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Green Biomineralization of Heterostructured Photocatalysts for Hydrogen Evolution

AUTHORS

John SAKIZADEH / LEHIGH UNIVERSITY, 111 RESEARCH DRIVE, BETHLEHEM
Joseph CLINE / LEHIGH UNIVERSITY, 5 EAST PACKER AVENUE, BETHLEHEM, PENNSYLVANIA
Mark SNYDER / LEHIGH UNIVERSITY, 111 RESEARCH DRIVE, BETHLEHEM, PENNSYLVANIA
Christopher KIELY / LEHIGH UNIVERSITY, 5 EAST PACKER AVENUE, BETHLEHEM, PENNSYLVANIA
Corresponding author : Steve MCINTOSH / mcintosh@lehigh.edu

PURPOSE OF THE ABSTRACT

While nanomaterials have been shown to have exquisite optical and catalytic properties relative to their bulk counterparts, conventional nanomaterial syntheses often involve high temperatures, organic solvents, and multi-step processing, which limits the scalability of their production. On the other hand, organisms have demonstrated the ability to synthesize nanomaterials, like intricate skeletons, shells, and nanoparticles, under low temperature, aqueous conditions through the process of biomineralization. To take advantage of the green characteristics of biomineralization, there is scientific interest in biomineralizing functional nanomaterials to reduce the energy intensity of synthesis relative to conventional production methods. For instance, we have studied the use of the bacteria, Stenotrophomonas maltophilia, to biomineralize photoluminescent metal sulfide nanocrystals in water at 37 °C; however, while it was demonstrated that final product performance and morphology could be controlled by the synthesis environment, the performance of these biomineralized products was found to lag in comparison to conventionally synthesized counterparts. Therefore, for biomineralization to become a feasible synthesis strategy for nanomaterials with catalytic and optical functionalities, the performance of these materials must improve while maintaining the environmentally benign characteristics of biomineralization. In our lab, we have approached this challenge by first simplifying the biomineralization system, reducing the biological components necessary by isolating the single enzyme responsible for biomineralization, and then using low temperature, aqueous post-synthetic processing to enhance the performance of these materials so that they are comparable to or outperform nanomaterials made through conventional syntheses. This approach is evident in our work on the biomineralization of advanced cadmium sulfide-based hydrogen evolution photocatalysts, in which we have self-assembled cadmium sulfide/reduced graphene oxide nanocomposites and cadmium sulfide/zinc sulfide core/shell nanocrystal photocatalysts both with hydrogen evolution rates comparable to the conventionally synthesized materials. The combined green, single-enzyme biomineralization and post-synthetic modification strategy offers a potentially generalizable approach to efficient synthesis of complex photocatalysts that offer performance comparable to, or beyond, those synthesized by typical chemical routes.

FIGURES

FIGURE 1

FIGURE 2

KEYWORDS

Nanomaterials | Biomineralization | Hydrogen generation | Photocatalysis

BIBLIOGRAPHY