00324
Bio-phosphors with natural and artificial fluorescent proteins for deep-red light-emitting diodes

N. Sustainable advanced and multifunctional polymer based materials for sensor and actuators, energy and environmental applications

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Abstract

Bio-phosphors have emerged as an alternative to rare-earth color down-converting filters in light-emitting diodes (LEDs). They are mainly produced with biogenic emitters, like Fluorescent Proteins (FPs), embedded in polymer matrices.[1–3] The first bio-hybrid LED (Bio-HLED) with FP-phosphors featured a loss <10% of the emission intensity after 100 h.[1] This performance was recently enhanced using zero-thermal quenching PMMA-FP phosphors, reaching >150 days and 5 min of stability at low and high powers.[4] Here, we first disclose the optimization of a bio-derived biodegradable polymer hosting and stabilizing a natural red FP – mCherry, as red-emitting phosphor in Bio-HLEDs. The photoluminescent properties of the bio-phosphors led to Bio-HLEDs with excellent photo-stabilities > 2600 h operating upon low power (55 mW cm^{-2}), representing 2 orders of magnitude enhancement compared to prior art. This represents a crucial breakthrough in the development of red emitting bio-phosphors and in the stabilization of further natural FPs. Finally, we report a second approach involving the design and characterization of an innovative protein-based phosphor using an artificial fluorescent protein (AFP) hosting a highly emissive organic dye and its application in Bio-HLEDs. The remarkable stability of the complex in solid polymer matrix with QY ~ 30% led to a Bio-HLEDs photostabilities > 1500 h under high power (130 mW cm^{-2}). These achievements drastically outperform previous proof of concepts devices bearing Lactococcal multidrug resistance Regulator (LmrR) – Squaraine dye adducts (> 300 h upon low power).[5] Thus, here we provided two main strategies towards marketable protein-based LEDs: i) the stabilization of natural FPs thanks to a deep understanding of the FP deactivation mechanism in the solid state, ii) the use of *ad hoc* designed proteins

with suitable characteristics for lighting applications. Overall, we strongly believe that these steps bring a real commercialization of protein-based phosphors closer and closer.

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