International Journal of Innovative Research in Advanced Engineering (IJIRAE) ISSN: 2349-2163
Issue 09, Volume 4 (September 2017) www.ijirae.com

NANOTECHNOLOGY'S POTENTIAL AND PROMISE: BETTER TECHNIQUES FOR POLLUTION CONTROL

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Manuscript History
Number: **IJIRAE/RS/Vol.04/Issue09/SPAE10084**
Received: 20, August 2017
Final Correction: 30, August 2017
Final Accepted: 05, September 2017
Published: **September 2017**
Editor: Dr.A.Arul L.S, Chief Editor, IJIRAE, AM Publications, India

Abstract-- The basic concept of pollution control on a molecular level is separating specific elements and molecules from a mixture of atoms and molecules. The current method for separating atoms is thermal partitioning which uses heat to force phase changes. However, the preparation of reagents and the procedure itself are costly and inefficient. Current methods of energy extraction utilize combustion to create heat energy, most of which is wasted and results in unwanted byproducts that require purification and proper disposal. Theoretically, these high costs could be solved with the Nano structuring of highly specific catalysts that will be much more efficient. Unfortunately, we have yet to find an optimal way of obtaining the particles in workable form. Current means are essentially "shake and bake" methods called wet-chemical synthesis, which allows for very limited control on the final product and may still result in unwanted byproducts. Although there are still many obstacles to overcome, the world is starting to recognize the potential in nanotechnology. The high surface area characteristic of Nano-sized particles makes such technology particularly efficient for applications with space constraints. Early tests have shown that this process will require only a small percentage of the energy used by current technology.

I. INTRODUCTION

During the last twenty years, scientists have been looking towards nanotechnology for the answer to problems in medicine, computer science, ecology and even sports. In particular, new and better techniques for pollution control are emerging as nanoparticles push the limits and capabilities of technology. Nanoparticles defined as particles 1-100 nanometers in length (one nanometer being the equivalent of one billionth of a meter) hold enormous potential for the future of science. Their small size opens up possibilities for targeting very specific points, such as diseased cells in a body without affecting healthy cells. In addition, elemental properties can change rather dramatically at the nanometer range: some become better at conducting heat or reflecting light, some change color, some get stronger, and some change or develop magnetic properties (1). Certain plastics at the nanometer range have the strength of steel. Tennis racquet manufactures already utilize Nano-silicon dioxide crystals to improve equipment performance. The super-strength and other special properties emerge because micro scale flaws between molecules are absent at the Nano scale (1). Nanoparticles without these flaws allow materials to reach the maximum strength of their chemical bonds. These special properties and the large surface area of nano-particles prove valuable for engineering effective energy management and pollution control techniques. For example, if super-strength plastics could replace metal in cars, trucks, planes, and other heavy machinery. There would be enormous energy savings and consequent reduction in pollution. Batteries are also being improved using Nano scale materials that allow them to deliver more power faster.

Nano-materials that absorb enough light for conversion into electrical energy have also been used to recharge batteries. Other environmentally-friendly technologies include energy efficient non-thermal white LED's and Solar Stucco, a self-cleaning coating that decomposes organic pollutants using photo catalysts. Pollution results from resource production and consumption, which in their current state are very wasteful. Most waste cannot be reintegrated into the environment effectively or cheaply. Thus processes like petroleum and coal extraction, transportation, and consumption continue to result in photochemical smog, acid-mine drainage, oil slicks, acid rain, and fly ash. In his paper for the Foresight Institute, Stephen Gillett identifies the "Promethean Paradigm": the inefficient dependence on heat for energy since burning fuel discards much of its free energy during the conversion of chemical energy into heat and then to mechanical energy. Biological systems, on the other hand, efficiently oxidize fuel through molecular-scale mechanisms without extracting the chemical energy through thermalization (1). Overcoming the Promethean Paradigm requires controlling reactions at the Nano scale. Thus, nanofabrication holds much potential for effective pollution control, but it currently faces many problems that prevent it from mass commercialization — particularly its high cost. The basic concept of pollution control on a molecular level is separating specific elements and molecules from a mixture of atoms and molecules (1).

The current method for separating atoms is thermal partitioning, which uses heat to force phase changes. However, the preparation of reagents and the procedure itself are costly and inefficient. Current methods of energy extraction utilize combustion to create heat energy, most of which is wasted and results in unwanted byproducts that require purification and proper disposal. Theoretically, these high costs could be solved with the Nano structuring of highly specific catalysts that will be much more efficient (2). Unfortunately, we have yet to find an optimal way of obtaining the particles in workable form. Current means are essentially "shake and bake" methods called wet-chemical synthesis, which allows for very limited control on the final product and may still result in unwanted byproducts (1). Although there are still many obstacles to overcome, the world is starting to recognize the potential in nanotechnology. In 2007, the Brian Mercer Award for Innovation from the Royal Society was awarded to researchers at the University of Bath for their work in developing nano-porous fibers that trap and remove carbon dioxide along with other pollutants and recycle them back into the production process. These fibers can recycle many forms of gases depending on their composition and the way they are spun (3). The high surface area characteristic of nano-sized particles makes such technology particularly efficient for applications with space constraints. Early tests have shown that this process will require only a small percentage of the energy used by current technology. The hope is to eventually utilize it for pollution control by removing benzene from petrol vapor.

