However, the process begins with ethylene formation followed by trimerization to hexenes and finally oligomerization to jet and diesel fractions.

[0009] Accordingly, there remains a needs for improved, efficient, and cost effective catalytic processes resulting in the direct conversion of bio-based alcohols to olefinic mixtures.

SUMMARY

[0010] Examples of the current subject matter relate *inter alia* to systems and processes for converting one or more C_1-C_5 linear or branched alcohols to one or more C_2-C_5 olefins.

[0010a] In an aspect, there is provided a process for converting one or more C_1-C_5 linear or branched alcohols to one or more C_2-C_5 olefins, the process comprising:

contacting an input stream comprising the one or more C_1-C_5 linear or branched alcohols with a catalyst in a reactor to form an output stream comprising the one or more C_2-C_5 olefins, the catalyst consisting essentially of zeolite doped with boron and phosphor;

wherein the reactor is at a temperature from about 300 °C to about 600 °C, a gauge pressure from 0 to about 30 bar, and a weight hourly space velocity (WHSV) from about 0.25 to about 10.

[0010b] In another aspect, there is provided a process for converting one or more C_1-C_5 linear or branched alcohols to one or more C_2-C_5 olefins, the process comprising:

contacting an input stream comprising the one or more C_1-C_5 linear or branched alcohols with a single catalyst in a reactor to form an output stream comprising the one or more C_2-C_5 olefins, the single catalyst comprising zeolite doped with boron and phosphor;

wherein the reactor is at a temperature from about 350 °C to about 750 °C, a gauge pressure from 0 to about 30 bar, and a weight hourly space velocity (WHSV) from about 0.25 to about 5.

[0010c] In another aspect, there is provided a process for converting one or more C_1-C_5 linear or branched alcohols to one or more C_2-C_5 olefins, the process comprising:

contacting an input stream comprising the one or more C_1-C_5 linear or branched alcohols with a catalyst in a reactor to form an output stream comprising the one or

more C_2-C_5 olefins, the catalyst consisting essentially of a ZSM-5 zeolite doped with boron and phosphor;

wherein the reactor is at a temperature from about 350 °C to about 475 °C, a gauge pressure from 0 to about 5 bar, and a weight hourly space velocity (WHSV) from about 0.25 to about 10;

wherein boron is present in the catalyst in an amount from about 0.05 wt. % to about 5 wt. %, and wherein phosphor is present in the catalyst in an amount from about 0.2 wt. % to about 7 wt. %.

[0011] In one example, process for converting one or more C1-C5 linear or branched alcohols to one or more C2-C5 olefins includes contacting an input stream comprising the one or more C1-C5 linear or branched alcohols with at least a first catalyst and a second catalyst in a single bed reactor to form an output stream. The output stream including the one or more C2-C5 olefins. The single bed reactor being at a temperature from about 350 °C to about 750 °C, a gauge pressure from 0 to about 30 bar, and a weight hourly space velocity (WHSV) from about 0.5 to about 5.0. The first catalyst being a doped or undoped alumina catalyst including, in neutral or ionic form, one or more of zirconium (Zr), titanium (Ti), tungsten (W), or silicon (Si), to form a first mixture, and the second catalyst being a doped or undoped zeolite catalyst.

[0012] In some examples, the single bed reactor can be a fixed bed reactor. In other examples, the single bed reactor can be a fluidized bed reactor.

[0013] In some examples, contacting the input stream can further include contacting the input stream with a third catalyst in the single bed reactor. The third catalyst can include a doped or undoped SiO_2 catalyst.

[0014] In some examples, the C_1-C_5 linear or branched alcohols can be bio-based and produced by fermentative processes. In some examples, the C_1-C_5 linear or branched alcohols can be not derived from petroleum.

[0015] In some examples, the one or more C_2-C_5 olefins can be present in the output stream in an amount that can be at least 80 wt. %, at least 85 wt. %, at least 90 wt. %, or at least 95 wt. %.

