Supplementary Information

# Direct electrochemical co-polymerization of EDOT and hydroquinone

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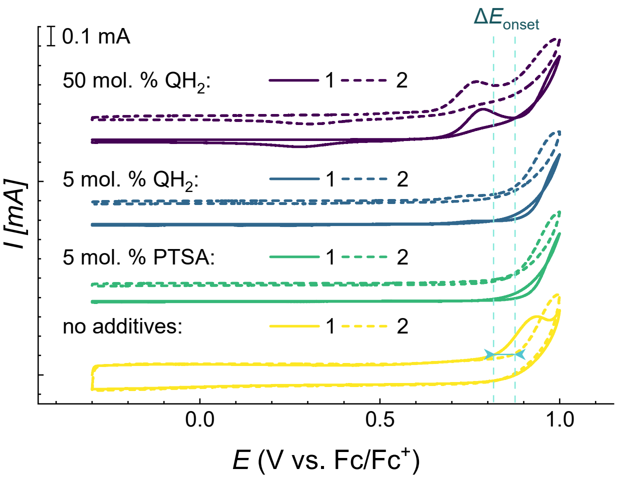

*Figure S1. The first and the second cycle for potentiodynamic electropolymerization of EDOT in the presence of $QH_2$ or PTSA.*

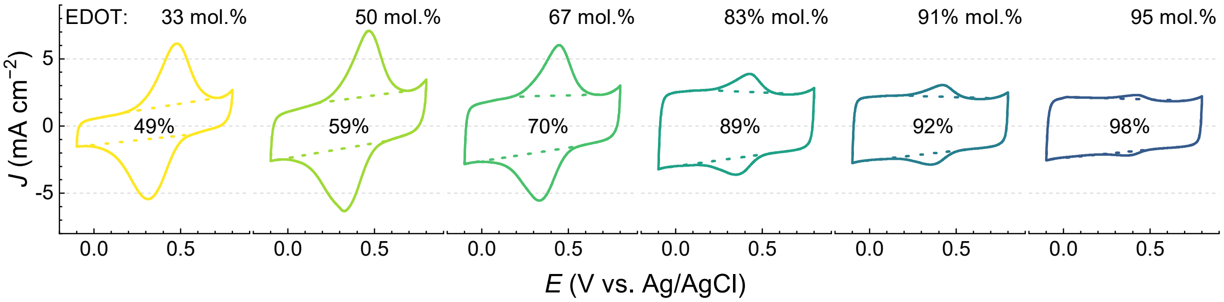

*Figure S2. CVs of co-PEDOT-$QH_2$ films synthesized via cyclic voltammetry deposition from EDOT:$QH_2$ solution with various EDOT to $QH_2$ ratios. Molar share of $QH_2$ with respect to EDOT is shown next to each CV. CVs are recorded in −0.2 V to 0.9 V at 50 mV $s^{-1}$ in 0.1 M $HClO_4$. The percentage values indicated inside CVs show contribution of PEDOT-related capacity towards total recorded capacity.*