II. AIR POLLUTION

Air pollution can be remediated using nanotechnology in several ways. One is through the use of Nano-catalysts with increased surface area for gaseous reactions. Catalysts work by speeding up chemical reactions that transform harmful vapors from cars and industrial plants into harmless gases. Catalysts currently in use include a Nano fiber catalyst made of manganese oxide that removes volatile organic compounds from industrial smokestacks (4). Other methods are still in development. Another approach uses nanostructured membranes that have pores small enough to separate methane or carbon dioxide from exhaust (5). CNT can trap gases up to a hundred times faster than other methods, allowing integration into large-scale industrial plants and power stations. This new technology both processes and separates large volumes of gas effectively, unlike conventional membranes that can only do one or the other effectively. The substances filtered out still presented a problem for disposal, as removing waste from the air only to return it to the ground leaves no net benefits. In 2006, Japanese researchers found a way to collect the soot filtered out of diesel fuel emissions and recycle it into manufacturing material for CNT (6). The diesel soot is used to synthesize the single-walled CNT filter through laser vaporization so that essentially, the filtered waste becomes the filter.

III. WATER POLLUTION

As with air pollution, harmful pollutants in water can be converted into harmless chemicals through chemical reactions. Trichloroethene, a dangerous pollutant commonly found in industrial wastewater, can be catalyzed and treated by nanoparticles. Studies have shown that these "materials should be highly suitable as hydrodehalogenation and reduction catalysts for the remediation of various organic and inorganic groundwater contaminants" (7). Nanotechnology eases the water cleansing process because inserting nanoparticles into underground water sources is cheaper and more efficient than pumping water for treatment (8). The deionization method of using Nano-sized fibers as electrodes are not only cheaper, but also more energy efficient (8). Traditional water filtering systems use semi-permeable membranes for electro dialysis or reverse osmosis. Decreasing the pore size of the membrane to the nanometer range would increase the selectivity of the molecules allowed to pass through. Membranes that can even filter out viruses are now available (9).

Also widely used in separation, purification, and decontamination processes are ion exchange resins, which are organic polymer substrate with nano-sized pores on the surface where ions are trapped and exchanged for other ions (10). Ion exchange resins are mostly used for water softening and water purification. In water, poisonous elements like heavy metals are replaced by Sodium or Potassium. However ion exchange resins are easily damaged or contaminated by iron, organic matter, bacteria, and chlorine.

IV. CLEANING UP OIL SPILLS

According to the U.S. Environmental Protection Agency (EPA), about 14,000 oil spills are reported each year (11). Dispersing agents, gelling agents and biological agents are most commonly used for cleaning up oil spills. However, none of these methods can recover the oil lost. Recent developments of nano-wires made of Potassium Manganese Oxide can clean up oil and other organic pollutants (12). These nanowires form a mesh that absorbs up to twenty times its weight in hydrophobic liquids while rejecting water with its water repelling coating. Since the potassium manganese oxide is very stable even at high temperatures, the oil can be boiled off the nanowires and both the oil and the nanowires can then be reused (12). In 2005, Hurricane Katrina damaged or destroyed more than thirty oil platforms and nine refineries (13). The Interface Science Corporation successfully launched a new oil remediation and recovery application, which used the water repelling nanowires to clean up the oil spilled by the damaged oil platforms and refineries (14).

V.CONCERNS

In 2009, NanoImpactNet, the European Network on Health and Environmental Nanomaterials organized its first conference to study the impact of nanomaterials on health and environment. The small size of nanoparticles warrants investigation of the consequences of inhalation and absorption of these particles and their effects inside the body as they are small enough to penetrate the skin and diffuse through cell membranes. The special properties of nanoparticles inside the body are unclear and unpredictable. Also, many are worried about the effects of nanoparticles on the environment. New branches of science such as eco-nanotoxicology have arisen to study the movement of nanomaterials through the biosphere. We do not yet know how much will be absorbed by the soil, air, or water, and how severely the widespread presence of nanoparticles in the environment will impact the ecosystem. To address these concerns, Nano Impact Net aims to set up regulations and legislation to ensure that nanoparticles with so much potential for cleaning up pollution, will not become a new form of pollution themselves.

VI. CONCLUSION

Nanotechnology's potential and promise have steadily been growing throughout the years. The world is quickly accepting and adapting to this new addition to the scientific toolbox. Although there are many obstacles to overcome in implementing this technology for common usage, science is constantly refining, developing, and making breakthroughs.

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