[0016] In some examples, the output stream can include one or more aromatic (C_{7+}) compounds in an amount from about 2 wt. % to about 10 wt. %. In some examples, the output stream can include one or more aromatic (C_{7+}) compounds in an amount that does not exceed 10 wt. %.

[0017] In some examples, the process can include removing at least a portion of C_2 olefins from the output stream. In some examples, the process can include removing at least a portion of C_4 olefins from the output stream. In some examples, the process can include removing at least a portion of C_5 olefins from the output stream.

[0018] In some examples, the temperature can be from about 550 °C to about 750 °C. In some examples, the temperature can be from about 350 °C to about 550 °C.

[0019] In some examples, the WHSV can be from about 0.5 to about 1.0. In some examples, the WHSV can be from about 2.0 to about 5.0.

[0020] In another example, a process for converting methanol to one or more C2-C5 olefins includes contacting an input stream comprising the methanol with at least a first catalyst and a second catalyst in a single bed reactor to form an output stream. The output stream including the one or more C2-C5 olefins. The single bed reactor being at a temperature from about 350 °C to about 750 °C, a gauge pressure from 0 to about 30 bar, and a weight hourly space velocity (WHSV) from about 0.5 to about 5.0. The first catalyst being a doped or undoped alumina catalyst including, in neutral or ionic form, one or more of zirconium (Zr), titanium (Ti), tungsten (W), or silicon (Si), and the second catalyst being a doped or undoped zeolite catalyst.

[0021] In some examples, the single bed reactor can be a fixed bed reactor. In other examples, the single bed reactor can be a fluidized bed reactor.

[0022] In some examples, contacting the input stream can further include contacting the input stream with a third catalyst in the single bed reactor. The third catalyst can include a doped or undoped SiO_2 catalyst.

[0023] In some examples, the C_1-C_5 linear or branched alcohols can be bio-based and produced by fermentative processes. In some examples, the C_1-C_5 linear or branched alcohols can be not derived from petroleum.

[0024] In some examples, the one or more C_2-C_5 olefins can be present in the output stream in an amount that can be at least 80 wt. %, at least 85 wt. %, at least 90 wt. %, or at least 95 wt. %.

[0025] In some examples, the output stream can include one or more aromatic (C_{7+}) compounds in an amount from about 2 wt. % to about 10 wt. %. In some examples, the output stream can include one or more aromatic (C_{7+}) compounds in an amount that does not exceed 10 wt. %.

[0026] In some examples, the process can include removing at least a portion of C_2 olefins from the output stream. In some examples, the process can include removing at least a portion of C_4 olefins from the output stream. In some examples, the process can include removing at least a portion of C_5 olefins from the output stream.

[0027] In some examples, the temperature can be from about 550 °C to about 750 °C. In some examples, the temperature can be from about 350 °C to about 550 °C.

[0028] In some examples, the WHSV can be from about 0.5 to about 1.0. In some examples, the WHSV can be from about 2.0 to about 5.0.

[0029] In another example, a process for converting one or more C_1-C_5 linear or branched alcohols to one or more C_2-C_5 olefins includes contacting an input stream that includes the one or more C_1-C_5 linear or branched alcohols with a first catalyst in a stacked bed reactor at a temperature from about 350 °C to about 550 °C, a gauge pressure from 0 to about 30 bar, and a weight hourly space velocity (WHSV) from about 1.0 to about 2.0 to form a first mixture. The first catalyst being a doped or undoped alumina catalyst including, in neutral or ionic form, one or more of zirconium (Zr), titanium (Ti), tungsten (W), or silicon (Si). The process further including contacting the first mixture with at least a second catalyst in the stacked bed reactor to form an output stream that includes the one or more C_2-C_5 olefins, in which the second catalyst is a doped or undoped zeolite catalyst.

[0030] In some examples, the stacked bed reactor can be a fixed bed reactor. In other examples, the stacked bed reactor can be a fluidized bed reactor.

