Chapter 21
Implications of Nanotechnology into Next Generation Biofuel Industry

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ABSTRACT

Biofuels are emerging as integral and necessary research areas towards clean, next generation energy production, while providing alternative sources of sustainability. In addition to advancements in nanotechnology, many obstacles remain on the way for producing economically viable biofuels such as the challenges involved in the breakdown of cellulose, hemicelluloses, and lignin found in woody biomass. The use of micro-algae as a feedstock in biofuel has already been impacted by the advancements of nanotechnology. However, interdisciplinary breakthroughs are needed to make biofuels viable contenders as replacements for traditional fossil fuels. The authors discuss recent advances, benefits, and challenges facing nanotechnology in accordance with furthering our understanding and improving the state of biofuel manufacturing, including the implementation of nanotechnology in other aspects of biofuels production, such as cracking catalyst design, carbon nanotube electrodes for fuel cells, and enzymatic production of biofuels.

INTRODUCTION

Over the past two decades, there has been a substantial increase geared toward research and development in the arena of biofuels. Given the unlikely near-term resolution involving atmospheric CO_2 levels and their effects on the climate, the adoption of global conservation measures, and the stabilization of fossil fuel prices, it is a near certainty that global oil and gas supplies will be largely depleted in a matter of decades. That much is clear from even a cursory comparison of the independent estimates of the world's oil and natural gas reserves as well as the respective data on oil and gas consumption (EISA 2007). The United States Energy Independence and Security Act (EISA) of 2007 mandates the production of 36 billion gallons of renewable fuel, and 21 billion gallons of advanced biofuels (cellulosic biofuel and biomass-based diesel) per

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year, by 2022 (EISA 2007) while the European Union (EU) has set a target of 10 percent use of biofuels in transportation by 2020 (Landeweerd et al. 2011). Adding to the difficulties of building a sustainable fuel economy, many of the world's top producers of petroleum are in economically and politically unstable regions and other existing known reserves are difficult or impossible to access (Landeweerd et al. 2011).

Nature offers abundant renewable resources that can be used to replace fossil fuels but the issues and challenges of cost, technology readiness levels, and compatibility with existing distribution networks remain. Cellulosic ethanol and biodiesel are the most immediately obvious target fuels, with aviation fuels, hydrogen, methane, butanol, and biogasoline as other potentially viable products, as well as many other aliphatic and aromatic compounds used in sectors outside the fuels industry (Singh & Harvey 2008; Maznanera et al. 2008; Fortman et al. 2008; Adjaye et al. 1996). The production, modification, and use of oils are integral to the functioning of modern society, with particular importance in the production transportation fuels. Traditionally, mineral feedstock (crude oil) has been used to produce gasoline, diesel and jet fuel, but with rising costs of crude oil, higher demand, and concerns about CO_2 emissions, fuel alternatives are needed. Nanotechnology could create and provide many valuable tools for creating and modifying these fuel alternatives.

Nanotechnology is defined as innovation and manipulation of materials at the "atomic, molecular or macromolecular levels, in the length scale of approximately 1 - 100 nanometer range" (www.nsf.gov). Many nanotechnological applications may have molecules larger than the 100 nm upper-limit per the definition, however, the important sites in and on many macromolecules fit well into the prescribed definition, as the functional sites are within the 0-100 nm range. Such materials may be referred to as "nanoporous materials" and occur both naturally and synthetically (Ying 2005). There are many materials used in the production of biofuels that utilize nanotechnology, such as cracking catalysts and others discussed throughout this chapter. Some introductory examples of nanotechnology's role in biofuels include the use of nanocrystalline zeolites (nanoscale versions of commercial catalysts from the petroleum industry), used for cracking mineral, animal, and vegetable oils into desired products (Usui et al. 2004; Ong & Bhatia 2010; Taufiqurrahmi et al. 2011b). Nanocatalysts are the much smaller counterparts to traditional catalysts used in the fuels industry such as nano-forms of HZSM-5, β-zeolite, and ultra-stable zeolite Y (USY) which, in this scenario, are used for converting biofuels into other desirable hydrocarbons (Adjaye et al. 2006; Huber & Corma 2007).

Zeolites have many useful applications due to their many interesting properties (Rhodes 2010). A general property of zeolites may be considered an ability to crack and modify oils as well as water softening and environmental decontamination, due to the ability to perform cation exchange (Rhodes 2010). The nanonization of zeolites and other macro-materials may provide them with novel properties and characteristics. One such example are the nanocrystalline zeolites, capable of producing gasoline fractions from waste palm oil and converting waste cooking palm oil into biofuels (Taufiqurrahmi et al. 2011b). This finding suggests other oils with similar chemical profiles can be similarly converted. Reducing the crystal size of a zeolite, called HZSM-5, into the nanoscale gives it "super catalytic properties such as higher activity, lower coke content and better stability"(Zhang et al. 2007).

Nanoscale particles can have markedly different properties and characteristics than those of their bulkier parent materials (Moshfegh 2009). Controlling the surface, size, and pore properties of nanocrystalline catalysts while utilizing the correct protocols for chemical conversion can render any oil or sugar producing biomass into biofuel. In addition to nanocatalysts, carbon nanotubes (CNTs) have been implemented into biofuel cells

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