNT (Diameter: 1.2-1.7 nm, Length: 1-2 μm)[S2]
C12A7:e^-	$[Ca_{24}Al_{28}O_{64}]^{4+}\cdot 4e^-$
Ca2N:e^-	$[Ca_2N]^+\cdot e^-$
C12A7:e^--HSWNT film	$[Ca_{24}Al_{28}O_{64}]^{4+}\cdot 4e^-$-HiPco SWNT-PVDF-HFP film
Ca2N:e^--HSWNT film	$[Ca_2N]^+\cdot e^-$-HiPco SWNT-PVDF-HFP film
C12A7:e^--PSWNT-Ag paste	$[Ca_{24}Al_{28}O_{64}]^{4+}\cdot 4e^-$-Plasma purified SWNT-Ag-Epoxy paste
Ca2N:e^--PSWNT-Ag paste	$[Ca_2N]^+\cdot e^-$-Plasma purified SWNT-Ag-Epoxy paste

Table S1. Acronyms of base materials and synthesized specimens

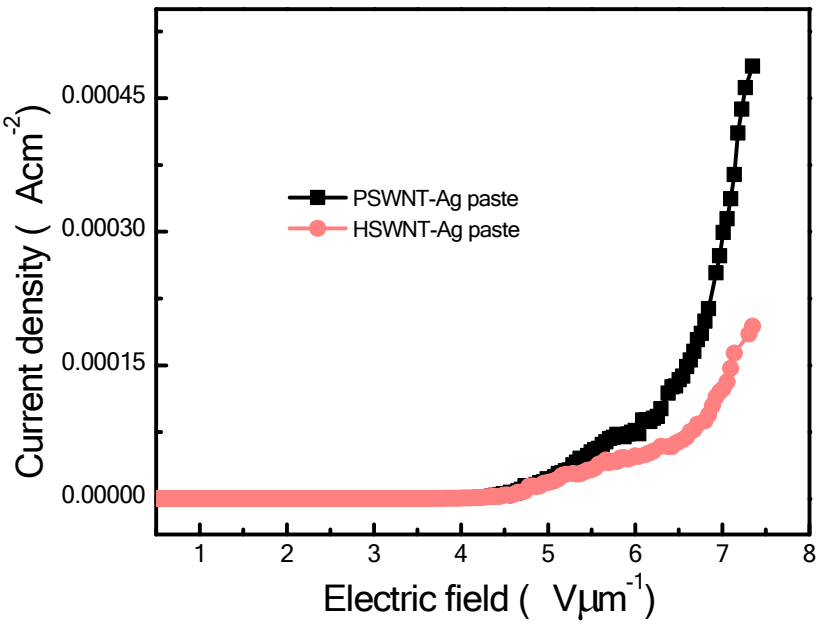

Figure S1. Field emission characteristics of the PSWNT-Ag paste and HSWNT-Ag paste. The nanotubes were mixed with Ag pastes without electride particles. The nanotube, silver, and epoxy concentrations were 2.5, 80, and 17.5 wt.%. The field emission current density of PSWNT-Ag paste was 0.48 mA/cm^2 at 7.3 V/μm with a turn on voltage of 4.14 V/μm. The field emission current density of HSWNT-Ag paste was 0.19 mA/cm^2 at 7.34 V/μm with a turn on voltage of 4.2 V/μm.