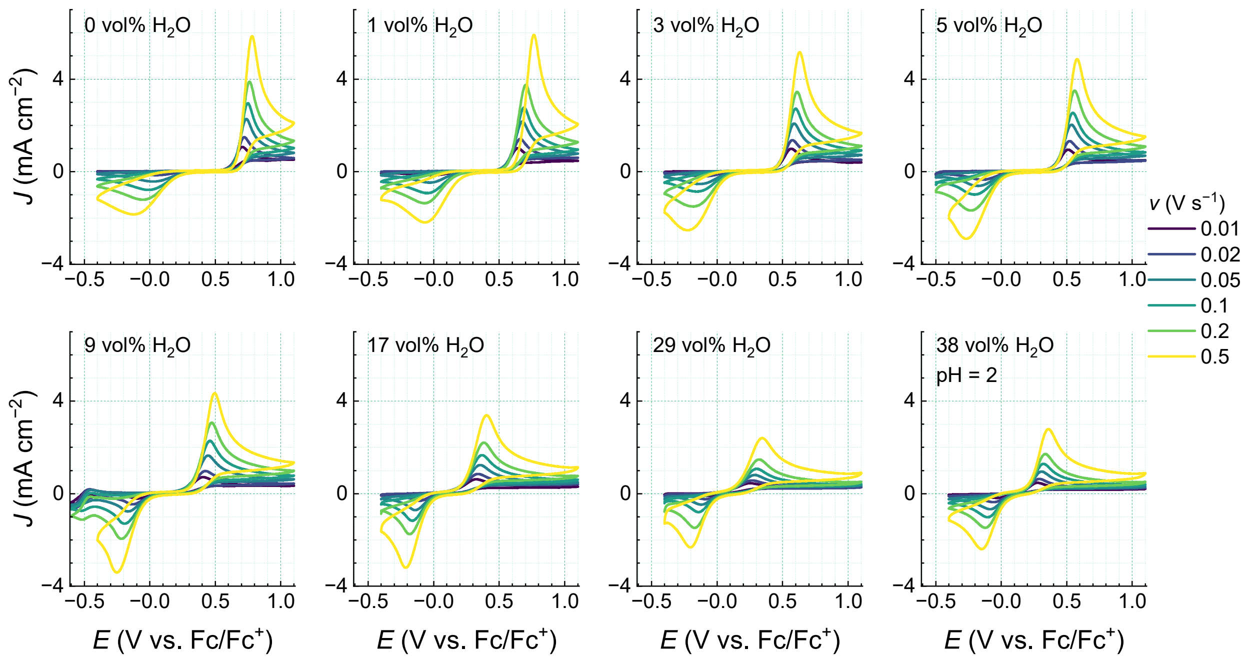

*Figure S3. Cyclic voltammetry curves of $QH_2$ in MeCN (1 м $LiClO_4$) at different scan rates with variable water content.*

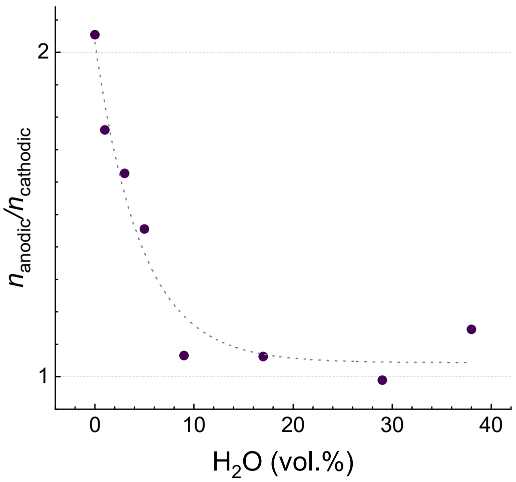

*Figure S4. The ratio of the number of electrons involved in the anodic and cathodic reactions depending on the water content in the solution based on the peak analysis in the cyclic voltammograms of $QH_2$ (MeCN, 1 м $LiClO_4$) via the Randles–Ševčík equation.*

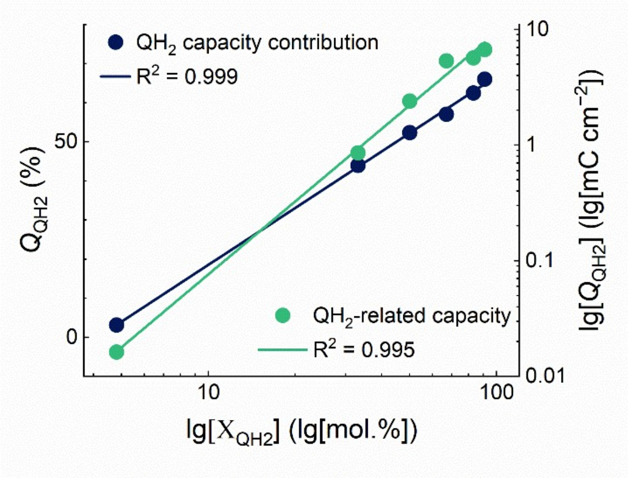

*Figure S5. The relation of the capacity contribution of $QH_2$ towards total capacity of co-PEDOT-$QH_2$ films in relative (%, left) and absolute ($mC \cdot cm^{-2}$, right, logarithmic) values on the logarithm of molar share of $QH_2$ in the polymerization feed.*

