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(54) Title: PROCESS FOR CONVERTING MIXED WASTE PLASTIC INTO LIQUID FUELS BY CATALYTIC CRACKING

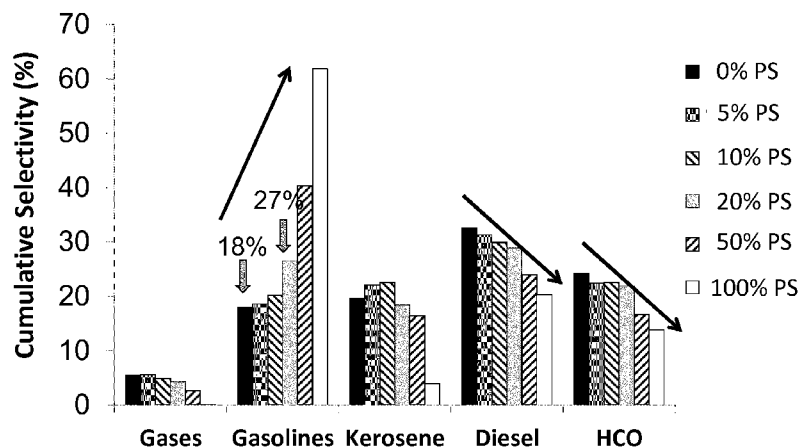


Figure 4

(57) Abstract: The present invention relates to a process for converting mixed waste plastic into liquid fuels by catalytic cracking. The process comprises the steps of introducing mixed waste plastic and a catalyst comprising an amorphous-type catalyst within a reactor; allowing at least a portion of the mixed waste plastic to be converted to liquid fuels within the reactor; and removing a product stream containing said liquid fuels from the reactor.

WO 2017/103015 A1

Process for converting mixed waste plastic into liquid fuels by catalytic cracking

This application claims priority to European application No. 15201124.3 - filed on December 18, 2015-, the whole content of this application being incorporated herein by reference for all purposes.

5 The present invention relates to a process for converting mixed waste plastic into liquid fuels by catalytic cracking. The process comprises the steps of introducing mixed waste plastic and a catalyst comprising an amorphous-type catalyst within a reactor; allowing at least a portion of the mixed waste plastic to be converted to liquid fuels within the reactor; and removing a product stream containing said liquid fuels from the reactor.

10 In view of the increasing importance of polymers as substitutes for conventional materials of construction, such as glass, metal, paper, and wood, the perceived need to save non-renewable resources such as petroleum and dwindling amounts of landfill capacity available for the disposal of waste products, considerable attention has been devoted in recent years to the problem of recovering, reclaiming, recycling or in some way reusing waste plastic.

15 It has been proposed to pyrolyze or catalytically crack the waste plastic so as to convert high molecular weight polymers into volatile compounds having a much lower molecular weight. The volatile compounds, depending on the process employed, can be either relatively high boiling liquid hydrocarbons useful as fuel oils or fuel oil supplements or light to medium boiling hydrocarbons useful as gasoline-type fuels or as other chemicals.

20 Catalytic cracking of mixed waste plastic is a process well known to the person skilled in the art. For example, US 5,216,149 discloses a method for controlling the pyrolysis of a complex waste stream of plastics to convert such stream into useful high-value monomers or other chemicals, by identifying catalyst and temperature conditions that permit decomposition of a given polymer in the presence of others, without substantial decomposition of the other polymers.

25 K.-H. Lee, et al. disclose in Polymer Degradation and Stability 84 (2004) 123-127 the liquid-phase catalytic degradation of mixtures of waste high-density polyethylene and polystyrene over spent FCC catalyst. The effect of the mixing proportions of polyethylene to polystyrene was studied and the authors found

30

that an increase of polystyrene content in the reactants showed an increase of gasoline fraction and a decrease in kerosene and diesel fraction in the obtained liquid product. However, at the same time, the fraction of aromatic components in the liquid product dramatically increased to 70 % and more even at a polystyrene content of only about 40 %. This finding is confirmed in the publication of K.-H. Lee in Polymer Degradation and Stability 93 (2008) 1284-1289 where at a polystyrene content of 40 % even 90 % aromatics were obtained. The experiments reported by K.-H. Lee were conducted using 20 g of catalyst per 200 g of plastic.