[0031] In some examples, contacting the first mixture can further include contacting the first mixture with a third catalyst in the stacked bed reactor. The third catalyst can include a doped or undoped SiO_2 catalyst.

[0032] In some examples, the C_1-C_5 linear or branched alcohols can be bio-based and produced by fermentative processes. In some examples, the C_1-C_5 linear or branched alcohols can be not derived from petroleum.

[0033] In some examples, the one or more C_2-C_5 olefins can be present in the output stream in an amount that can be at least 80 wt. %, at least 85 wt. %, at least 90 wt. %, or at least 95 wt. %.

[0034] In some examples, the output stream can include one or more aromatic (C_{7+}) compounds in an amount from about 2 wt. % to about 10 wt. %. In some examples, the output stream can include one or more aromatic (C_{7+}) compounds in an amount that does not exceed 10 wt. %.

[0035] In some examples, the process can include removing at least a portion of C_2 olefins from the output stream. In some examples, the process can include removing at least a portion of C_4 olefins from the output stream. In some examples, the process can include removing at least a portion of C_5 olefins from the output stream.

[0036] In some examples, the temperature can be from about 550 °C to about 750 °C. In some examples, the temperature can be from about 350 °C to about 550 °C.

[0037] In some examples, the WHSV can be from about 0.5 to about 1.0. In some examples, the WHSV can be from about 2.0 to about 5.0.

[0038] In another example, a process for converting methanol to one or more C_2-C_5 olefins includes contacting an input stream that includes the methanol with a first catalyst in a stacked bed reactor at a temperature from about 350 °C to about 550 °C, a gauge pressure from 0 to about 30 bar, and a weight hourly space velocity (WHSV) from about 1.0 to about 2.0 to form a first mixture. The first catalyst comprises a doped or undoped alumina catalyst including, in neutral or ionic form, one or more of zirconium (Zr), titanium (Ti), tungsten (W), or silicon (Si). The process further including contacting the first mixture with at least a second catalyst in the stacked bed reactor to form an output stream that includes the

one or more C_2-C_5 olefins, in which the second catalyst is a doped or undoped zeolite catalyst.

[0039] In some examples, the stacked bed reactor can be a fixed bed reactor. In other examples, the stacked bed reactor can be a fluidized bed reactor.

[0040] In some examples, contacting the first mixture can further include contacting the first mixture with a third catalyst in the stacked bed reactor. The third catalyst can include a doped or undoped SiO_2 catalyst.

[0041] In some examples, the C_1-C_5 linear or branched alcohols can be bio-based and produced by fermentative processes. In some examples, the C_1-C_5 linear or branched alcohols can be not derived from petroleum.

[0042] In some examples, the one or more C_2-C_5 olefins can be present in the output stream in an amount that can be at least 80 wt. %, at least 85 wt. %, at least 90 wt. %, or at least 95 wt. %.

[0043] In some examples, the output stream can include one or more aromatic (C_{7+}) compounds in an amount from about 2 wt. % to about 10 wt. %. In some examples, the output stream can include one or more aromatic (C_{7+}) compounds in an amount that does not exceed 10 wt. %.

[0044] In some examples, the process can include removing at least a portion of C_2 olefins from the output stream. In some examples, the process can include removing at least a portion of C_4 olefins from the output stream. In some examples, the process can include removing at least a portion of C_5 olefins from the output stream.

[0045] In some examples, the temperature can be from about 550 °C to about 750 °C. In some examples, the temperature can be from about 350 °C to about 550 °C.

[0046] In some examples, the WHSV can be from about 0.5 to about 1.0. In some examples, the WHSV can be from about 2.0 to about 5.0.