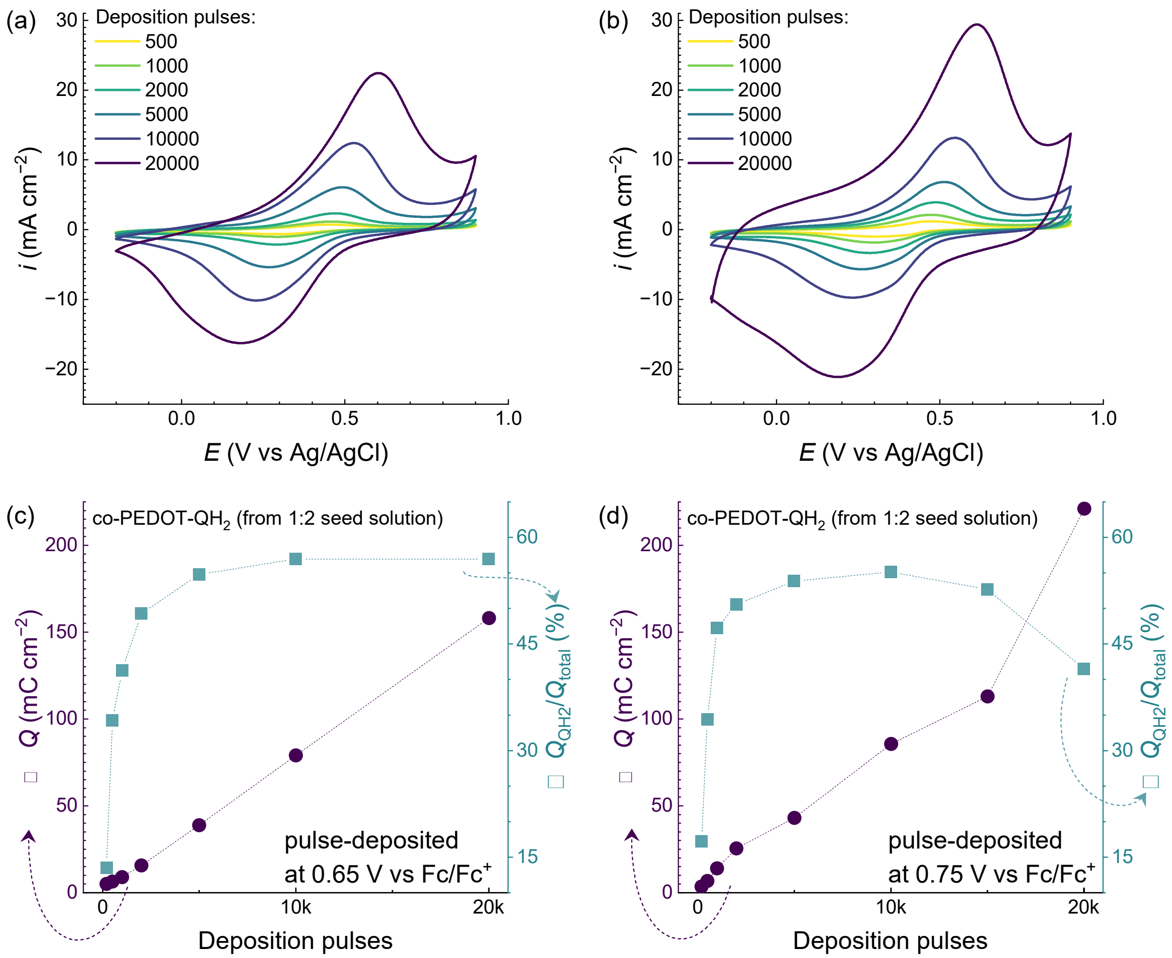

Figure S6. CVs (a, b) of co-PEDOT:QH$_2$ films synthesized on a 0.07 cm$^2$ glassy carbon electrode in pulse potentiostatic mode (0.65 V vs. Fc/Fc$^+$ (a) or 0.75 V vs. Fc/Fc$^+$ (b), $t_{dep}$ = 100 ms, $t_{rest}$ = 5 ms) by applying different numbers of pulses from the solution containing 67% QH$_2$ molar fraction, and (c, d) the total film specific capacity and the QH$_2$ contribution to the total capacity as functions of the number of synthesis pulses for films deposited at 0.65 V vs. Fc/Fc$^+$ (c) or 0.75 V vs. Fc/Fc$^+$ (d). CVs are recorded in −0.2 V to 0.9 V range at 50 mV s$^{-1}$ in 0.1 м HClO$_4$.

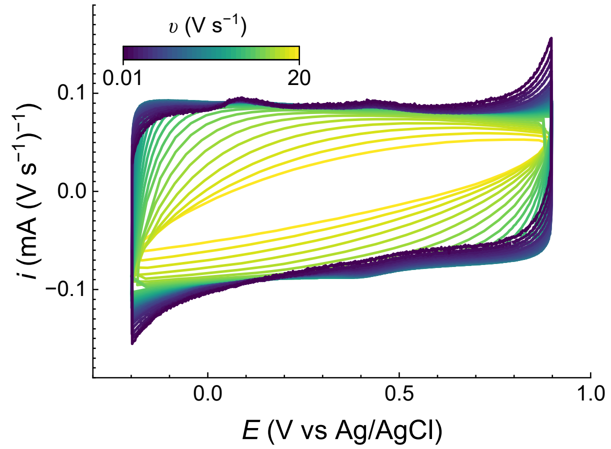

*Figure S7. Normalized cyclic voltammograms of a PEDOT film synthesized potentiodynamically ratio at different scan rates indicated in a color bar (V s*$^{-1}$*).*

