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(54) **MULTI-FUNCTIONAL CATALYST COMPOSITION FOR THE CONVERSION OF BIOMASS**

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(57) **ABSTRACT**

A process is disclosed for the conversion of cellulosic biomass, in particular ligno-cellulosic biomass. The process comprises heating the biomass to a conversion temperature in the range of from 200 to 500° C. in the presence of a catalyst system. The catalyst system comprises a basic functionality comprising an alkali metal component and a multivalent metal component. The catalyst system optionally further comprises an acidic component.

MULTI-FUNCTIONAL CATALYST COMPOSITION FOR THE CONVERSION OF BIOMASS

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The invention relates generally to a multi-functional catalyst system for the conversion of biomass, and more particularly to such a system for the catalytic pyrolysis of cellulosic biomass.

[0003] 2. Description of the Related Art

[0004] Cellulosic biomass, in particular ligno-cellulosic biomass, is an abundantly available source of energy. Many attempts have been described to convert cellulosic biomass to liquid fuel. In general, the conversion of cellulose to liquid fuel comprises depolymerization of the cellulose; cracking of the depolymerization reaction products; and the oxygenation of the cracked products. Most sources of cellulose also contain a significant amount of lignin, aquatic biomass such as algae being a notable exception. The presence of lignin in the biomass further complicates the reaction scheme to liquid fuels because lignin is chemically very different from cellulose and behaves very differently in the conversion reactions.

[0005] European patent application EP 0 366 138 A2 proposes a process for manufacturing fuel from ligno-cellulose material. The document describes a three step process. In the first step, called the digestion step, lignin is reacted with SO_2. In the second step the reacted lignin is dissolved in an alkaline solution. The remaining cellulose is subjected to a cracking reaction at high temperature in the presence of a molecular sieve catalyst.

[0006] U.S. published patent application 2003/0115792 A1 discloses a process for converting lignin into high octane blending components. The document describes a two-step process. In the first step, lignin is subjected to base catalyzed depolymerization. The catalyst is a dilute solution of sodium hydroxide, or a solid super base for example CsX-type zeolite, or a mixture of the two. In the second step, the depolymerized lignin is subjected to a hydro-processing step comprising simultaneous exhaustive hydro-de-oxygenation and mild hydro-cracking. The catalyst used in the second step is a traditional hydro-treatment catalyst.

[0007] Demirbas, A, "Partly chemical analysis of liquid fraction of flash pyrolysis products from biomass in the presence of sodium carbonate", Energy Conversion and Management 43 (2002) 1801-1809, describes experiments done on various types of biomass material. The addition of sodium carbonate as catalyst increases the yield of methanol.

[0008] The described processes tackle the complexity of the reaction feed either by proposing a multi-step process, or by focusing on a single aspect of the conversion.

[0009] Thus, there is a particular need for a catalyst system that can be used in a single step process for conversion of biomass to liquid fuel.

BRIEF SUMMARY OF THE INVENTION

[0010] The present invention addresses these problems by providing a process for the catalytic pyrolysis of cellulosic biomass, said process comprising heating the cellulosic biomass to a conversion temperature in the range of from 200° C. to 500° C. in the presence of a catalyst system, characterized in that the catalyst system comprises a basic functionality, said basic functionality comprising an alkali metal component and a multivalent metal component.

[0011] The catalyst system may further comprise an acidic component, in particular a solid acid.

DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

[0012] The following is a description of certain embodiments of the invention, given by way of example only.

[0013] It is desirable to provide a conversion process for biomass in which both cellulose and lignin are converted in the same reaction step. It is also desirable to provide a process for conversion of biomass in which the depolymerization and cracking of cellulose take place in the same reaction step.

[0014] It has now been found that these objectives can be achieved by providing a catalytic pyrolysis process in which a catalyst system is used comprising a basic functionality, said basic functionality comprising an alkali metal component and a multivalent metal component.

[0015] The multivalent component may comprise a divalent metal, a trivalent metal, or a combination of a divalent metal and a trivalent metal. Suitably, the multivalent metal component comprises a hydrotalcite, a hydrotalcite- like material, an anionic clay, a mixed metal oxide, or a mixture thereof

[0016] In a preferred embodiment the alkali metal component comprises an alkali metal carbonate. The alkali metal component and the multi-valence metal component may be present in separate catalyst particles, or they may be combined in a single catalyst particle. It is advantageous to carry out the catalytic pyrolysis in a fluid bed reactor. If a fluid bed reactor is used, the catalyst particles should have a shape and size to be readily fluidized. Preferred are catalyst particles in the form of microspheres having a particle size in the range of 100 μm to 3000 μm.

[0017] It is believed that the basic functionality of catalyst system primarily acts on the depolymerization reaction. It is desirable to also provide, within the catalyst system, a cracking functionality. Therefore, a preferred embodiment of the catalyst system further comprises an acidic component. Suitably, the acidic component comprises a solid acid. Examples of suitable acidic components include zeolites, silica-alumina, and combinations thereof. Particularly suitable zeolites include ZSM-zeolite, Y-zeolite, and mixtures thereof. Particularly preferred herein are catalyst systems comprising zeolite ZSM-5.

