

Effects of Lignocellulosic Compounds on the Yield, Nanostructure and Reactivity of Soot from Fast Pyrolysis at High Temperatures

Anna Trubetskaya^{1*}, Markus Broström¹, Jens Kling², Avery Brown³, Geoffrey Tompsett³, Kentaro Umeki⁴

¹ *Thermochemical Energy Conversion Laboratory, Umeå University, 90187 Umeå, Sweden*

² *Center for Electron Nanoscopy, Technical University of Denmark, 2800 Kgs. Lyngby, Denmark*

³ *Chemical Engineering Department, Worcester Polytechnic Institute, 01609 Worcester, MA, USA*

⁴ *Division of Energy Science, Luleå University of Technology, 97187 Luleå, Sweden*

* *anna.trubetskaya@umu.se*

Abstract

Gasification offers the utilization of biomass to a wide variety of applications such as heat, electricity, chemicals and transport fuels in an efficient and sustainable manner. High soot yields in the high-temperature entrained flow gasification lead to intensive gas cleaning and can cause a possible plant shut down. The reduction of soot formation increases the overall production system efficiency and improves the economic feasibility and reliability of the gasification plant.

The aim of this work is to present the effect of lignocellulosic compounds on the yield, nanostructure and reactivity of soot. Soot was produced from holocelluloses, extractives, two types of organosolv lignin (softwood and wheat straw), and lignin-derived compounds (syringol, guaiacol, p-hydroxyphenol) at temperature of 1250°C and residence time of 0.17 s and 0.35 s in a drop tube furnace. Soxhlet extraction was performed on soot samples from pyrolysis of both lignin samples using acetone and methanol as a solvent. The structure of solid residues was characterized by transmission electron microscopy and Raman spectroscopy. The reactivity of soot in O₂ oxidation and CO₂ gasification was investigated by thermogravimetric analysis.

The present results indicated that soot yields from pyrolysis of lignin from softwood and extractives at 1250°C with the residence time of 0.17 s were similar as shown in Figure 1. The highest soot yield was obtained from pyrolysis of wheat straw lignin and quantitatively comparable with the soot yield of hydroquinone. The presence of hydroxyl groups compared to other lignin-derived compounds representing S- and G-lignin types might enhance the soot formation. Lower soot yields were obtained from pyrolysis of cellulose and hemicellulose due to the lower presence of inherent aromatic rings [1-3]. Moreover, the soot yields from pyrolysis of potassium impregnated lignin at 1250°C with the residence time of 0.35 s were significantly lower than that of non-treated lignin samples indicating the catalytic influence of potassium inhibiting growth of polycyclic aromatic hydrocarbons, confirming the previous results of Umeki et al. [4].

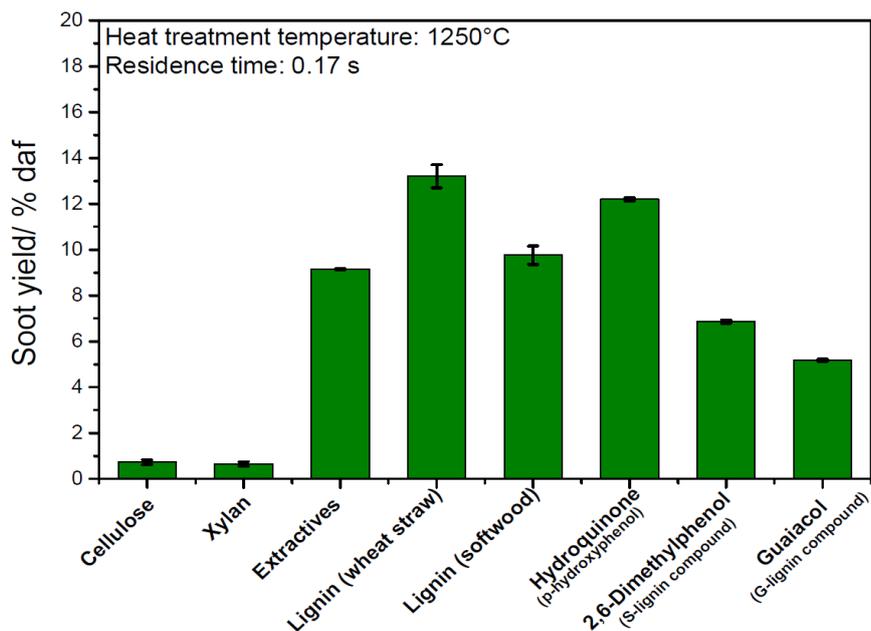


Figure 1. Soot yields (% daf) from pyrolysis at 1250°C with the residence time of 0.17 s in a drop tube reactor.

Results showed that soot from extractives, lignin and lignin-derived compounds was less reactive than soot generated from holocelluloses. The fact that both lignin types were less reactive than holocelluloses despite higher alkali content (i.e. Na^+) in original lignin indicated that this parameter is of minor importance. No differences in soot reactivity were observed with the increasing residence time in a drop tube reactor. Raman spectroscopy results demonstrated that differences in the carbon structure affect the reactivity of soot. The maximum reaction rate of soot samples from both lignin types was shifted to higher temperatures compared to holocelluloses soot, indicating a lower reactivity due to the more graphitic structure, less defects in graphene sheets and encapsulated larger polyaromatic clusters. TEM analysis showed that soot particles from lignin-derived compounds were well-ordered graphitic structures with the curved graphene layers. Low separation distances (close to that of graphite) and high periodicity led to lower oxidation reactivity of soot, while the more bent graphene layers might enhance the reactivity [5]. The particle size of lignin and extractives soot was larger than that of holocelluloses soot, and contained mainly multi-core structures.

Lignin and extractives are major compounds in biomass which enhance soot formation at high heating rates and high temperatures. The thermogravimetric analysis results showed that the soot reactivity towards O_2 and CO_2 depends mainly on the difference in carbon chemistry based on initial molecular structure, and less based on the residence time or the effect of alkali metals.

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