Towards highly stable eco-friendly squaraine-protein phosphors for Bio-HLEDs

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Bio-phosphors are emerging as an alternative to rare-earth down-converting filters applied to LEDs. They can be produced either with biogenic emitters, basically Fluorescent Proteins (FPs), embedded in polymer matrices,[1–3] or with artificial emitters dispersed in biogenic matrices, such as, DNA,[4] proteins,[5] etc. The first Bio-HLED based on FP phosphors featured a loss <10% of the emission intensity after 100 h.[1] This performance was recently enhanced by long-living devices featuring a zero-thermal quenching with a FP green phosphor, reaching >150 days of stability.[6] However, up to date there is a limited number of deep red emitting FPs meeting high photostabilities and photoluminescent quantum yields (QY) – tipically QY <10%. Therefore, red emitting FPs designed for lighting applications are strongly desired. Here, we report the design and characterization of an innovative protein-based phosphor using Lactococcal multidrug resistance Regulator (LmrR) hosting a highly emissive squaraine dye – SQR1 and we disclose its application as bio-phosphor in white Bio-HLEDs. The remarkable stability of the complex in solid polymer matrix with QY ~ 30% led to a Bio-HLEDs with power efficiencies of around 50 lm/W and remarkable photo-stabilities > 300 h. Thus, we provided two main advantages: i) a new route towards red bio-phosphors using emitters otherwise soluble in toxic solvents, ii) highly stable and efficient bio-hybrid LEDs. Overall, we strongly believe that this work opens the way to the use of *ad hoc* designed proteins in solid-state lighting applications.

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