BEYOND EFFICIENCY: THE ROLE OF DYE-SENSITIZED SOLAR CELLS IN FUTURE PHOTOVOLTAIC ECOSYSTEMS

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Dye-sensitized solar cells (DSSCs) are among the earliest third-generation photovoltaic technologies and remain a paradigmatic example of how molecular and interfacial chemistry can be harnessed for solar energy conversion. While their power conversion efficiency will never reach silicon-based and perovskite photovoltaics, DSSCs retain distinctive advantages in their chemical versatility, including modular dye design, tunable redox mediators, and controllable light–matter interactions. As a result, their contemporary relevance lies less in efficiency-driven competition and more in application-driven optimization enabled by chemistry.

DSSCs exhibit excellent performance under diffuse and low-irradiance illumination and offer wide freedom in optical and electronic tuning through rational molecular engineering. The absorption profile, color, and transparency of the device can be tailored via dye structure and electrolyte composition, while charge-transfer kinetics and stability can be controlled through redox shuttle chemistry and interfacial passivation strategies. These features make DSSCs particularly attractive for indoor photovoltaics, Internet-of-Things (IoT) energy harvesting, and semi-transparent building-integrated photovoltaics (BIPV). [1, 2, 3] From a photochemical perspective, greenhouse-integrated DSSCs represent another compelling application, as spectrally selective dyes can be designed to harvest non-photosynthetically active radiation while transmitting or modulating light in the photosynthetically active range.

Finally, recent advances in dye chemistry, redox mediators, and quasi-solid-state or solid-state electrolytes are driving DSSCs toward improved durability and application-specific performance. In future photovoltaic ecosystems, DSSCs are therefore best viewed as chemically programmable solar devices, complementary to high-efficiency technologies and uniquely suited for environments where spectral selectivity, aesthetics, and low-light operation are critical. [4]

References

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