While for certain applications increasing the fraction of gasoline obtained from the catalytic cracking of waste plastic can be of advantage, a high fraction of aromatic compounds can be undesired, for example due to the toxicity of such compounds. It would therefore be desirable to provide a process for catalytic cracking of waste plastic wherein the ratio of gasoline to diesel fractions obtained can be tailored without undesirably increasing the fraction of aromatic compounds obtained.

The present inventors found that this and other problems as described below can surprisingly be solved by selecting a certain ratio of polystyrene to polyolefin in the mixed waste plastic and increasing the ratio of catalyst comprising an amorphous-type catalyst to waste plastic in the reactor.

The present invention therefore relates to a process for converting mixed waste plastic into liquid fuels by catalytic cracking, the process comprising :

- introducing mixed waste plastic and a catalyst comprising an amorphous-type catalyst within a reactor;
- allowing at least a portion of the mixed waste plastic to be converted to liquid fuels within the reactor; and
- removing a product stream containing said liquid fuels from the reactor, characterized in that the mixed waste plastic contains from 5 to 50 % by weight of polystyrene and from 50 to 95 % by weight of polyolefin, each based on the total weight of polystyrene and polyolefin in the mixed waste plastic, and in that the weight ratio of catalyst to mixed waste plastic in the reactor is above 1:10.

In the catalytic cracking of plastic several fractions of chemical compounds are obtained. Usually, there is a gas fraction containing light weight chemical compounds with less than 5 carbon atoms. The gasoline fraction contains compounds having a low boiling point of for example below 216°C. This fraction includes compounds having 5 to 11 carbon atoms. The kerosene and

diesel fraction has a higher boiling point of for example 216°C to 359°C. This fraction generally contains compounds having 12 to 21 carbon atoms. The even higher boiling fraction is generally designated as wax (Heavy Cycle Oil or HCO). In all the fractions, the compounds are hydrocarbons which optionally
5 comprise heteroatoms, such as N, O, etc. "Liquid fuels" in the sense of the present invention therefore are fuels like gasoline and diesel but may also be used as other valuable chemicals or solvents.

A plastic is mostly constituted of a particular polymer and the plastic is generally named by this particular polymer. Preferably, a plastic contains more
10 than 25 % by weight of its total weight of the particular polymer, preferably more than 40 % by weight and more preferably more than 50 % by weight. Other components in plastic are for example additives, such as fillers, reinforcers, processing aids, plasticizers, pigments, light stabilizers, lubricants, impact modifiers, antistatic agents, inks, antioxidants, etc. Generally, a plastic
15 comprises more than one additive.

Plastics used in the process of the present invention are polyolefins and polystyrene, such as high density polyethylene (HDPE), low density polyethylene (LDPE), polypropylene (PP) and polystyrene (PS). Mixed plastics mostly constituted of polyolefin and polystyrene are preferred. In this context
20 "mostly constituted" is to be understood such that the concentration of the polyolefin and the polystyrene in the mixed plastic is above 50 % by weight, more preferably above 75 % by weight, each based on the total weight of the dry mixed plastic. The mixed plastic may be constituted of polyolefin and polystyrene. Preferably, the mixed plastic contains less than 99.5 % by weight,
25 more preferably less than 99 % by weight of polyolefin and polystyrene, based on the total weight of the dry mixed plastic.

Other plastics, such as polyvinylchloride, polyvinylidene chloride, polyethylene terephthalate, polyurethane (PU), acrylonitrile-butadiene-styrene (ABS), nylon and fluorinated polymers are less desirable. If present in the waste
30 plastic, they are preferably present in a minor amount of less than 50 % by weight, preferably less than 30 % by weight, more preferably less than 20 % by weight, even more preferably less than 10 % by weight of the total weight of the dry waste plastic. Preferably, the individual content of any less desirable plastic is less than 5 % by weight, more preferably less than 2 % by weight based on the
35 total weight of the dry waste plastic.

Preferably, the plastics waste starting material comprises one or more thermoplastic polymers and is essentially free of thermosetting polymers. Essentially free in this regard is intended to denote a content of thermosetting polymers of less than 15, preferably less than 10 and even more preferably less than 5 wt % of the composition.

Usually, waste plastic contains other non-desired components, namely foreign material, such as paper, glass, stone, metal, etc.

In the context of the present invention whenever it is referred to the weight of the waste plastic or the weight of the polystyrene and polyolefin in the mixed waste plastic, this weight relates to the weight of the dry plastic without any foreign material being admixed with the plastic. However, the weight includes any components in the plastic, such as the above described additives.

