Supplementary Material for: *An Optimal Route towards Green Optoelectronics: Enhancing Electrical Conductivity of Conducting Polymers using Microbubble Lithography*

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S1 Temperature-dependent charge-transport model fitting

To quantitatively assess the charge-transport mechanism governing the R–T behavior of our MBL-patterned PEDOT:PSS structures, we fitted the measured resistance data to standard transport frameworks used for conducting polymer systems: (i) Arrhenius thermally activated transport, and (ii) Variable-Range Hopping (VRH) in Mott (3D, 2D) and Efros–Shklovskii (ES) regimes. All fittings were performed using Python (SciPy), within the parameters decribed below.

Figure 5(a-c) present in the manuscript summarizes the temperature-dependent transport analysis of the MBL-patterned PEDOT:PSS lines. Fig 5(b) shows the measured resistance as a function of temperature, which decreases monotonically from 100 to 300 K, consistent with thermally activated transport in a disordered conducting polymer. The slight saturation tendency at higher temperature indicates that the limiting energy barriers are progressively overcome and suggests the emergence of efficient, well-connected conduction pathways. Here, we present the emergence of various conductivity models to better describe these behaviours. Fig S1(a) presents the Arrhenius representation, where $\ln(\sigma)$ is plotted against 1/T. A purely thermally activated mechanism would yield a single straight line, but the data exhibit noticeable curvature, and linear fits to the full range and high-temperature subset give different slopes, showing that a single activation energy cannot fully describe the conduction process.

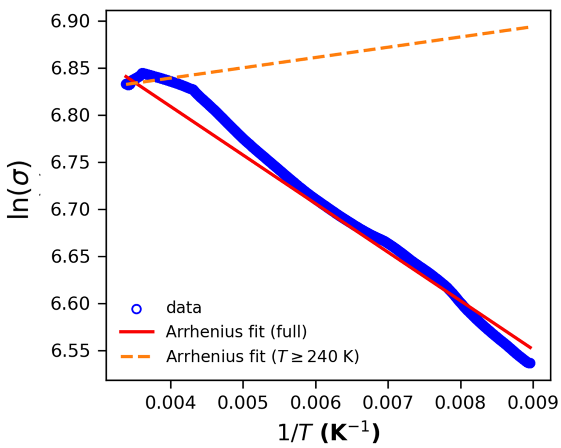

Figure S1: Comprehensive analysis of temperature-dependent transport in MBL-patterned PEDOT:PSS using Arrhenius test, $\ln(\sigma)$ versus 1/T.

Fig. S2(a-c) tests the three-dimensional Mott VRH model by plotting $\ln(\sigma)$ versus $T^{-1/4}$ to $T^{-1/2}$, respectively. Most of the data follow an almost linear trend, indicating that hopping between localized states with a distribution of energies and distances contributes significantly to transport. As already evident from the plots all three representations are more linear than the Arrhenius plot for both the full and saturated ranges, confirming the predominance of hopping conduction. Among them, the $T^{-1/2}$ (Efros–Shklovskii) form gives the most linear behaviour and is consistent with the best fit metrics from the quantitative analysis, indicating that Coulomb interactions and a soft Coulomb gap in the density of states play an important role in the self-assembled PEDOT:PSS networks, while the $T^{-1/3}$ and $T^{-1/4}$ plots still show reasonable agreement, reflecting the combined influence of structural disorder and electronic interactions.

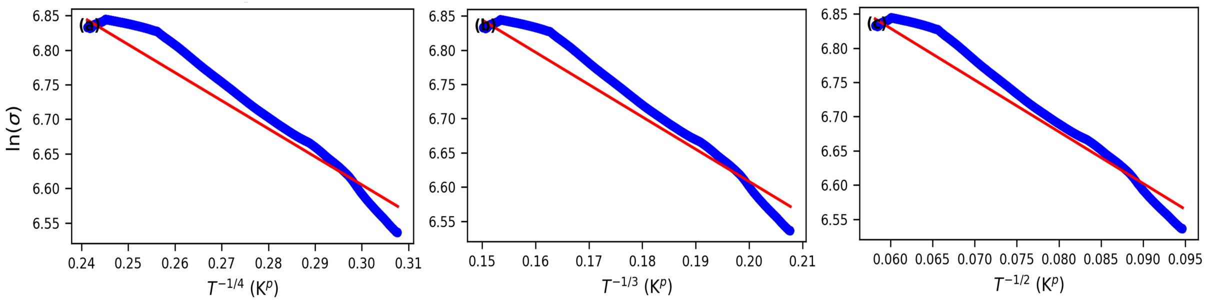

Figure S2: Variable-range hopping (VRH) test of the R-T data, showing $\ln(\sigma)$ versus (a) $T^{-1/4}$, (b) $T^{-1/3}$, and (c) $T^{-1/2}$, respectively with corresponding linear fits.