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Sustainable Energy Solutions for IoT: Low-Temperature, Low-Cost Thin-Film Organic Solar Cells

As the number of sensors and devices in the Internet of Things (IoT) grows, the demand for a reliable and sustainable energy supply becomes increasingly critical. Energy supply is particularly challenging in remote applications and/or in cases of poor accessibility. For these applications, batteries are unfavourable as they would have to be dimensioned for single-use discharge, making them bulky and expensive. Solar cells offer are better alternative as they can harness ambient light. However, the large ecological footprint of conventional solar cells presents a significant drawback in terms of sustainability as the production of silicon requires high temperatures (>~1400~°C) and significant amounts of material (750 g/m²). Therefore, thin-film solar cells made from perovskite or organic materials offer an ideal alternative to address these challenges. They make use of less material (approximately 0.8~g/m^2) which can be synthesized at low temperatures (<~120~°C) from abundant materials. Additionally, the substrate can be flexible and thin, allowing for a broader range of applications.

In our EU-funded project FOXES, we developed monolithic organic solar cell modules providing USB bus voltage (5~V) already under low level indoor lighting conditions (400~lux). Furthermore, our publications demonstrated that thin-film encapsulation preserved stability at over 90~% of the initial efficiency for more than 1000~h under elevated aging conditions (70~°C, 70~%~R.H.). These results indicate robust durability under harsh environmental stress, meeting key reliability benchmarks typically required for pre-qualification in industrial applications. Therefore, these cells are strong candidates for industrial-scale production.
In addition, thin-film solar cells offer notable economic and ecological benefits through energy-efficient recycling. Organic solvents can be kept in closed process cycles, and precious metal electrodes of the solar cell can be recovered by filtering and drying, enabling sustainable reuse.

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