The present inventors found that when using a catalyst comprising an amorphous-type catalyst, the addition of polystyrene to polyolefin raw material increases the reaction rate of the de-polymerization reaction of the polyolefins. There is, however, an optimum polystyrene to polyolefin ratio that maximizes the rate kinetic constant of the polyolefin's de-polymerization reaction. The increase of rate kinetic constant is a significant advantage for an industrial process as it allows higher conversions as well as higher productivity.

It was found that the rate kinetic constant of the polyolefin's de-polymerization reaction has a maximum when the mixed waste plastic contains about 20 % by weight of polystyrene based on the total weight of polystyrene and polyolefin in the mixed waste plastic. Still good values are achieved if the mixed waste plastic contains from 5 to 50 % by weight of polystyrene, preferably from 5 to 40 % by weight, more preferably from 5 to 30 % by weight and even more preferably from 10 to 30 % by weight of polystyrene, each based on the total weight of polystyrene and polyolefin in the mixed waste plastic. Most preferably, the mixed waste plastic contains from 15 to 25 % by weight, such as about 20 % by weight of polystyrene based on the total weight of polystyrene and polyolefin in the mixed waste plastic.

It was furthermore found that increasing the polystyrene content allows modifying the selectivity of the products. Increasing the polystyrene content in the mixed waste plastic results in higher selectivity to gasoline and lower selectivity to gases and diesel.

However, contrary to what was reported by K.-H. Lee (see above cited references), the inventors found that increasing the weight ratio of catalyst to

mixed waste plastic in the reactor not only results in the above benefits with respect to rate kinetic constant and selectivity of the process, but additionally results in a low yield of aromatic compounds. Even at a polystyrene concentration of up to 50 % by weight in the mixed waste plastic, the concentration of aromatic compounds in the gasoline and diesel fractions is low. It was even found that the quality of the diesel obtained with the process of the invention meets EN 590:2009+A1 (version of February 2010) specification. In particular, the concentration of poly-aromatic compounds in the diesel fraction is low.

As further benefit of the present process, the inventors found that the gasoline quality in particular at a concentration of about 20 % by weight of polyolefin in the mixed waste plastic is increased with respect to an increase in Research Octane Number (RON) and Motor Octane Number (MON).

The process of the present invention therefore is also characterized in that the weight ratio of catalyst to mixed waste plastic in the reactor is above 1:10. Preferably, the weight ratio of catalyst to mixed waste plastic in the reactor is above 1:9, more preferably above 1:8, more preferably above 1:7, more preferably above 1:6, more preferably above 1:5, more preferably above 1:4 and even more preferably above 1:3, such as above 1:2. A particularly preferred weight ratio of catalyst to mixed waste plastic in the reactor is about 1:1.5.

The weight ratio of catalyst to mixed waste plastic in the reactor can be below 10:1, preferably below 7:1. Thus, the weight ratio of catalyst to mixed waste plastic in the reactor can be for example in the range of from 1:9 to 10:1, preferably from 1:8 to 10:1, preferably from 1:7 to 10:1, preferably from 1:6 to 10:1, preferably from 1:5 to 10:1, preferably from 1:4 to 10:1, preferably from 1:3 to 10:1 and even more preferably from 1:2 to 10:1 or from 1:2 to 7:1.

The catalyst used in the process of the present invention comprises an amorphous-type catalyst. In one embodiment, the catalyst predominantly is an amorphous-type catalyst. In a further embodiment, the catalyst consists of an amorphous-type catalyst. In a third embodiment, the catalyst additionally comprises a further catalyst, in particular a zeolite-type catalyst.

In the context of the present invention "amorphous-type catalyst" is to be understood as an amorphous solid, such as an amorphous powder. Such amorphous solids are known to the skilled person. Amorphous solids lack crystallinity, namely the long-range order characteristic of a crystal. This feature

may be observed via X-ray diffraction analysis by the lack of sharp Bragg reflexes.

Nevertheless, an amorphous-type catalyst may comprise a certain amount of crystalline solids. Preferably, the amorphous-type catalyst comprises less than
5 50 % by weight, more preferably less than 25 % by weight, even more preferably less than 10 % by weight, such as less than 5 % by weight or less than 2 % or even less than 1 % by weight of crystalline solids, each based on the total weight of the catalyst.

