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Gasification of Biomass and Waste

Gasification presents a promising technology for converting solids, such as biomass or waste, into useful fuels. Gasification involves heating the solid in the presence of another gas such as air, N_2, CO_2, or H_2O. Unlike combustion, gasification involves only partial oxidation of the fuel, since reactants are introduced in sub-stoichiometric amounts. The primary product is synthesis gas, which is composed of CO and H_2 (and by-products such as CO_2 and small hydrocarbons). Synthesis gas can be used to make other fuels such as gasoline, methane, or diesel fuel via Fischer-Tropsch synthesis. One of the current issues with biomass gasification is that two primary by-products are produced: ash and tar. Ash is a solid residue composed of minerals and metals from the raw material that did not enter the gas phase. Tar is a mixture of heavy hydrocarbons that must be removed as they can cause problems for downstream equipment. Ash is a high surface area material that contains both carbon and minerals and metals which are often used as catalysts. Therefore, ash has the potential to be a catalyst for decomposition of the tars which are produced from biomass gasification. It has been shown that the properties of ash may vary based on the gasification process by which it is created (temperature, reactive gas, heating rate). This work investigates the potential to use ash to catalyze decomposition of tar.

Results to date

Ash was generated in a fluidized bed reactor under different conditions and its properties were analyzed. It is important for catalysts to have high surface area. The surface area of the ash was found to be highly dependent on the gasification atmosphere, as well as the time and temperature of gasification, as shown in Figure 1. This shows that increasing gasification temperature or gasification time leads to higher surface area. The physical properties of the ash were also analyzed using an Environmental Scanning Electron Microscope (ESEM).

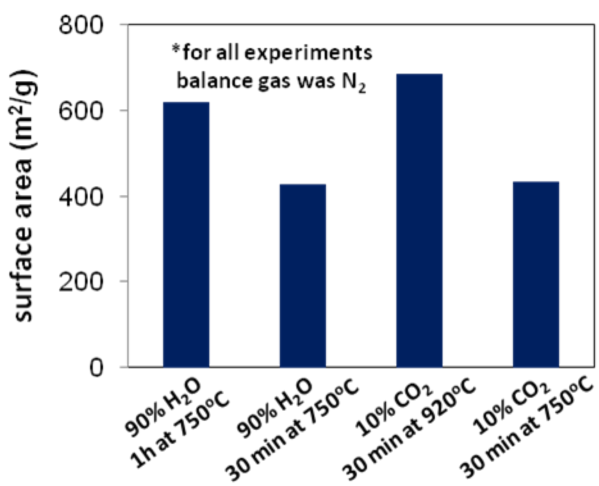

Figure 1 BET analysis of ash from gasification of poplar wood

Gasification was performed in the microscope by heating the sample to 1000^{o}C under different gasification atmospheres (CO_2, H_2O, and air) and the sample was observed throughout gasification. Images of the samples at 1000°C are shown in Figure 2. Sintering is observed for gasification under steam (Figure 2A) and air (Figure 2B) but not with CO_2 (Figure 2C). This is important if the ash is to be used as a catalyst since sintering should be avoided in order to maintain a high surface area catalyst. The catalytic activity of the ash was tested in a thermo-gravimetric analyzer (TGA). It was of interest to see if the ash could catalyze decomposition of different hydrocarbons, since ultimately it will be used to decompose aromatics which are the primary component of tar. Methane and propane were introduced into the TGA and the temperature was increased and mass gain was measured. Mass gain is representative of reaction taking place where the hydrocarbon decomposes into solid carbon on the catalyst surface and H_2 or other light gases. Figure 3 shows the mass gain of an ash sample when heated under N_2, CH_4, and C_3H_8. With nitrogen, there is a slight mass loss, reflecting the decomposition of the ash as it is heated. Under methane mass gain at high temperatures indicates carbon deposition on the surface. Propane, being a more reactive hydrocarbon than methane, shows higher mass gain at higher temperatures. This indicates that the ash has the ability to catalyze decomposition of hydrocarbons, and may be a good candidate for decomposition of tars from gasification of biomass.

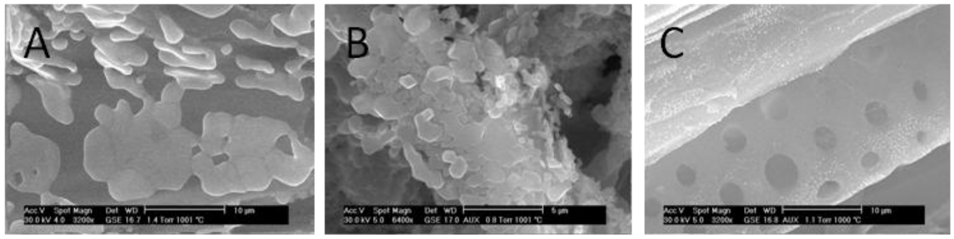

Figure 2 ESEM image at 1000°C during gasification of poplar with A. H_2O B. air C. CO_2

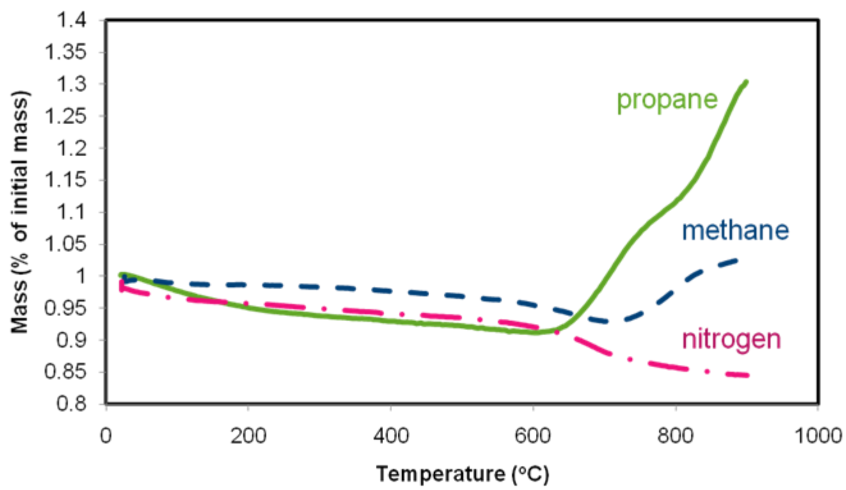

Figure 3 Catalytic decomposition of different gases using ash. Mass gain reflects carbon deposition on ash surface.

Current and future work

Currently, we are working on developing an understanding of how the properties of the ash impact its catalytic activities. We are also doing more detailed characterization to better understand how the gasification process impacts the properties of the ash. In future work, we will test the catalytic activity of the ash with tar surrogates and attempt to relate the properties of the ash to its catalytic activity in order to design a process with highly active ash.