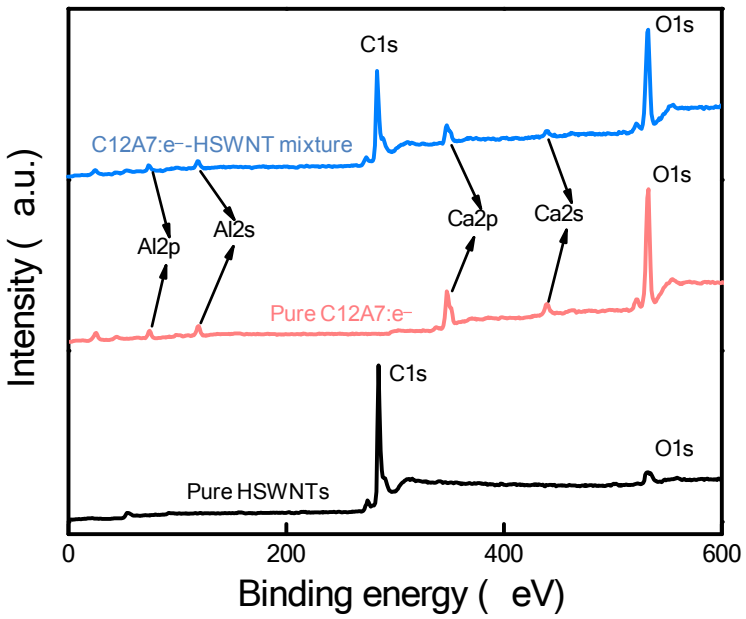

Figure S2. Wide scan XPS data of pure HSWNTs, pure C12A7:e^- powder, and C12A7:e^--HSWNT powder mixture (50:50 wt.%).

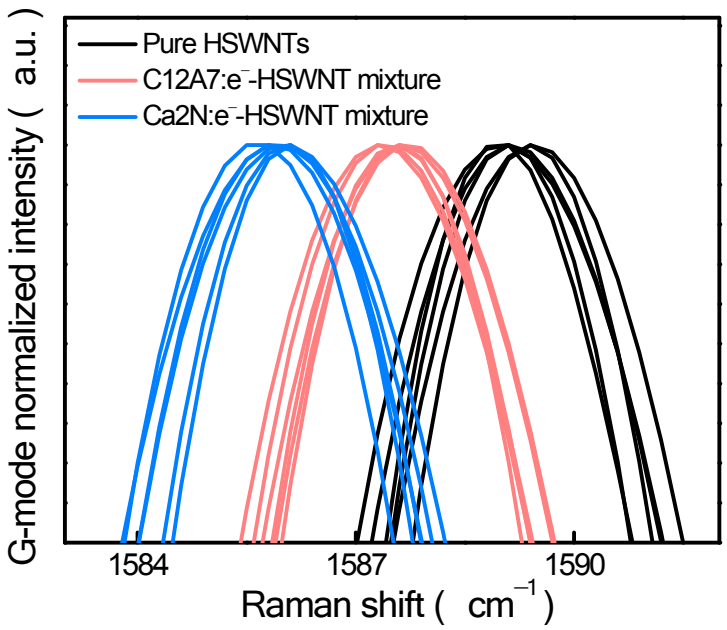

Figure S3. The G-mode of Raman spectra measured at 6 different locations in pure HSWNTs, C12A7:e^--HSWNT, and Ca2N:e^--HSWNT powder mixtures.

Estimation of transferred electrons from electrides to nanotubes

The fitting to the calculation of density functional theory correlates the G-mode shift of nanotubes ($\Delta\omega$ (cm^{-1})) with the number of transferred electrons per carbon atom (f_c).[S3]

$$\Delta\omega = \Delta\omega_s + \Delta\omega_d \quad \text{(S1)}$$

$$\Delta\omega = 350 f_c + 101\sqrt{f_c} \quad \text{(S2)}$$

$$f_c^* = (f_c \times N_{C\text{-}atoms})/L_{Tube} \quad \text{(S3)}$$

where $\Delta\omega_s$ is the Raman shift due to the lattice contraction (strain), $\Delta\omega_d$ is the nonadiabatic effects (dynamical) due to electron-phonon coupling, f_c^* is the total number of electrons transferred per unit length of a nanotube ($\#/cm^{-1}$), $N_{C\text{-}atoms}$ is the total number of carbon atoms in a nanotube, and L_{Tube} is the length of a nanotube.

The following equations were used to calculate $N_{C\text{-}atoms}$[S4]

$$N_{C\text{-}atoms} = (M_{Tube} \times N_A)/M_{carbon} \quad \text{(S4)}$$

$$M_{Tube} = (\pi\, L_{Tube} \times D_{Tube})/1315\ m^2g^{-1} \quad \text{(S5)}$$

where N_A is Avogadro's number (6.02×10^{23} $mole^{-1}$), M_{carbon} is the molar mass of carbon (12.011 g $mole^{-1}$), M_{Tube} is the mass of a single nanotube, and D_{Tube} is the diameter of a nanotube.