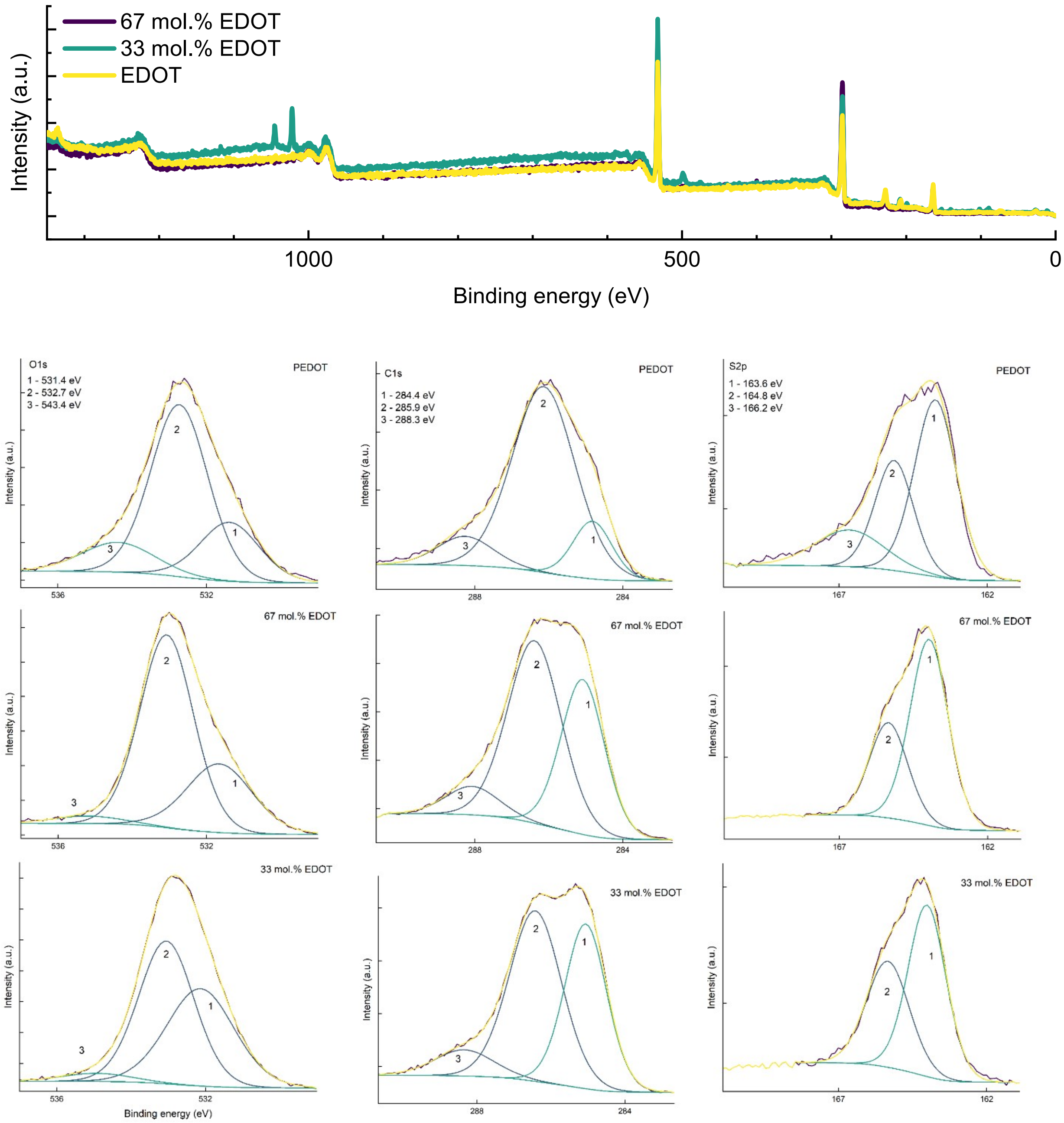

*Figure S8. XPS spectra of co-PEDOT-QH$_2$ films synthesized from the EDOT:QH$_2$ solutions with 67 mol. % and 33 mol. % QH$_2$, and PEDOT film. Survey spectra (top), and background-subtracted (Shirley algorithm) O1s (left), C1s (middle) and S2p (right) spectra.*

