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Materials for Renewable Energy Harvesting and Storage: Fostering Renewable Energy at HEIs for a Sustainable Environment

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Abstract

The transition towards renewable energy systems requires materials capable of efficiently harvesting, converting and storing energy while supporting sustainable and low-carbon development. This presentation highlights research and technological developments in nanostructured, polymeric, inorganic, and hybrid materials for renewable energy harvesting, energy conversion, and energy storage applications from my research group. The presentation will emphasize (i) nanostructured TiO_2-based materials developed through microwave-assisted sol–gel synthesis for enhanced sunlight harvesting and photovoltaic applications, (ii) integration of broadband plasmonic Au and Ag nanostructures with mesoporous TiO_2 for enhanced solar absorption and an improvement in the power conversion efficiency of dye-sensitized solar cells, (iii) the development of solid-state polymer–inorganic composite electrolytes incorporating GARNET fillers and cross-linked polymer networks to enhance lithium-ion transport, interfacial stability and electrochemical safety while suppressing dendrite formation, providing opportunities for next-generation high-energy solid-state batteries, (iv) polymer-encapsulated phase change materials (PCMs) for solar-thermal energy storage, offering improved thermal charging–discharging characteristics and latent heat capacity, (v) high-solar-reflectance, water-based roof-cool coatings will also be highlighted as a passive cooling approach for reducing solar heat absorption and indoor cooling demand, (vi) silver nanoparticles integrated with dual B/P-doped g-C_3N_4 enhance visible-light absorption and charge separation, boosting hydrogen-generation efficiency for sustainable solar-driven water splitting will be discussed. Overall, the presentation will demonstrate how the integration of materials science, nanotechnology, and renewable-energy engineering can contribute to efficient energy harvesting, thermal and electrochemical storage, hydrogen production, and sustainable energy systems. The presentation will also highlight our initiative to promote Pondicherry University's adoption of solar energy for its energy needs and its vision to achieve net-zero carbon emissions by 2035, thereby promoting sustainable practices at HEIs.

Keywords: *Li-ion battery; materials; nanotechnology; renewable-energy systems; solar energy*