The average length and diameter of HSWNTs were used for the calculation in this study (L_{Tube}= 600 nm, D_{Tube} = 1.03 nm).[S1,S5] The resulting M_{Tube} was 1.48×10^{-18} g and $N_{C\text{-}atoms}$ was 7.4×10^4. The experimentally observed G-mode shifts of nanotubes were 1.8 and 2.7 cm^{-1} for C12A7:e^- and Ca2N:e^-, respectively. The calculated f_c values were 2.8×10^{-4} and 6.1×10^{-4} for

C12A7:e^- and Ca2N:e^-, respectively. The corresponding f_c* were 3.5×10^5 cm^{-1} and 7.48×10^5 cm^{-1} for C12A7:e^- and Ca2N:e^-, respectively.

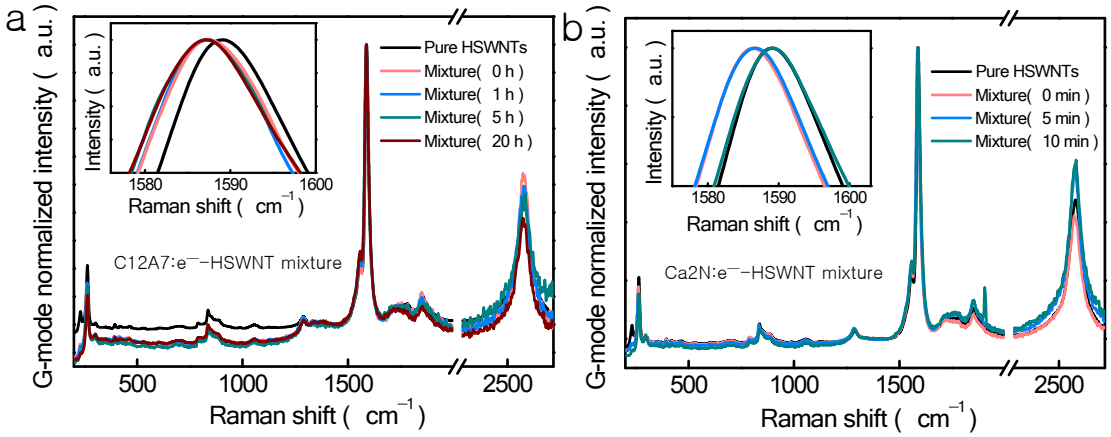

Figure S4. Raman spectra of pure HSWNTs and electride-HSWNT powder mixtures. The time after exposure of the powder mixtures to air is shown in parenthesis. The G-mode shift is magnified in the inset. a) C12A7:e$^-$-HSWNT powder mixture. b) Ca2N:e$^-$-HSWNT powder mixture.

