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Review Article

Nano – A Splendid Material for Overwhelming the Hurdles of Hydrogen (H2) Production

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Abstract

This article summarizes the role of nanomaterials in H2 production. H2 is a clean fuel which faces many hurdles starting from production upto the final application. Among the various available methods for H2 production, this piece of work focuses on photoactive based methods of applying nanomaterials to improve the production rate. Nanomaterials of different structures including 0-D, 1-D and 2-D materials such as quantum dots, nanocrystals, nanorods, core-shell nano structures and nano-rust are employed in this process. Designing of biologically inspired nanostructures and mimicked nanostructures, so called 'nano-reactors' and 'champion nanostructures' produces H2 upto a comparable limit with the natural sources. Future research work in designing these fundamental structures for large scale H2 production is also reviewed.

Keywords: Nanomaterial, H2 production, Efficiency, Large-scale production

Introduction

Hydrogen is a clean alternative fuel source and its consumption reaches 53 million metric tons per year [1]. Hydrogen production technologies fall under 3 main categories, namely thermal process, electrolytic process and photolytic process. There are many methods to produce hydrogen including steam reforming, plasma reforming, partial oxidation of fossil fuels, electrolysis, thermolysis, photocatalytic water splitting etc. Nanomaterials play a major role in enhancing the efficiency of H2 production [2]. The inclusion of nanomaterials show improved efficiency of 90 % in steam reforming method compared with the conventional method producing only 73.8 % [3, 4]. Major hurdles faced in H2 production technology is Hydrogen quality, Production cost, Regulatory issues and Safety & control. Solar energy is the cleanest way to produce H2 which is a one-step process. photocatalytic H2 production requires materials with high durability and efficiency. Nanomaterials are able to meet both the above criteria. Nanocrystals introduce disorder in the surface of the photocatalysts thereby enhancing the efficiency [5]. The interfacial charge transfer which greatly affects the photoefficiency was controlled by employing parallel nano-twin structures which introduce back to back potential facilitating improved charge separation [6]. Nitride nanocrystals acts as a promising catalytic material for PEMFCs (poly electrolyte membrane fuel cells) inducing fast kinetic of the oxygen reduction reaction on the cathode which decreases the voltage losses in PEMFC [7]. In a recent advancement, Nanoreactor namely "P22-Hyd", mimicking the virus ability to produce H2 was created for H2 production which can process at room temperature [8].

In another work, nano pulsed power module was designed for H2 production and it efficiency produced H2 to a desired limit [9]. Moreover, nanocrystals prepared by ionic liquid assisted hydrothermal method showed a better yield of H2, noticeably 2-fold increase in production rate which was attributed to the porous structure and increased surface area of the nanocrystals [10]. Ten-fold increase in H2 producing efficiency was achieved with a photo cathode comprising of an array of gallium phosphide nanowires. The same gallium phosphide when used as flat surface instead of nanowires showed reduced efficiency [11]. In a most exciting system of H2 production using nano-photocatalyst comprising of quantum dots and platinum produced 3,60,000 molecules of H2 per hour [12].

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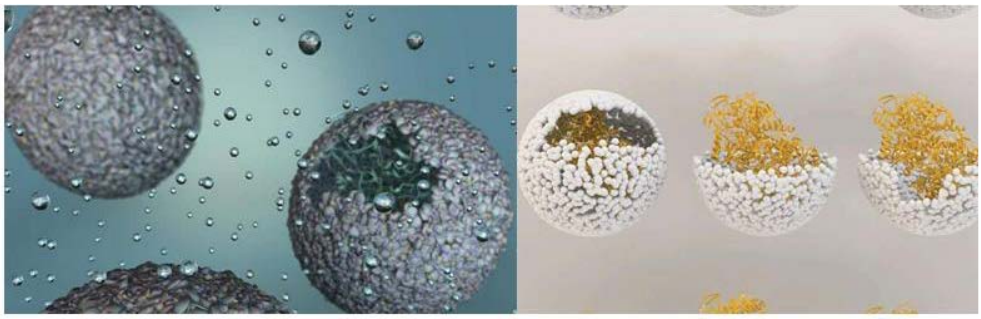

Figure 1: Nanoreactor for H2 production [8].

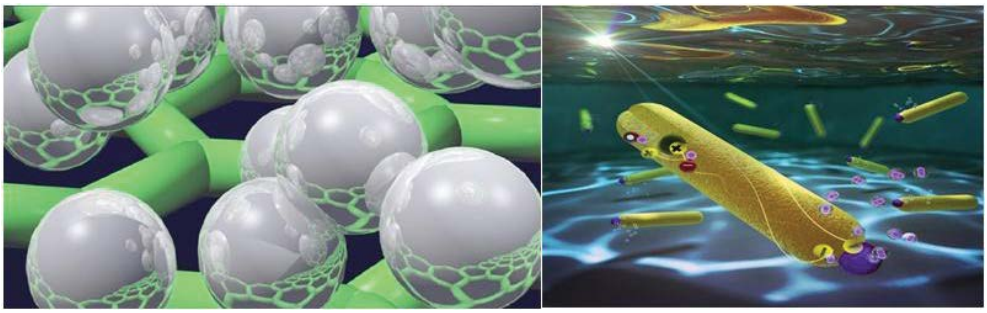

Figure 2: Nano- photocatalyst for H_2 production composed of quantum dot (green) embedded in nano-rod (yellow) with platinum (purple) [12].

Figure 3: H_2 production with Nano-rust [14].

Nanomaterial can replace expensive platinum in the process of H_2 production. Similarly, nanoparticles of silicon contribute a major role in H_2 production instantly [13]. An attempt for Large-scale manufacturing of H_2 was performed using nano-rust of iron. This champion structure having a 10×10 cm prototype can produce H_2. The role of each nanostructure in charge transport property was studied with each colour of the nano cauliflowers representing different crystal orientation [14]. H_2 production using the above structure was depicted in figure 3.

- The future research is on designing catalysts for producing H_2 at low temperatures which will be suitable for on-scale applications like fuelling marine vehicles and low temperature motors.
- Improved catalyst tolerance for impurities to promote the quality of H_2.
- Design of novel architecture for large scale H_2 production.

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