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Eco-friendly Egyptian blue ($CaCuSi_4O_{10}$) dye for luminescent solar concentrator applications

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This study focuses on synthesizing the heavy metal-free ancient Egyptian blue (EB; $CaCuSi_4O_{10}$) dye using a facile ceramic method for luminescent solar concentrator (LSC) application. XRD, SEM and EDX results confirmed that this well-crystallized material is successfully synthesized. Optical studies revealed that EB has a high Stokes shift and possesses an average lifetime of 110.50 μs with a quantum yield of 12.93%. Finally, an EB-integrated LSC was fabricated that exhibits a power conversion efficiency (η) of 0.15% and an optical conversion efficiency (η_{opt}) of 1.21%, which are the highest values reported so far using EB.

1. Introduction

One of the constraints with electricity production using conventional Si-based solar cells is the amount of area that is needed for roof-top or stand-alone installations.[1] The lack of flexibility and weight are other challenges that must be addressed to ensure affordable energy for all (*i.e.*, Sustainable Development Goal 7) based on solar cell technologies.[2] Lots of research into solar cells has been focused on novel materials and new processes for solar cell fabrication. Luminescent solar concentrators (LSCs) have been explored as a potential solution to tackle the aforementioned limitations. A typical LSC consists of a transparent glass plate, which is coated with a highly luminescent material that absorbs solar radiation. These materials then re-emit the absorbed photons at long wavelengths which are transported to the edges of the LSCs that are coupled with the solar cell, thus producing electricity.[3,4] LSCs serving as semitransparent photovoltaic windows could become an important element in net-zero-energy-consumption buildings of the future.[5] Such laminated glass offers benefits towards security, soundproofing and energy conservation through the building of windows, facades, and transparent roofs.[6,7] In addition, an LSC does not require solar tracking and can operate in both diffuse and direct sunlight.[6] Nevertheless, LSC development faces various challenges, many of which are related to the materials used in its design. Luminescent materials can be either organic or inorganic.[8–11] The major inorganic luminescent materials are quantum dots (QDs) and rare-earth (RE)-based luminescent materials, where each type possesses its own benefits and drawbacks, making neither of them an ideal LSC candidate.[12] Organic luminescent dyes typically suffer from large self-absorption losses (a large overlap between the absorption and emission spectra), poor stability, narrow-band absorbance, and a lack of spectral matching with the peak external quantum efficiency (EQE) of the solar cells.

Egyptian blue (EB) is a luminescent material that is also called cuprorivaite ($CaCuSi_4O_{10}$). It is a copper-based dye and can overcome the limitations of toxicity and cost-related issues that are seen with other luminescent materials.

It has superior stability and was produced by ancient chemists as a pigment (Fig. 1), which shows luminescent abilities even after

Fig. 1 Ancient painting in ceiling reliefs in the Hathor Temple in Qena, Egypt (Source: https://www.chemistryworld.com/features/egyptian-blue-more-than-just-a-colour/9001.article)

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