Popular Science Summary: Production of biofuel – processing of paper mill by-products to fuel components

A new process is being developed to produce fuel from the paper mill by-product black liquor. In this Thesis, a new heat treatment method was investigated to degrade large molecules in the black liquor to smaller ones, using microwaves.

The production of fuel is the largest use of fossil petroleum. Therefore, finding sustainable alternatives is an important step to reduce the emissions of greenhouse gases that are causing climate change. One such alternative is to use biomass, for example waste products from the agriculture and the forest industry. In Sweden, the forest industry is an important part of the national economy. The pulp and paper mills produce excessive amounts of a by-product called *black liquor*, which today is used to produce steam for energy production in the mills. However, the black liquor has a high content of the macromolecule lignin, which has the potential to be used for more refined and valuable products. Lignin is one of the main components of wood, providing the wood with its firm structure. The lignin molecules consist of various rings of carbon atoms linked together in complex irregular networks. Breaking down these networks into smaller fragments, the resulting components are similar to molecules found in petrol.

An idea is to use black liquor to produce biofuel similar to gasoline or diesel. SunCarbon is developing a process that can be integrated with pulp mills with the intention to extract the lignin from the black liquor and recycle the other chemicals to the mill. The lignin is separated from the black liquor by a series of processes starting with membrane filtration, after which follows a heat treatment that breaks down lignin and other large molecules into smaller components. It is especially important to degrade hemicellulose, which is another molecule found in wood. Otherwise, the hemicellulose may cause problems downstream in the process. After the heat treatment, carbon dioxide is added, which acidifies the liquor and makes the lignin precipitate. The precipitated lignin can then be separated from the remaining liquid. The lignin is further purified in several steps before it is mixed with an oil that dissolves the lignin. What kind of oil will be used is still a topic of investigation; it could be a fossil or a biobased oil. The formed suspension is then further processed in a petroleum refinery to fuel.

During the process development, some problems have been encountered in the heat treatment. The high temperature causes corrosion of the steel reactor in which the heating of the liquor takes place. The corrosion causes leaching of metals, such as molybdenum, that are difficult to remove in the purification step and that pollute the product oil. To tackle this problem, an idea is to do the heating using microwaves. Microwaves heat up the liquid directly, compared to traditional heating, which requires the reactor vessel to heat up first and then transfer the heat to the liquid. There are two important benefits with the direct heating of microwaves. Firstly, it can enable lower working temperature of the reactor vessel, allowing for the use of Teflon coating in the reactor to avoid leaching of metals to the liquor. Secondly, the heating can be faster since there is no need to heat up a heating medium.

In this Master Thesis, microwave heating was tested and compared to standard heating in an autoclave. The results indicate that microwaves degrade lignin and hemicellulose to the same degree as autoclave heating does. The hemicellulose was not degraded as much as expected, neither with microwaves nor traditional heating. This could be due to a shorter heating time. The microwave oven could not be operated at temperatures above 180°C for a long time, since the high pressure caused leakage. Conclusively, microwave heating appears to work equally

well as the autoclave heating, although a microwave equipment that can work at temperatures above 200°C is required for sufficient degradation of hemicellulose.