The embodiment in which the catalyst predominantly is an amorphous-type catalyst is preferred. In this context, the term "predominantly" defines a
10 catalyst which is a mixture of an amorphous-type catalyst and a non-amorphous-type catalyst, such as a zeolite-type catalyst, but wherein the catalyst comprises more than 50 % by weight of the amorphous-type catalyst based on the total weight of the catalyst. Preferably, the catalyst comprises more than 60 %, more
15 preferably more than 70 %, even more preferably more than 80 % and most preferably more than 90 % of the amorphous-type catalyst. The catalyst can comprise a single amorphous-type catalyst or a mixture of two or more amorphous-type catalysts.

As catalyst all types of FCC catalysts may be used. FCC catalysts are well
20 known to the person skilled in the art. For example, the amorphous-type catalyst may comprise silica, alumina, kaolin, or a mixture thereof. Silica, in particular in the form of sand, is well known for FCC catalytic applications. Preferred amorphous-type catalysts comprise at least 60 % by weight, preferably at least 70 % by weight and even more preferably at least 80 % by weight of silica-
25 equivalent of an oxidic compound based on silicon like silica (SiO_2), kaolin, etc.

If the catalyst additionally comprises a zeolite-type catalyst, this may be selected from crystalline microporous zeolites which are known to the person skilled in the art and which are commercially available. Preferred examples for zeolite-type catalysts are described in WO 2010/135273, the content of which is
30 incorporated herein by reference. Specific examples for suitable zeolite-type catalysts include but are not limited to ZSM-5, ZSM-11, ZSM-22, ZSM-23, ZSM-35, ZSM-48, ZSM-50, TS-1, TS-2, SSZ-46, MCM-22, MCM-49, FU-9, PSH-3, ITQ-1, EU-1, NU-10, silicalite-1, silicalite-2, boralite-C, boralite-D, BCA, and mixtures thereof.

35 The catalyst can be fresh catalyst, equilibrated catalyst (such as spent catalyst), or a mixture thereof.

The mixed waste plastic and the catalyst comprising the amorphous-type catalyst can be introduced within the reactor simultaneously or subsequently. Furthermore, the mixed waste plastic and the catalyst comprising the amorphous-type catalyst can be introduced within the reactor batchwise or continuously.

5 The skilled person is aware of suitable apparatus and equipment for carrying out the process in accordance with the present invention and will select the suitable system based on his professional experience, so that no further extensive details need to be given here. However, without wishing to be bound to theory, some examples of reactor technologies that can be effectively used to

10 carry out the invention comprise the stirred reactor, the rotary kiln, the bubbling fluidized bed reactor and the circulating fluidized bed reactor riser or downer. The rotary kiln is a cylindrical vessel, inclined slightly to the horizontal, which is rotated slowly about its axis. The material to be processed is fed into the upper end of the cylinder. As the kiln rotates, material gradually moves down towards

15 the lower end, and may undergo a certain amount of stirring and mixing. In a bubbling fluidized bed reactor a fluid (gas or liquid) is passed through the catalyst particles at high enough velocities to suspend the catalyst and cause it to behave as though it were a fluid. In a circulating fluidized bed, also called transport reactor, the catalyst and the fluid flow co-currently at high speed.

20 Generally a cyclone system is used to separate the fluid, which can undergo downstream processing, from the solid, which is recirculated to the reactor. These reactors can be either upflow for risers, or downflow for downers.

Preferably, they are introduced continuously. In one embodiment, the whole process is conducted continuously. In the reactor, in presence of the

25 catalyst, at least a portion of the mixed waste plastic is converted to liquid fuels. This conversion preferably takes place at an elevated temperature of for example above 350°C, preferably above 400°C, more preferably above 410°C. Suitably, the conversion takes place at a temperature in the range of above 410°C to 500°C, more preferably in the range of from 420°C to 470°C, such as about 450°C.

