4af Reaction Engineering, Process Design, and Catalyst and Material Development Research on the Utilization of Biorenewable Resources for Bioenergy and Bioproducts

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The rise of modernization and industrialization in multitude parts of the world, which results in the increasing both demands and productions of energy and chemical derived products, has resulted in the increase use of fossil gas and oil and in the production of wastes which are potentially hazardous to the environment. From 1991 to 1999 the world oil demand rose annually about 1 million barrels a day. In 2004, demand jumped 2.7 million barrels a day. It is predicted that the fossil oil and gas world's supply production will reach its peak within this decade and it is likely that their prices will remain high. The increase emission of pollutants is another important issue. An example is the emission of CO2 which is known as a greenhouse gas. In 1990's, carbon in the form of CO2, accumulated at rates ranging from 1.9 to 6.0 x 109 metric tons C per year and increasing CO2 levels by 0.9 to 2.8 ppm/year. These situations have made it crucial for many countries, especially the developed countries, such as the United States, to find ways to use resources other than fossil fuels and to reduce emissions of harmful pollutants while, at the same time, meeting the world's perennially increasing needs for energy and chemical derived products. Biomass, which for decades has been seen as the best raw materials to replace fossil fuels, will become more attractive as a resource to produce chemicals and energy. It is estimated that the total amount of biomass available economically in the United States is over 510 million dry tons per year. This is a vast renewable resource that when utilized efficiently and optimally can significantly reduce our present reliant on fossil fuels. My interest is to use my skills and knowledge in reaction engineering, process design, and catalyst and material developments to conduct research in utilizing biomass resources for bioenergy and biobased products in environmentally friendly manners conforming to the green chemistry principles. An example of research work that I would like to work on is the development of a system for maintaining soil fertility that employs biomass, such as cornstover or woods, for production of carbon-supported nitrogen fertilizers, such as ammonium bicarbonate. When injected to the soil, the fertilizer-loaded carbon serves three purposes: nitrogen fertilizer, biologically-active soil amendment, and a means for sequestering carbon from the atmosphere. Multiple research activities incorporating reaction engineering, chemical process design, and catalyst and material development would be required to develop the system. The system requires advances in understanding of thermoconversion processes, such as pyrolysis, steam reforming of bio-oil from pyrolysis, and synthesis of nitrogen-rich carbon. Fast pyrolysis is the rapid thermal decomposition of organic compounds in the absence of oxygen to produce liquids, gases, and char. The product distribution depends on the biomass composition, particle size, and rate and duration of heating. Controlling product distribution to meet the desired composition requirement requires intensive research in reaction engineering and reactor design. With the density 8-10 times of the original biomass, bio-oil offers an intriguing opportunity to densify biomass for transport to a central processing facility. Pretreatment of bio-oil to increase its suitability for steam reformer feedstock might be needed. Treatments include separating lignin from bio-oil and catalytic upgrading to increase bio-oil stability. Lignin by-product has several potential applications for producing chemicals which provide more research opportunities. Bio-oil is steam-reformed to hydrogen. A catalyst development research is required for obtaining a high performing catalyst suitable for reforming bio-oil. Furthermore, since the reforming process produces CO2 as by-product, a method to separate CO2 efficiently and economically is needed. A combined catalyst and CO2 sorbent material is a promising method to remove CO2 from gas product to produce high purity hydrogen with very low concentrations of CO and CO2. The material serves two functions by catalyzing the reaction of hydrocarbons with steam to produce hydrogen while simultaneously absorbing carbon dioxide formed by the reaction. The in situ removal of CO2 shifted the reaction equilibrium towards increased H2 concentration and production. Research in developing a sorbent material with high absorption capacity and high stability to undergo multiple absorption/regeneration cycles will be required. Some of hydrogen is converted to anhydrous ammonia which is then reacted with carbon dioxide, water, and char, which are byproducts of pyrolysis of biomass, to yield ammonium bicarbonate (NH4HCO3) precipitated within the pores of the char. Optimizing NH4HCO3 loading on the char will be an interest of study. The study will also involve characterization of the char's surface properties and how the properties affect the behavior of the rate of fertilizer release from the char.