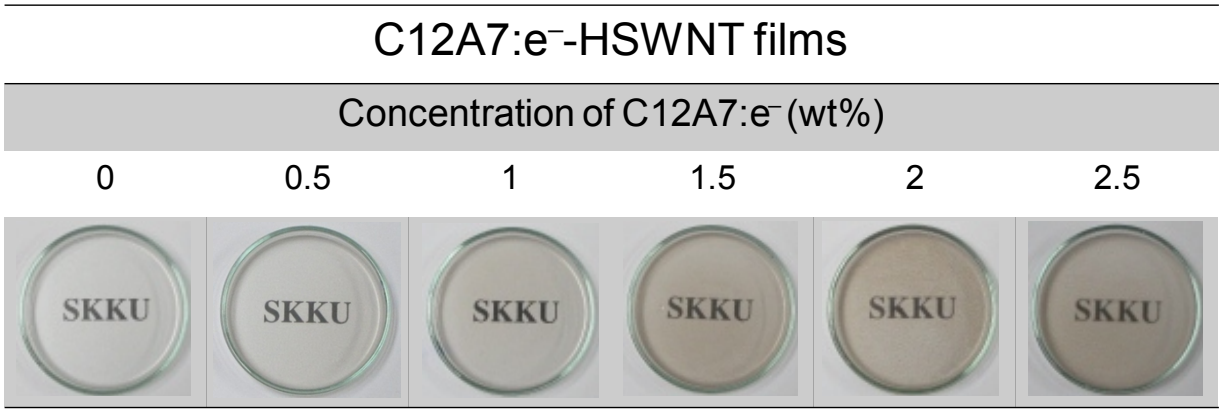

Figure S5. Optical images of C12A7:e^--HSWNT films. The letters SKKU are placed behind the films. The transmittance decreased from 84.8 % to 30 % at 550 nm with the addition of 0 to 2.5 wt.% C12A7:e^- particles.