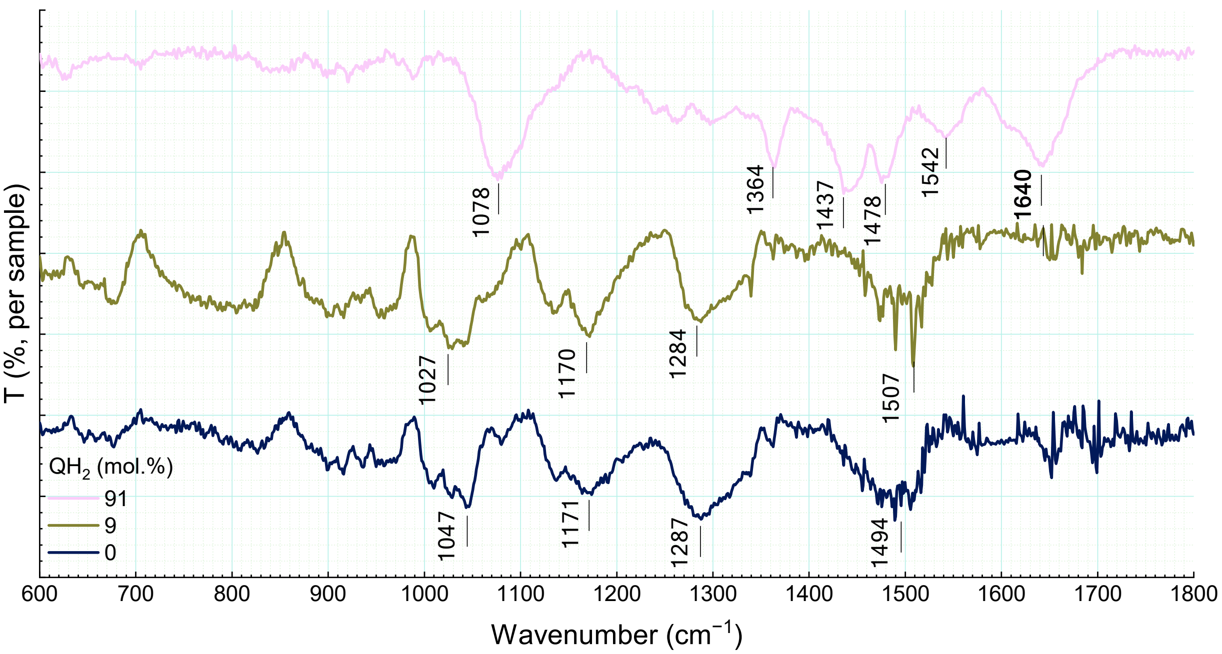

*Figure S9. ATR FT-IR spectra of the films synthesized from EDOT:QH$_2$ solutions with various QH$_2$ concentration and from EDOT solution, as well of a PEDOT film.*

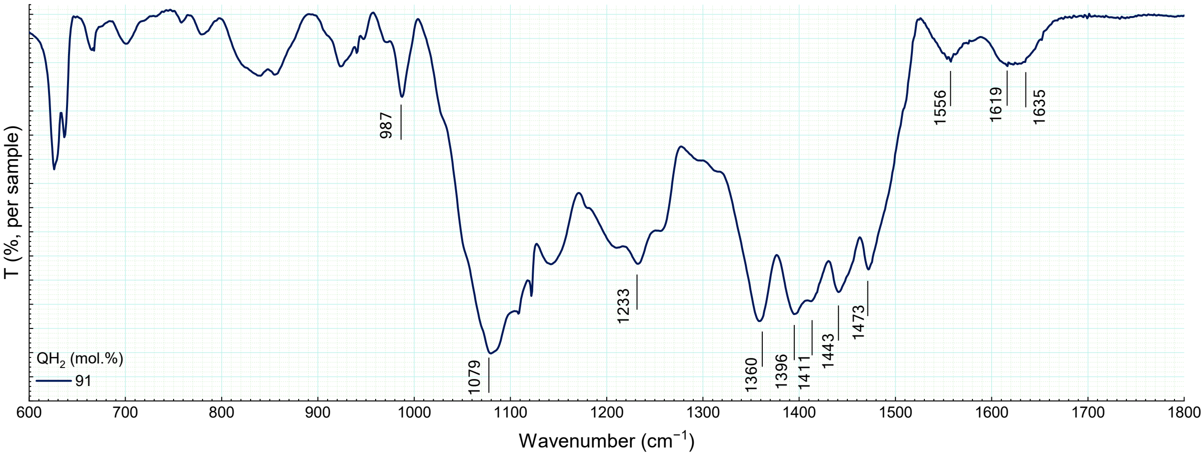

*Figure S10. FT-IR (KBr) spectrum of the film synthesized from the solution with 1:10 EDOT:QH$_2$ ratio.*