30 The effect of the polystyrene content in the mixed waste plastic at a high weight ratio of catalyst to mixed waste plastic in the reactor is now explained in more detail with reference to the following examples and the attached figures which show in

- Figure 1 the evolution with time of the overall cumulative conversion for
- 35 different polystyrene loadings,

- Figure 2 the evolution with time of corrected HDPE cumulative conversion for different polystyrene loadings. To determine the corrected HDPE conversion, without the PS contribution, it is assumed that the pyrolysis process of the two different plastics is independent. Based on this premise, it is possible to subtract the PS conversion to the overall conversion, thus obtaining the HDPE conversion,
- Figure 3 the relative values of kinetic rate constant for different polystyrene loadings,
- Figure 4 the effect of polystyrene loading on selectivity,
- Figure 5 the effect of polystyrene loading on the quality of the gasoline fraction, and
- Figure 6 the effect of polystyrene loading on the quality of the diesel fraction.

The examples below were conducted according to the following general experimental procedure.

In each catalytic run in semibatch mode, 30 g of plastic (high density polyethylene (HDPE) and variable amounts of polystyrene (PS)) and a defined amount of the amorphous-type catalyst (SiO_2) were loaded inside the reactor. The reactor was closed and heated from room temperature to 200°C during 20 minutes, while simultaneously purging with a 150 mL/min nitrogen flow. When the internal temperature reached the melting point of the plastic, stirring was started and was slowly increased until 690 rpm. The temperature was held at 200°C for 25-30 minutes. During this heating process, nitrogen coming out from the reactor was not collected.

After this first pretreatment step, the temperature was increased to the reaction temperature at a heating rate of 10°C/min, and the collection of gases and nitrogen in the corresponding gas sampling bag was started. When the internal temperature reached the reaction temperature, the circulation of the gaseous products was commuted to another pair of glass traps and corresponding gas sampling bag. This was considered as the zero reaction time.

During selected time periods, liquid and gaseous products were collected in a pair of glass traps and their associated gas sampling bag, respectively. At the end of the experiment the reactor was cooled to room temperature. During this cooling step, liquids and gases were also collected.

The reaction products were classified into 3 groups : i) gases, ii) liquid hydrocarbons and iii) residue (waxy compounds, ashes and coke accumulated on the catalyst). Quantification of the gases was done by gas chromatography (GC)

using nitrogen as the internal standard, while quantification of liquids and residue was done by weight.

The simulated distillation (SIM-DIS) GC method allowed the determination of the different fractions in the liquid samples (according to the selected cuts); the detailed hydrocarbon analysis (DHA) GC method allowed the
5 determination of the PIONA (paraffins, iso-paraffins, olefins, naphthenes, aromatics) components in the gasoline fraction of the last withdrawn sample (C5-C11 : Boiling point < 216.1°C; what includes C5-C6 in the gas sample and C5-C11 in the liquid samples), and GCxGC allowed the determination of
10 saturates (everything that is not aromatic), mono-, di- and tri-aromatics in the diesel fraction of the last withdrawn liquid samples (C12-C21; 216.1 < BP < 359°C).

To determine the corrected HDPE conversion, without the PS contribution, it was assumed that the pyrolysis process of the two different plastics is
15 independent. Based on this premise, it is possible to subtract the PS conversion to the overall conversion, thus obtaining the HDPE conversion.

Should the disclosure of any patents, patent applications, and publications which are incorporated herein by reference conflict with the description of the present application to the extent that it may render a term unclear, the present
20 description shall take precedence.

Example 1

The experiment was carried out following the general procedure described above. In this example, the raw material was pure HDPE (labelled 0 % PS). Reaction temperature was set at 450°C. In this example, 20 g of silica were
25 used. Catalyst to plastic weight ratio was equal to 20/30.

Example 2

The experiment was carried out following the general procedure described above. In this example, the raw material is a mixture containing 95 wt. % HDPE and 5 wt. % PS (labelled 5 % PS). Reaction temperature was set at 450°C. In
30 this example, 20 g of silica have been used. Catalyst to plastic weight ratio was equal to 20/30.

Example 3

The experiment was carried out following the general procedure described above. In this example, the raw material was a mixture containing 90 wt. %
35 HDPE and 10 wt. % PS (labelled 10 % PS). Reaction temperature was set at

450°C. In this example, 20 g of silica were used. Catalyst to plastic weight ratio was equal to 20/30.

Example 4

5 The experiment was carried out following the general procedure described above. In this example, the raw material was a mixture containing 80 wt. % HDPE and 20 wt. % PS (labelled 20 % PS). Reaction temperature was set at 450°C. In this example, 20 g of silica were used. Catalyst to plastic weight ratio was equal to 20/30.