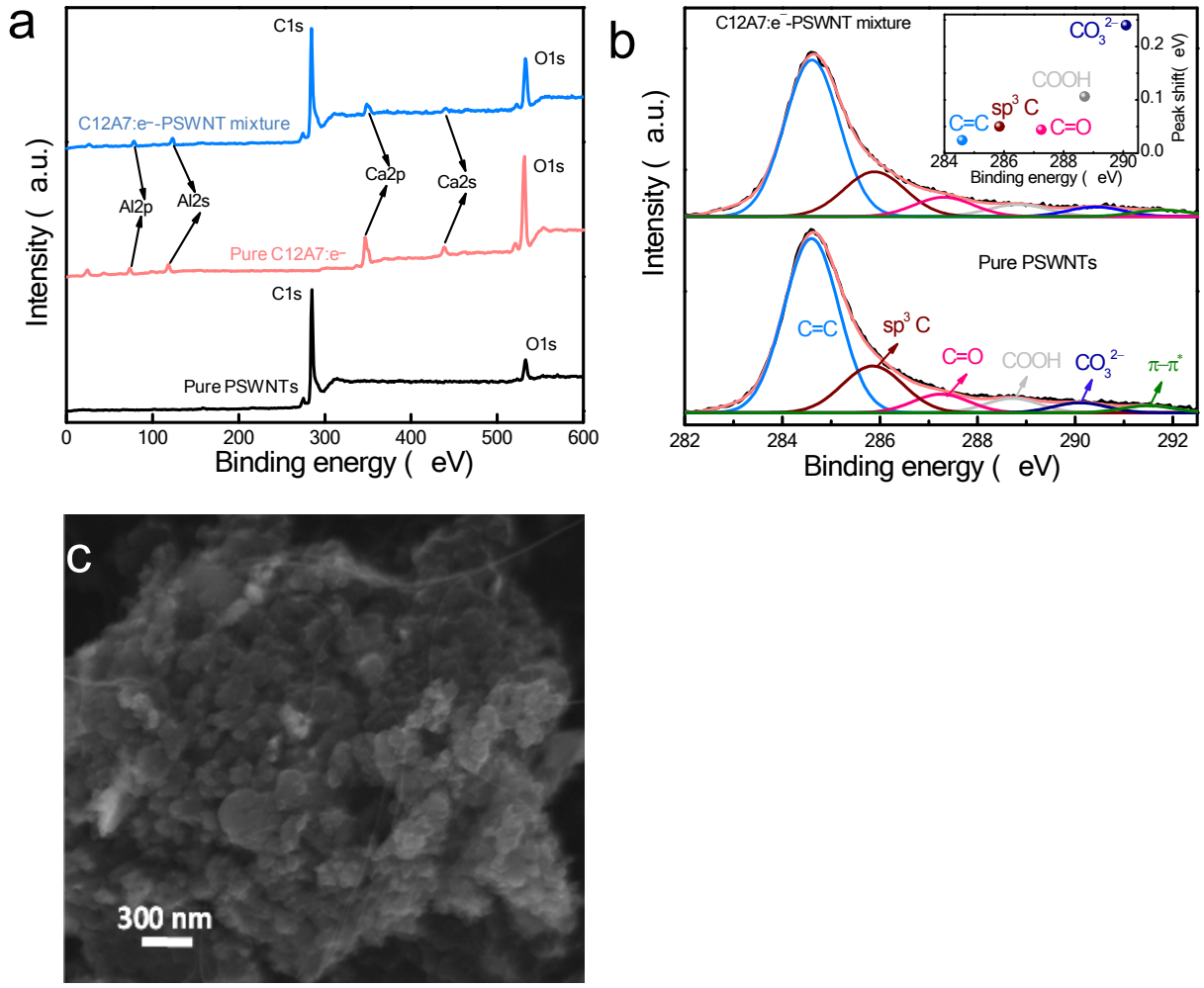

Figure S6. XPS and SEM analysis. a,b) Wide scan and C1s XPS data of pure PSWNTs, pure C12A7:e^- powder, and C12A7:e^--PSWNT powder mixture (50:50 wt.%). The inset compares the shift of binding energies with the addition of C12A7:e^- to PSWNTs. The peaks of graphitic structure of PSWNTs (C=C bonds @284.6 eV), defect sites (sp^3 carbon atoms), and surface functional groups (C=O, COOH, and carbonates) were investigated. c) SEM image of C12A7:e^--PSWNT powder mixture.

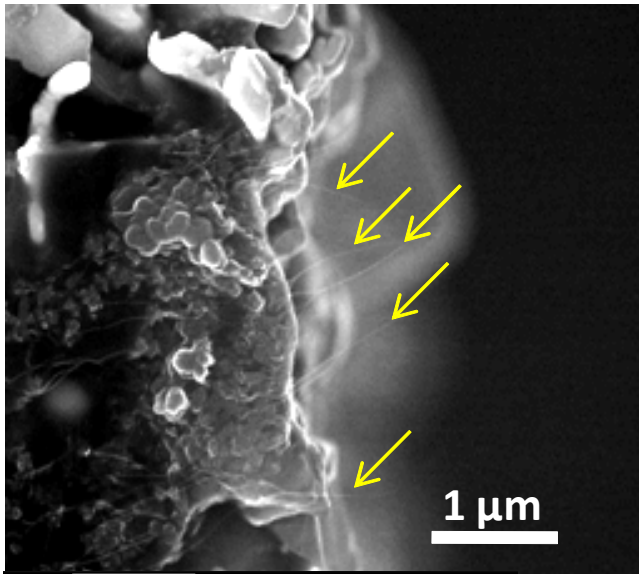

Figure S7. Cross-sectional SEM image of the tape-activated PSWNT-Ag paste. The surface was activated 10 times using Scotch tapes.[S6] The yellow arrows indicate nanotubes.

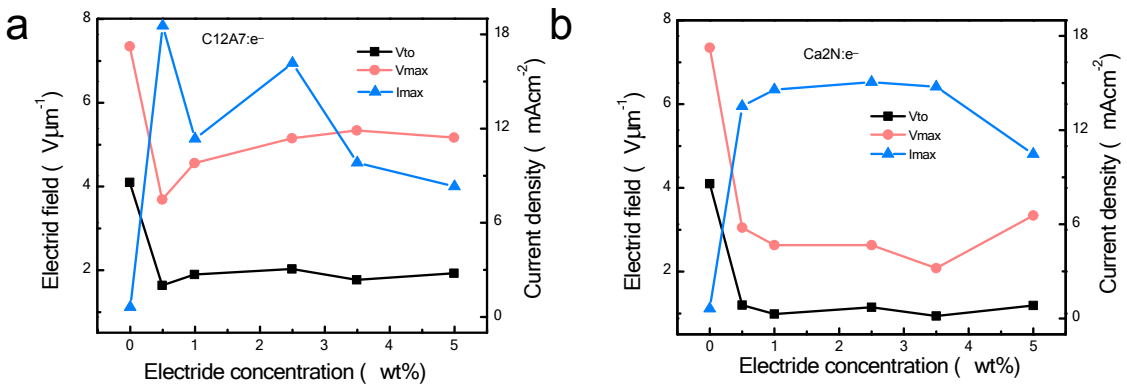

Figure S8. Comparison of the turn on voltage (V_{to}), maximum current density (I_{max}), and the electric field at maximum current density (V_{max}). a) C12A7:e⁻-PSWNT-Ag pastes. b) Ca2N:e⁻-PSWNT-Ag pastes.

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