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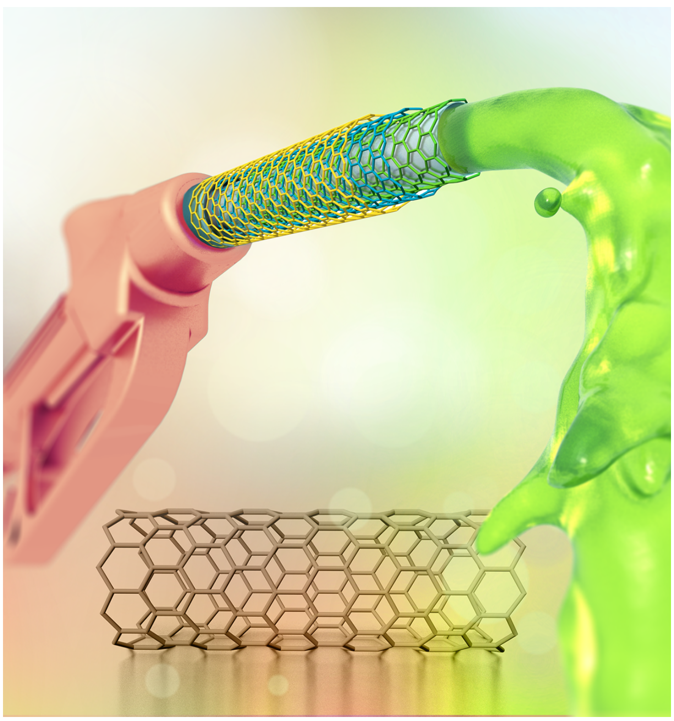
Editorial

Towards nanotechnology-based biofuel industry



Abstract

The biofuel industry is rapidly growing with a promising role in producing renewable energy and tackling climate change. Nanotechnology has tremendous potential to achieve cost-effective and process-efficient biofuel industry. Various nanomaterials have been developed with unique properties for enhanced biofuel production/utilization. The way forward is to develop nanotechnology-based biofuel systems at industrial scale.

The current energy demands and future supplies have become one of the national and strategic agenda of almost every country today (Waqas et al., 2018). Currently, more than around 75% of this energy is generated from non-renewable sources. We are ignoring the consequences of over-exploitation of natural resources on our climate and the need of our future generations (Nizami et al., 2017). There has been intensive research and development work carried out in the area of biofuels to move towards sustainable and renewable energy systems. The biofuel industry is rapidly growing and is believed to have a significant potential role in tackling the issues of environmental pollution and climate change, besides the production of renewable energy (Rai and Da Silva, 2017). Scientists and engineers are continuously striving to improve the various components of the biofuel industry, including biomass/feedstock pretreatment, process parameters, reactor designs, product quality and yields, and overall process optimization, as well as the process and capital costs, public acceptance, and market availability for various biofuels (Hussein, 2015).

The use of nanotechnology and nanomaterials in the biofuel industry has emerged as a promising tool in providing cost-effective and process-efficient methods to improve biofuel production (Serrano et al., 2009; Sekhon, 2014). The core principle to exploit nanotechnology in biofuel industry is to apply both the scientific (green and catalytic chemistry) and engineering solutions together in the quest of eco-friendly energy sources (Ramsurn and Gupta, 2013). Tremendous research has been conducted to design and fabricate nanomaterials including advanced functional catalysts for biofuel and energy-related applications (Trindade, 2011). What makes nanomaterials exceptional candidates in various biofuel systems are their high surface areas and unique characteristics such as a high degree of crystallinity, catalytic activity, stability, adsorption capacity, durability, and efficient storage which could collectively help optimize the overall system. They also have a high potential for recovery, reusability, and recycling (García-Martínez, 2010). Examples of successful use of nanotechnology in biofuel technologies include transesterification, anaerobic digestion, pyrolysis, gasification, and hydrogenation for the production of fatty esters, biogas, renewable hydrocarbons, etc. The combinations of these technologies with nanotechnology have been proven to be efficient, economical and mature, but are still mostly at laboratory and pilot scale and are expected to be promising way-forward for replacing conventional systems when developed at commercial scale (Zhang et al., 2010).

For instance, nanotechnology has attracted a significant deal of interest for the optimization of biodiesel production through nanomaterial-based catalysts. This has led to the development of more efficient, economic, durable, and stable nano-catalysts holding the potential to achieve higher product quality and yields. Various metal oxide nano-catalysts such as titanium dioxide (Gardy et al., 2017), calcium oxide (Liu et al., 2008), magnesium oxide (Verziu et al., 2008), and strontium oxide (Liu et al., 2007) have been developed with high catalytic performance for biodiesel production. Magnetic nanoparticle-based catalysts have been shown to be advantageous due to their ability to be easily separated from reaction media and reused, leading to more economical, industrial-scale biodiesel production (Gardy et al., 2018). A number of mesoporous nano-catalysts, with excellent structural properties for enhanced catalytic activities, have also been designed and successfully used in biodiesel production (Yahya et al., 2016). Carbon-based nano-catalysts such as carbon nanotubes (Guan et al., 2017), carbon nanofibers (Stellwagen et al., 2013), graphene oxide (Mahto et al., 2016), and biochar (Dehkhoda et al., 2010) have also been shown to hold great potentials for biodiesel production from a wide range of feedstocks, especially from non-food ones.

Another promising application of nanotechnology in the biofuel industry is enzyme (biocatalysts) immobilization during lipase-catalyzed biodiesel and cellulosic ethanol production processes (Kim et al., 2018). The benefits nanostructures offer in this domain include large surface area for high enzyme loading, higher enzymatic stability, and possibility of enzyme reusability, which could reduce the operational cost of large-scale biofuel production plants (Trindade, 2011). Examples of the techniques developed for enzymes immobilization using nanotechnology are nano-encapsulation, self-entrapment with silaffin, and adsorption. Nanoparticles have also been used for extracting oils from algae without harming the cells. More specifically, for algal fuel production, nanomaterials like silica, metal oxide nanoparticles, single-walled

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carbon nanotubes, and nano-clay have been positively used in various stages of lipid accumulation, extraction, and transesterification (Zhang et al., 2013). These techniques could reduce the production cost at commercial scale algae biofuel plants.

The use of nanoparticles as fuel additives to boost fuel blends performance is another growing application of nanotechnology (Trindade, 2011). The utilization of nanoparticles like alumina and hollow carbon nanotubes have shown to enhance the combustion characteristics of biodiesel-operated engines resulting in less harmful emissions (Basha and Anand, 2011). In the anaerobic digestion, the use of nano-iron oxide, nano zero-valence iron, nano fly ash, nano bottom ash, and bioactive nano-metal oxides have positively affected/increased methane production (Ganzoury and Allam, 2015).

Finally, potential areas of biofuel industry where nanotechnology could potentially bring about breakthroughs include advanced fermentation, fast catalytic pyrolysis, jet fuels, catalytic conversion of syngas, hydrocarbon biorefineries, biofuel cell, biochar, carbon capture and storage, gasification, hydrothermal liquefaction or carbonization, converting and upgrading of ethanol, volatile products and tars. In biomass-based energy systems, the use of nano-based precision farming technology could optimize crops production for higher yields of biofuels. Moreover, future research should not only be focused on biofuels sources and energy production, but also on energy efficiency and storage, transportation, transformation, and end-product use of biofuels. Nanotechnology could significantly contribute to these areas to address both the engineering and scientific limitations.

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