Example 5

10 The experiment was carried out following the general procedure described above. In this example, the raw material was a mixture containing 50 wt. % HDPE and 50 wt. % PS (labelled 50 % PS). Reaction temperature was set at 450°C. In this example, 20 g of silica were used. Catalyst to plastic weight ratio was equal to 20/30.

Example 6

The experiment was carried out following the general procedure described above. In this example, the raw material was pure PS (labelled 100 % PS). Reaction temperature was set at 450°C. In this example, 20 g of silica were used. Catalyst to plastic weight ratio was equal to 20/30.

20 The evolution of the overall cumulative conversion for the different polystyrene loadings over time is shown in Figure 1. As explained above in the general description of the experimental procedure, the PS conversion was then subtracted from the overall conversion thus obtaining the HDPE cumulative conversion for different polystyrene loadings shown in Figure 2. From these values, the relative values of kinetic rate constant for different polystyrene loadings in HDPE pyrolysis were calculated. The results are shown in Figure 3. It is evident that the kinetic rate constant for the polyolefin conversion has a maximum at about 20 % by weight of polystyrene present in the mixed waste plastic.

30 The effect of polystyrene loading on the selectivity of the process is shown in Figure 4. It is evident that the selectivity for gasoline increases with increasing polystyrene loading while the selectivity for gases, diesel and waxes decreases.

35 However, contrary to the expectation of the skilled person and contrary to what is described in the prior art, the process of the present invention provides a gasoline fraction as well as a diesel fraction which both comprise only a low

amount of aromatic compounds. Only in case of 100 % polystyrene as starting plastic (which is not according to the invention), the amount of aromatic compounds in the gasoline and diesel fractions increases. These findings are summarized in Figures 5 and 6.

5 Figure 5 shows the effect of the polystyrene loading on the quality of the gasoline fraction (P : paraffins, I : iso-paraffins, O : olefins, N : naphthenes, A : aromatics, U : unidentified). Figure 5 additionally shows the RON and MON of the gasoline fractions obtained with different polystyrene loadings. Surprisingly, both RON and MON increase if the amount of polystyrene in the mixed waste
10 plastic is increased from 0 % to 20 %.

 Figure 6 shows the effect of the polystyrene loading on the quality of the diesel fraction (S : saturated, MA : monoaromatic, DA : diaromatic, TA : triaromatic, PA : polyaromatic). It is evident that the overall amount of aromatic compounds in the diesel fraction remains low even if the polystyrene content in
15 the mixed waste plastic is increased up to 50 % by weight. Only when the polystyrene content is increased to 100 % (which is not according to the invention), the amount of aromatic compounds in the diesel fraction significantly increases.

CLAIMS

1. Process for converting mixed waste plastic into liquid fuels by catalytic cracking, the process comprising :
introducing mixed waste plastic and a catalyst comprising an amorphous-type catalyst within a reactor;
5 allowing at least a portion of the mixed waste plastic to be converted to liquid fuels within the reactor; and
removing a product stream containing said liquid fuels from the reactor,
characterized in that the mixed waste plastic contains from 5 to 50 % by weight
10 of polystyrene and from 50 to 95 % by weight of polyolefin, each based on the total weight of polystyrene and polyolefin in the mixed waste plastic, and in that the weight ratio of catalyst to mixed waste plastic in the reactor is above 1:10.
2. Process according to claim 1, wherein the mixed waste plastic contains from 5 to 40 % by weight, preferably from 5 to 30 % by weight, more preferably
15 from 10 to 30 % by weight of polystyrene, based on the total weight of polystyrene and polyolefin in the mixed waste plastic.
3. Process according to claim 1 or 2, wherein the weight ratio of catalyst to mixed waste plastic in the reactor is above 1:8, preferably above 1:5, more preferably above 1:3.
- 20 4. Process according to any of the preceding claims, wherein the weight ratio of catalyst to mixed waste plastic in the reactor is below 10:1, preferably below 7:1.
5. Process according to any of the preceding claims, wherein the catalyst predominantly is an amorphous-type catalyst.
- 25 6. Process according to any one of claims 1 to 4, wherein the catalyst consists of amorphous-type catalyst.
7. Process according to any one of claims 1 to 5, wherein the catalyst additionally comprises a zeolite-type catalyst.

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8. Process according to any of the preceding claims, wherein the amorphous-type catalyst comprises silica, alumina, kaolin, or a mixture thereof.