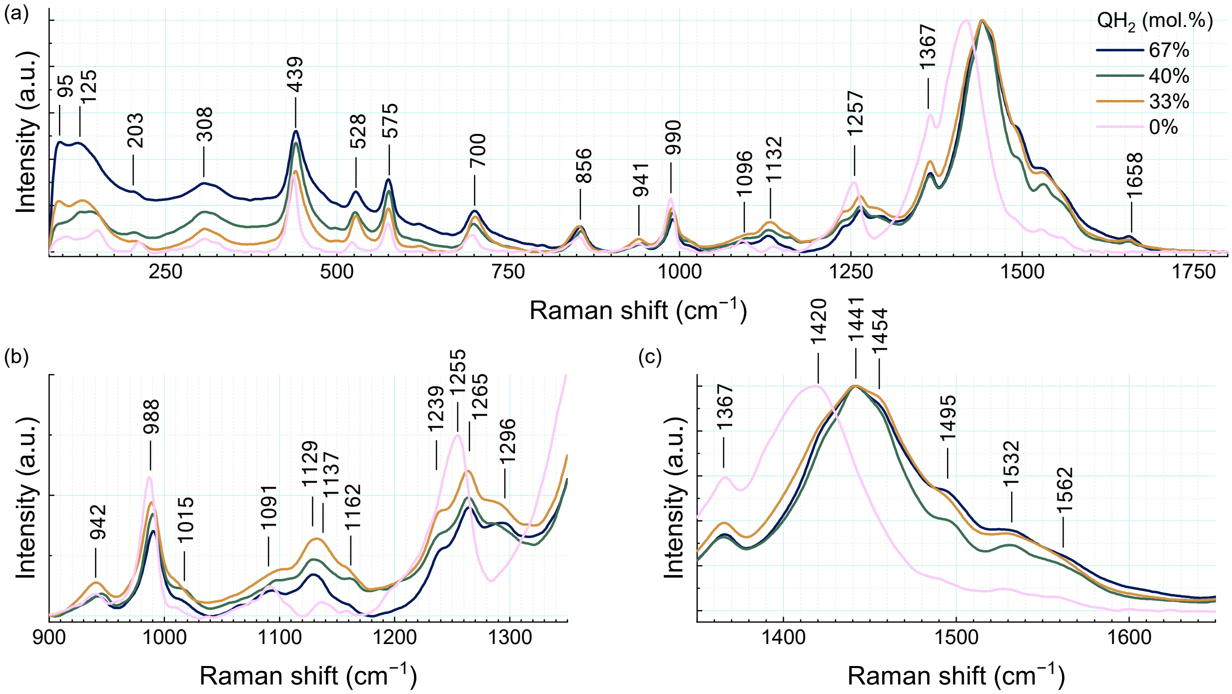

*Figure S11. Raman spectra of the films synthesized from EDOT:QH$_2$ solutions with various QH$_2$ concentration and from EDOT solution: (a) in 80–1800 cm$^{-1}$ range, (b) in 900–1350 cm$^{-1}$ range, and (c) in 1350–1650 cm$^{-1}$ range.*

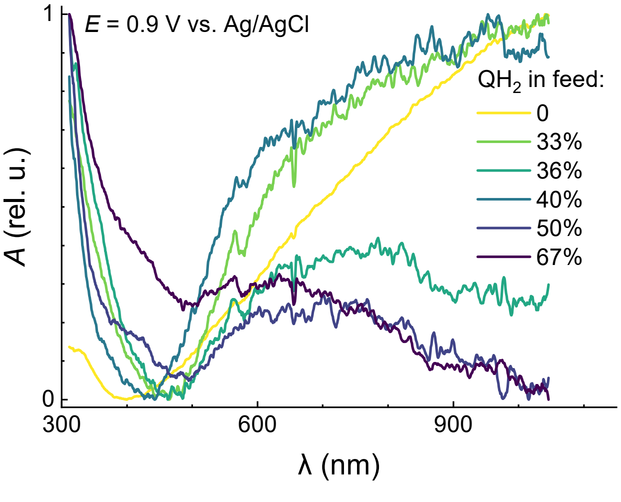

*Figure S12. UV-Vis spectra of co-PEDOT-QH$_2$ films synthesized from feed solutions with different QH$_2$ content recorded at 0.9 V vs. Ag/AgCl.*

