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Advanced Luminescent Nanostructures for Enhanced Solar Cell Applications

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Properties of core-shell-structured nanostructures based on NaGdF4 and lanthanides have emerged as a prominent research area in recent years. These materials exhibit unique luminescence properties that can be tailored for various applications, including solar cells, photocatalysis, and biological markers. One common method to enhance their luminescence efficiency is by growing a shell around the core. Lanthanide-based nanoparticles can enhance solar cell efficiency through both upconversion and downconversion of light. In upconversion, the nanoparticles can convert near-infrared (NIR) sunlight into visible light, thereby broadening the spectral absorption range of the solar cell and increasing its conversion efficiency. On the other hand, in downconversion, the nanoparticles can absorb high-energy photons, such as those from ultraviolet (UV) light, and emit lower-energy photons that are more easily captured by the solar cell, thus increasing the overall efficiency of converting solar energy into electricity. These combined properties of lanthanide-based nanoparticles significantly improve the performance and efficiency of solar cells.. In this study, core and core-shell-structured NaGdF4 nanocrystals were prepared via high-temperature thermolysis using oleic acid, octadecene, and lanthanide salts as precursors. Various structures were synthesized, including NaGdF4 (host matrix), NaGdF4:Yb3+,Er3+ (UC core), NaGdF4:Yb3+,Er3+@NaGdF4 (UC core-shell), NaGdF4:Yb3+,Er3+@NaGdF4:Eu3+ (dual core-shell), and NaGdF4:Yb3+,Er3+@NaGdF4:Eu3+ (dual core-2shells), exhibiting dual-mode emission. NaGdF4:Yb3+,Er3+ is a material that exhibits upconversion luminescence, with energy transfer from ytterbium to erbium. Upon excitation at 980 nm, corresponding to Yb3+ absorption (transition 2F7/2 ? 2F5/2), emissions in the green (540 nm) and red (650 nm) regions of the electromagnetic spectrum are observed, attributed to 4S3/2 ? 4I15/2 and 4F9/2 ? 4I15/2 transitions, respectively. On the other hand, NaGdF4:Eu3+ demonstrates typical downconversion luminescence, displaying intense multicolor visible emissions under excitation at 274 nm (Gd3+ absorption) and 395 nm (Eu3+ absorption) in the UV region. The emission spectrum in the 575 to 700 nm range corresponds to 7F0 ? (5LJ + 5GJ) absorption transitions of Eu3+, with distinct peaks at 591, 615, and 694 nm arising from 5D0 ? 7F1, 5D0 ? 7F2, and 5D0 ? 7F4 transitions, respectively. Characterization using XRD, EDS, and TEM confirmed the hexagonal phase (?) and nanometric size of the crystals, with a diameter of approximately 15 nm. These nanoparticles show promise for application in solar cells to enhance energy conversion efficiency.