Diffuse Light to Structured Information

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Molecular engineering of dye-sensitized solar cells (DSCs) has catalyzed a paradigm shift in indoor photovoltaics (IPV), enabling the realization of self-powered, intelligent Internet of Things (IoT) devices. Through synergistic co-sensitization of XY1 and L1 dyes, power conversion efficiency has surged from 29.0% to 38.0% under 1000 lux fluorescent illumination [1,2]. Precise tailoring of the Cu(II/I)(tmby)2 electrolyte, with Cu(II) concentration optimized to 0.06 M, has yielded an exceptional open-circuit voltage of 0.995 V and short-circuit current density of 147 µA cm-2 [2]. Interfacial dynamics, probed via photoinduced absorption spectroscopy, have revealed efficient dye regeneration even at near-zero driving force, challenging established electron transfer theories [2]. Electrochemical impedance spectroscopy has elucidated the critical role of Lewis bases in modulating TiO2 conduction band energetics and recombination kinetics [2,3]. This molecular-level understanding has facilitated the evolution from liquid electrolytes to solid-state hole conductors, culminating in "zombie" cells that retain efficiency post-electrolyte solidification [1,4]. Scalability has been demonstrated with 3.2 cm2 active areas maintaining 37.1%, 34.8%, and 33.7% efficiencies at 1000, 500, and 200 lux, respectively [2]. The seamless integration of these advanced IPV cells with microelectronics has propelled IoT capabilities from basic wireless communication to sophisticated on-device machine learning. A 7-cell array (22.4 cm2) now powers an ESP32 microcontroller executing Long Short-Term Memory (LSTM) neural networks, achieving 93.5-100% accuracy in deployment scenario prediction and performing up to 0.560 VAX MIPS [2,5]. This multidisciplinary synergy - from molecular design to materials engineering, device optimization, and edge computing implementation - exemplifies the transformative potential of chemistry-driven innovation in sustainable technology. The convergence of diffuse light harvesting, and artificial intelligence paves the way for autonomous, energy-efficient IoT ecosystems with far-reaching implications for smart infrastructure and sustainable digital transformation.

[1] Michaels et al., Chem. Sci., 2020, 11, 2895-2906.

[2] Michaels et al., Chem. Sci., 2023, 14, 5350-5360.

[3] Zhang et al., Nat. Commun., 2021, 12, 1777.

[4] Cao et al., Nat. Commun., 2017, 8, 15390.

[5] Freitag et al., Nat. Photonics, 2017, 11, 372-378.