Transport resistance dominates the fill factor losses in record organic solar cells

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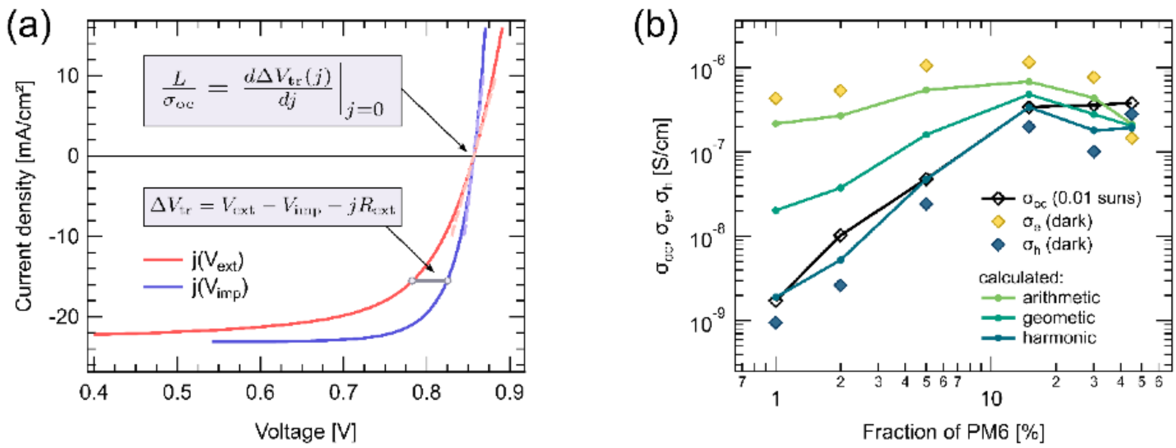
Organic solar cells have recently reached 20% power conversion efficiency. However, even in the most efficient devices, fill factor losses due to transport resistance – arising from low active layer conductivity – remain significant. For example, a single-junction organic solar cell with a certified efficiency of 19.1% achieved a fill factor of 79.6%. From the data provided, we can estimate the pseudo-fill factor – the fill factor of the solar cell if it had no series resistance losses – to 87.4%. The 7.8 percentage point difference is mainly due to transport resistance losses. It is therefore important to understand the transport resistance, as it impacts organic solar cell performance under continuous operation [2] and tends to increase with aging [3].

I will discuss the connection between active layer conductivity, transport resistance, and the resulting fill factor losses. To investigate conductivity, we study the PM6:Y12 system with varying donor content, reducing it from the optimized 45% down to 1%. This allows us to systematically decrease hole conductivity in the donor phase while keeping electron conductivity roughly constant. Effective conductivity is determined using a new method, shown in Figure (a), which is based entirely on current-voltage measurements under varying illumination intensities. Additionally, by measuring conductivity in electron- and hole-only devices, we can disentangle the individual contributions of electrons and holes to the effective conductivity of the active layer, as shown in Figure (b). These results are further supported by mobility data obtained from space-charge-limited current and intensity-modulated photocurrent spectroscopy measurements. Our findings provide insights into how transport resistance limits the fill factor in organic solar cells, pointing to strategies for reducing these losses and further improving efficiency.



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