Abstract

Innovative research ideas in the field of science and technology have the ability to garner solutions to current world problems – harnessing and storing clean and sustainable sources of energy without leaving any carbon foot print, other global problems such as reducing environmental pollution – clean water and air. For example, semiconductor catalysts have the potential to utilize solar energy to address the aforementioned issues when incorporated in devices. However, these semiconductor materials need to be tuned and engineered to suitable requirement to give optimum performance. In this study, we have reported various functional materials in the nano regime, synthesized using facile and replicable processes. These nanomaterials are further employed to explore possible applications.

Titanium dioxide is a cost-effective, environmentally benign and abundant material having a wide bandgap of 3.14 eV. This material is designed to a spherically structured morphology comprising of smaller TiO_2 nanoparticles with the bandgap reduced to 2.4 eV. This result was afforded by a two-step sol-gel and hydrothermal approach. The resulting nanomaterial was implemented for photocatalytic degradation of five different industrial dyes. Major findings related to dye degradation, including comparison at different pH medium and repeatability of the catalyst are outlined as a part of the thesis.

Additionally, stable and effective nanomaterials HfO_2 were devised for catalytic soot oxidation whereby soot from diesel and industrial engines can be oxidized before releasing into the atmosphere. Two chapters in the thesis explored HfO_2 hydrogenated at different time intervals and Ni and Co incorporated clay as sustainable catalysts for oxidation of soot. The synthesized catalysts were able to lower the light-off temperature of the catalyst, T_m. The chapters discuss the mechanism of soot oxidation and the role of oxygen vacant sites for the effective working of the catalysts.

Additionally, nitrogen-doped carbon material for multiple applications are further explored. Two types of nitrogen-doped carbons - hollow and solid are synthesized via a modified Stöber's process. The developed carbon materials are utilized as electrode materials in DSSC device as photoanode and counter electrode and also a potential material for CO_2 capture. Additionally, the materials were tested for possible electrode material in supercapacitor application.

Another material which with interesting prospect in the optoelectronic industry is the all-inorganic perovskite $CsPbX_3$ nanocrystals. A study is carried out based on these special perovskites involving the preparation and investigation for other significant physiochemical properties. These reportedly unstable luminescent nanocrystals are stabilized using a protecting encapsulation of metal oxides of Ti, Mo, Ta and Sn. Furthermore, composites of these halide perovskites with monolayer graphitic carbon nitride nanosheets were synthesized for photoelectrochemical application.

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