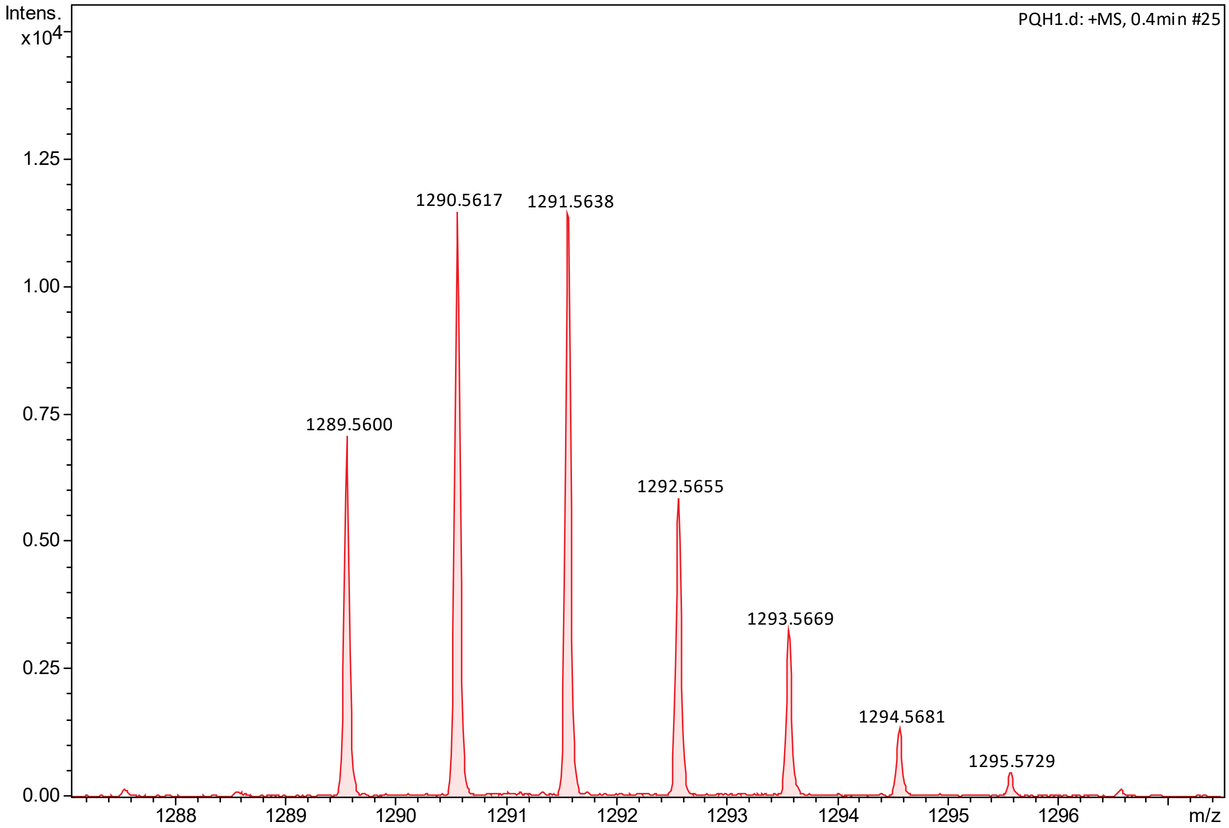

Figure S13. Mass-spectrum of the molecular ion of $(QH_2)_4(EDOT)_6$ oligomer found in co-PEDOT-$QH_2$ film synthesized from seed solutions with 1:2 EDOT:$QH_2$ ratio. $(QH_2)_4(EDOT)_6$ appears as [M+$Na^+$], the mass distribution is caused by both isotopic distribution and quinone protonation distribution. The least M/e value of 1289.6 corresponds to fully deprotonated $Q_4(EDOT)_6 \cdot Na^+$ form (calc. $M_w$ 1289.0). The connectivity of the co-monomers in the schematic chemical sketch of $Q_4(EDOT)_6 \cdot Na^+$ is arbitrary.

*Table S1. Fitting parameters used for the analysis of electrochemical impedance spectra of the films.*

| **Parameter** | **9 mol.% $QH_2$** | **67 mol.% $QH_2$** |
|---|---|---|
| $R_s$ (Ω) | 76.0 | 138 |
| $R_1$ (Ω) | 13.9 | 18.6 |
| $CPE_1^{\mathrm{T}}$ ($\mathrm{S \cdot s}^{P1}$) | $2.11 \cdot 10^{-5}$ | $7.32 \cdot 10^{-5}$ |
| *P1* | 0.68 | 0.95 |
| $R_2$ (Ω) | 2020 | 5660 |
| $CPE_2^{\mathrm{T}}$ ($\mathrm{S \cdot s}^{P2}$) | $5.80 \cdot 10^{-4}$ | $6.10 \cdot 10^{-4}$ |
| *P2* | 1.0 | 0.60 |
| $CPE_{\mathrm{lf}}^{\mathrm{T}}$ ($\mathrm{S \cdot s}^{\mathrm{Plf}}$) | $5.83 \cdot 10^{-5}$ | $5.43 \cdot 10^{-4}$ |
| *Plf* | 0.93 | 0.88 |
| *W* ($\mathrm{S \cdot s}^{½}$) | $1.35 \cdot 10^{-2}$ | $4.25 \cdot 10^{-3}$ |

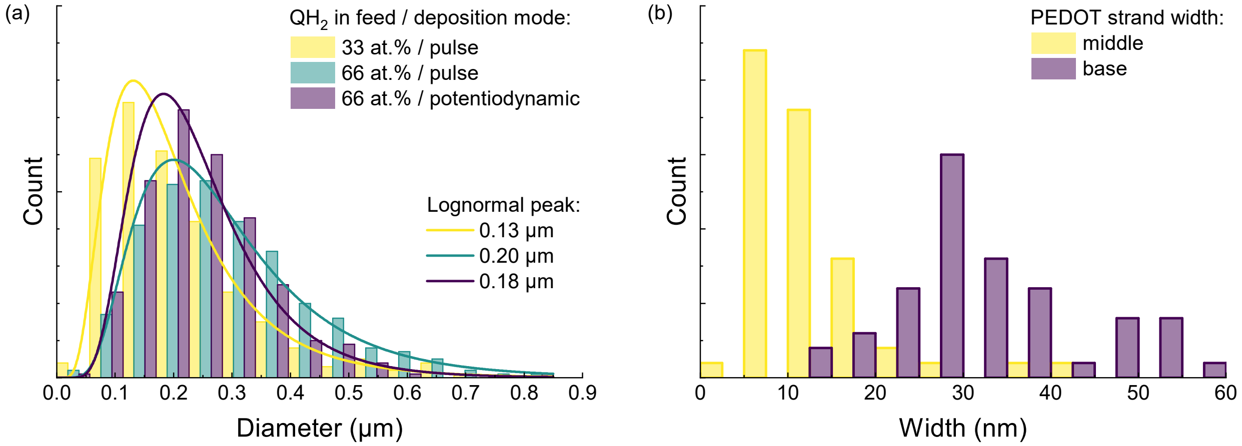

*Figure S14. Spherical particles diameter distribution for co-PEDOT-QH$_2$ films synthesized from feed solutions with different QH$_2$ content and in various deposition modes (a), and distribution of widths of the PEDOT strands in PEDOT films at the base and in the middle (at the narrowest) (b), according to SEM images.*