[0018] The conversion temperature in the process of invention is in the range of from 250° C. to 400° C., preferably from 300° C. to 380° C. Preferably, the cellulosic biomass is heated to the conversion temperature in a fluid bed reactor. Suitably, at least part of the catalyst system is used as a heat carrier in the fluid bed reactor.

[0019] As indicated above, the basic functionality of the catalyst system is believed to be active in the depolymerization of lignin and cellulose. This requires interaction of the catalyst system with solid biomass material. Although such interaction takes place in a fluid bed reactor, it is advantageous to contact the cellulosic biomass with at least one component of the catalyst system in a pretreatment step.

[0020] Such a pretreatment step can comprise impregnating the cellulosic biomass with a solution of a component of the catalyst system. For this embodiment of the process, it is desirable to use for the pretreatment a catalyst component that is soluble in water and aqueous solvents, so that an inexpensive solvent system can be used in the pretreatment step. Suitable examples of such soluble catalyst components include sodium carbonate and potassium carbonate.

[0021] In an alternate embodiment of the process, pretreatment is carried out with a solid catalyst component by mechanically treating the cellulosic biomass in the presence of the catalyst component in particulate form. The mechanical treatment can comprise milling, grinding, kneading, or a combination thereof.

[0022] The cellulosic biomass for use in the present process can be of aquatic origin, for example algae. Aquatic plants are far more efficient at converting solar energy to biomass than are land-based plants. For this reason, aquatic plants are a highly attractive energy crop.

[0023] In alternative embodiments, the cellulosic biomass is formed by land-based plants. Land-based plants virtually without exception form a combination of lignin and cellulose, commonly referred to as ligno-cellulosic biomass. Although food crops can be used for use in the process of the present invention, it is economically and ethically referred to use energy crop material, agricultural waste material, or forestry waste material. Examples of suitable energy crop materials include switch grass and fast-growing woods, such as willow and poplar.

[0024] Examples of agricultural waste material include straw, corn stover, bagasse, chaff, and the like. Examples of forestry waste material include tree bark, wood chips, and saw dust.

[0025] It will be understood that the catalyst system used in the process of the invention is suitably in the form of particles. As mentioned above, the catalyst particles may comprise all components of the catalyst system. Alternatively, different components of the catalyst system may be present in different particles.

What is claimed is:

1. A process for the catalytic pyrolysis of cellulosic biomass, said process comprising heating the cellulosic biomass to a conversion temperature in the range of from 200° C. to 500° C. in the presence of a catalyst system, characterized in that the catalyst system comprises a basic functionality, said basic functionality comprising an alkali metal component and a multivalent metal component.

2. The process of claim **1** wherein the multivalent component comprises a divalent metal, a trivalent metal, or a combination of a divalent metal and a trivalent metal.

3. The process of claim **1** or claim **2** wherein the multivalent metal component comprises a hydrotalcite, a hydrotalcite-like material, an anionic clay, a mixed metal oxide, or a mixture thereof.

4. The process of any one of the preceding claims wherein the alkali metal component comprises an alkali metal carbonate.

5. The process of any one of the preceding claims wherein the alkali metal component and the multivalent metal component are combined in a catalyst particle.

6. The process of any one of the preceding claims wherein the catalyst system further comprises an acidic component.

7. The process of claim **6** wherein the acidic component comprises a solid acid.

8. The process of claim **7** wherein the acidic component comprises a zeolite, a silica-alumina, or a combination thereof.

9. The process of claim **8** wherein the zeolite comprises a ZSM-zeolite, a Y-zeolite, or a mixture thereof.

10. The process of claim **9** wherein the zeolite comprises ZSM-5.

11. The process of any one of the preceding claims wherein the conversion temperature is in the range of from 250° C. to 400° C., preferably from 300° C. to 380° C.

12. The process of any one of the preceding claims wherein the cellulosic biomass is heated to the conversion temperature in a fluid bed reactor.

13. The process of claim **12** wherein at least part of the catalyst system acts as a heat carrier.

14. The process of any one of the preceding claims wherein the cellulosic biomass is contacted with at least one component of the catalyst system in a pretreatment step.

15. The process of claim **14** wherein the pretreatment step comprises impregnating the cellulosic biomass with a solution of a component of the catalyst system.

16. The process of claim **14** or **15** wherein the pretreatment comprises mechanically treating the cellulosic biomass in the presence of a component of the catalyst system in particulate form.

17. The process of claim **16** wherein the mechanical treatment comprises milling, grinding, kneading, or a combination thereof.

18. The process of any one of the preceding claims wherein the cellulosic biomass is of aquatic origin.

19. The process of any one of claims **1**-**17** wherein the cellulosic biomass comprises a ligno-cellulosic biomass.

20. The process of claim **19** wherein the lignocellulosic biomass is an energy crop material, an agricultural waste material, or a forestry waste material.

21. The process of any one of the preceding claim wherein the catalyst system comprises catalyst particles, said catalyst particles comprising all components of the catalyst system.

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