[0047] In another example, a process for converting one or more C_1-C_5 linear or branched alcohols to one or more C_2-C_5 olefins using a single catalyst system can include contacting an input stream that includes the one or more C_1-C5 linear or branched

alcohols with a catalyst in a reactor to form an output stream comprising the one or more C_2-C_5 olefins, in which the catalyst consists essentially of zeolite doped with boron and phosphor. The reactor is at a temperature from about 300 °C to about 600 °C, a gauge pressure from 0 to about 30 bar, and a weight hourly space velocity (WHSV) from about 0.25 to about 10.

[0048] In some examples, the reactor can be a single bed reactor. In some examples, the single bed reactor can be a fixed bed reactor. In some examples, the single bed reactor can be a fluidized bed reactor. In some examples, the single bed reactor can be a moving bed reactor.

[0049] In some examples, the one or more C_2-C_5 olefins can be present in the output stream in an amount that is from about 50 wt. % to about 99 wt. % of the total hydrocarbon products in the output stream. In some examples, the one or more C_2-C_5 olefins can be present in the output stream in an amount that is from about 85 wt. % to about 99 wt. % of the total hydrocarbon products in the output stream.

[0050] In some examples, the boron can be present in the catalyst in an amount from about 0.01 wt. % to about 10 wt. %. In some examples, the boron can be present in the catalyst in an amount of at least 0.05 wt. %.

[0051] In some examples, the phosphor can be present in the catalyst in an amount from about 0.1 wt. % to about 7 wt. %. In some examples, the phosphor can be present in the catalyst in an amount of at least 1.5 wt. %.

[0052] In some examples, the zeolite can be ZSM-5 zeolite.

[0053] In another example, a process for converting one or more C_1-C_5 linear or branched alcohols to one or more C_2-C_5 olefins using a single catalyst system can include contacting an input stream that includes the one or more C_1-C_5 linear or branched alcohols with a single catalyst in a reactor to form an output stream that includes the one or more C_2-C_5 olefins. The single catalyst includes zeolite doped with boron and phosphor. The reactor is at a temperature from about 350 °C to about 750 °C, a gauge pressure from 0 to about 30 bar, and a weight hourly space velocity (WHSV) from about 0.25 to about 5.

[0054] In some examples, the single catalyst can consist essentially of zeolite doped with boron and phosphor.

[0055] In some examples, the reactor can be a single bed reactor. In some examples, the single bed reactor can be a fixed bed reactor. In some examples, the single bed reactor can be a fluidized bed reactor. In some examples, the single bed reactor can be a moving bed reactor.

[0056] In some examples, the one or more C_2-C_5 olefins can be present in the output stream in an amount that is from about 50 wt. % to about 99 wt. % of the total hydrocarbon products in the output stream. In some examples, the one or more C_2-C_5 olefins can be present in the output stream in an amount that is from about 85 wt. % to about 99 wt. % of the total hydrocarbon products in the output stream.

[0057] In some examples, the boron can be present in the catalyst in an amount from about 0.01 wt. % to about 10 wt. %. In some examples, the boron can be present in the catalyst in an amount of at least 0.05 wt. %.

[0058] In some examples, the phosphor can be present in the catalyst in an amount from about 0.1 wt. % to about 7 wt. %. In some examples, the phosphor can be present in the catalyst in an amount of at least 1.5 wt. %.

[0059] In some examples, the zeolite can be a ZSM-5 zeolite.

[0060] In another example, the process for converting one or more C_1-C_5 linear or branched alcohols to one or more C_2-C_5 olefins using a single catalyst system can include contacting an input stream that includes the one or more C_1-C_5 linear or branched alcohols with a catalyst in a reactor to form an output stream that includes the one or more C_2-C_5 olefins. The catalyst consists essentially of ZSM-5 zeolite doped with boron and phosphor. The reactor is at a temperature from about 350 °C to about 475 °C, a gauge pressure from 0 to about 5 bar, and a weight hourly space velocity (WHSV) from about 0.25 to about 10. The boron is present in the catalyst in an amount from about 0.05 wt. % to about 5 wt. %, and the phosphor is present in the catalyst in an amount from about 0.2 wt. % to about 7 wt. %.