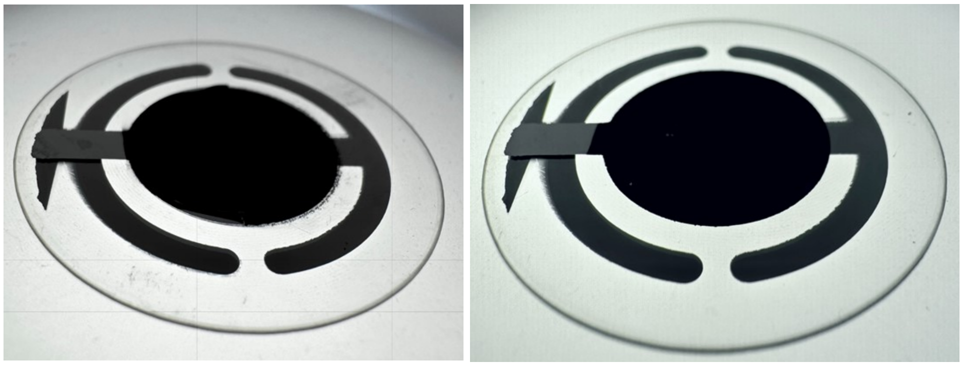

*Figure S15. Photo images of the films of QH$_2$–EDOT co-polymers on platinum plate deposited by pulse voltammetry from EDOT–QH$_2$ 1:2 (left) and 10:1 (right) solutions.*

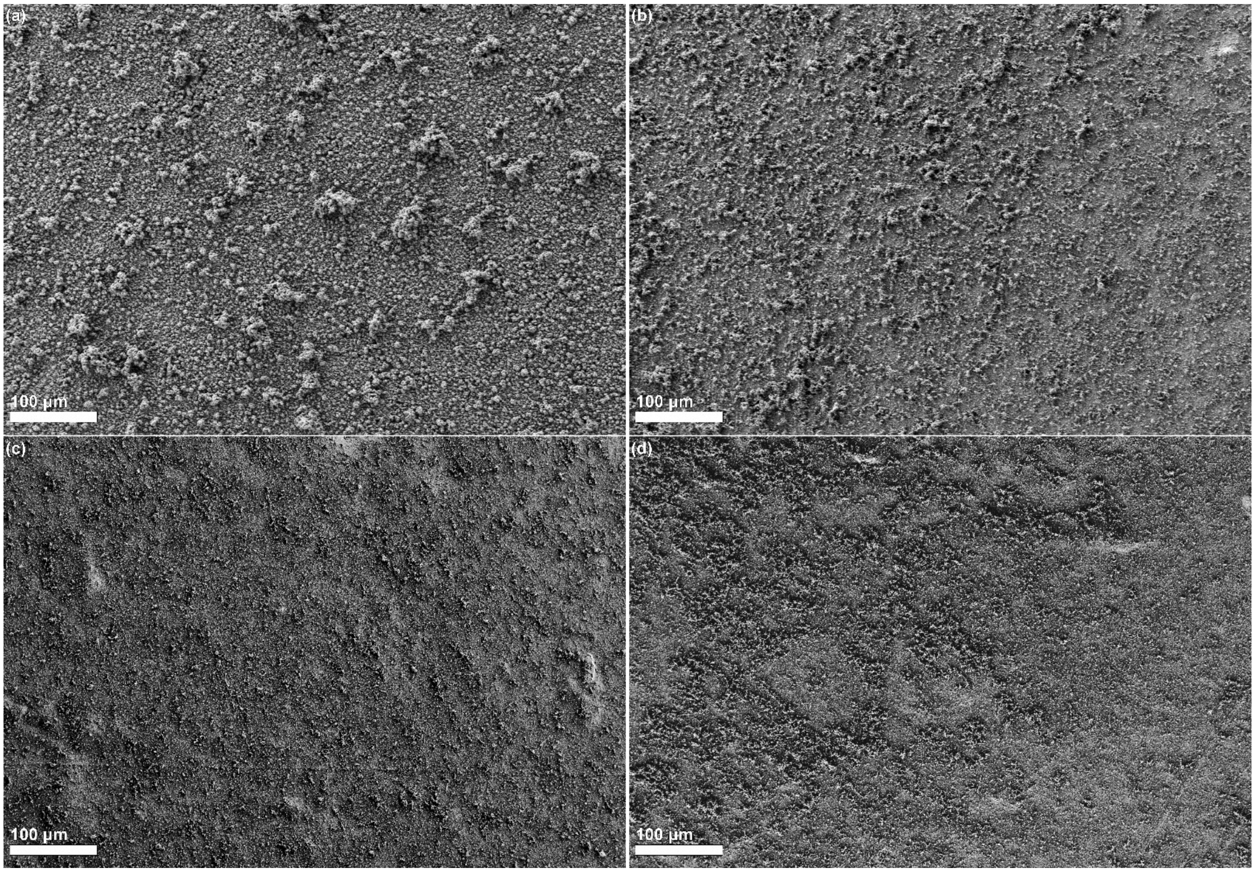

*Figure S16. Survey SEM images at low (300x) magnification in SE2 mode of the following films: (a) PEDOT (CV-deposited), (b) co-PEDOT-$QH_2$ (67 mol.% $QH_2$) (CV-deposited), (c) co-PEDOT-$QH_2$ (33 mol.% $QH_2$) (pulse-deposited), (d) co-PEDOT-$QH_2$ (67 mol.% $QH_2$) (pulse-deposited).*