9. Process according to any of the preceding claims, wherein the catalyst is fresh catalyst, equilibrated catalyst, or a mixture thereof.

5 10. Process according to any of the preceding claims, wherein the temperature at which at least part of the mixed waste plastic is converted to liquid fuels in the reactor is above 350°C, preferably above 410°C, more preferably in the range of above 410°C to 500°C, even more preferably in the range of from 420°C to 470°C.

10 11. Process according to any of the preceding claims, wherein the mixed waste plastic comprises more than 50 % by weight of polystyrene and polyolefin, based on the total weight of the mixed waste plastic.

12. Process according to any of the preceding claims, which is conducted continuously.

15 13. Process according to any of the preceding claims, wherein the waste plastic is selected from post consumer waste plastic, off-spec plastic and industrial scrap plastic.

14. Process according to any of the preceding claims, wherein the waste plastic is essentially free of thermosetting polymers.

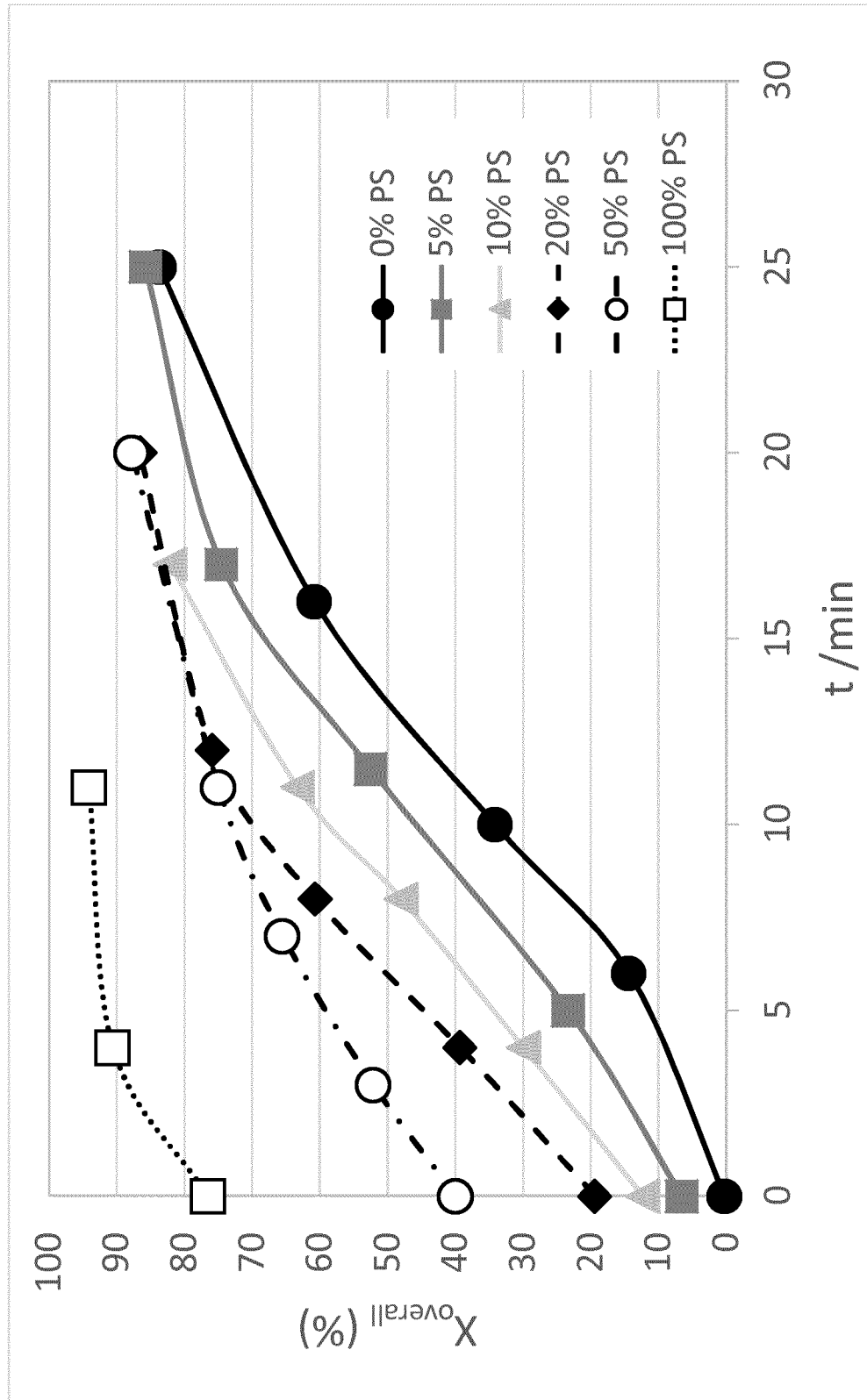


Figure 1

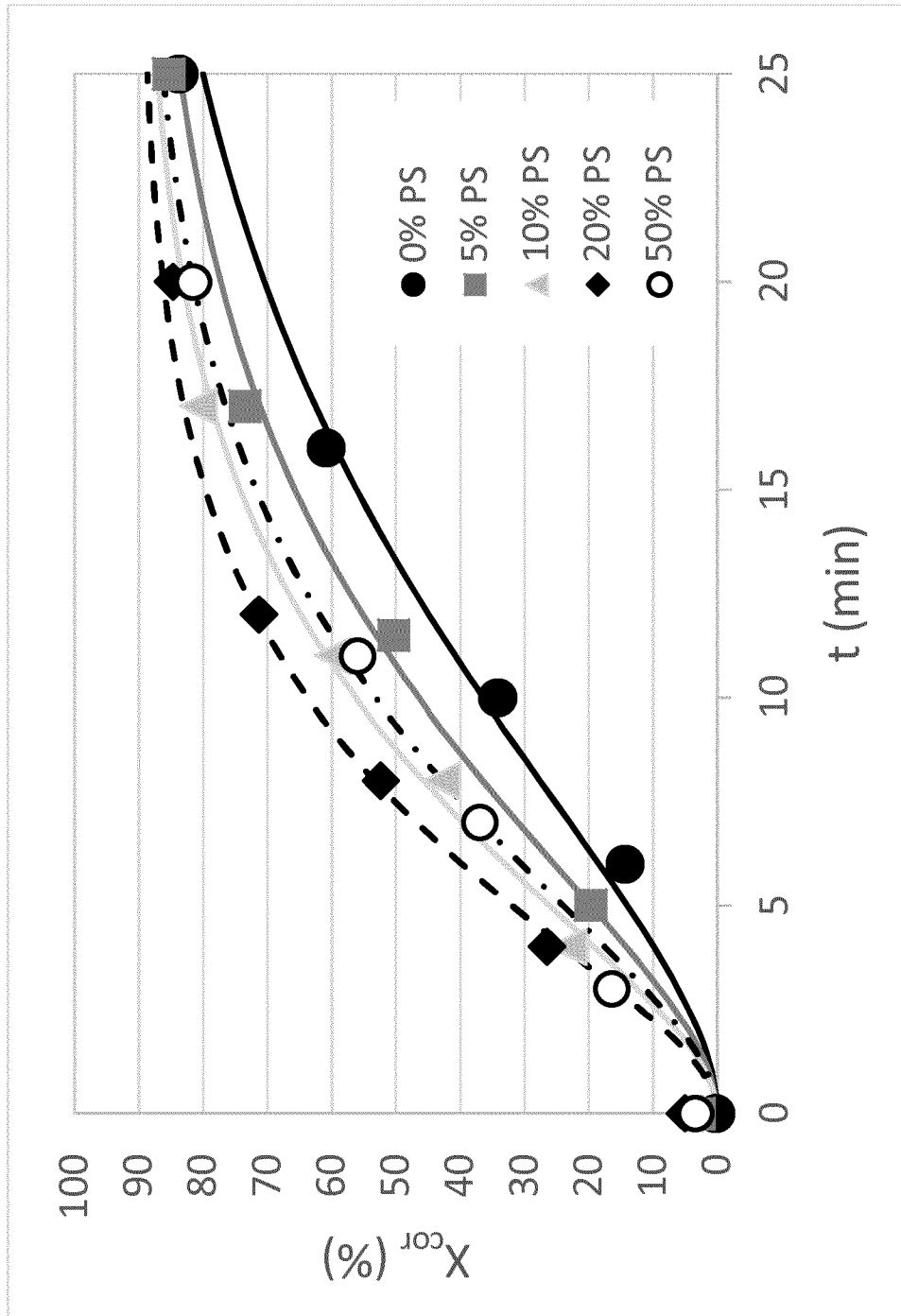


Figure 2

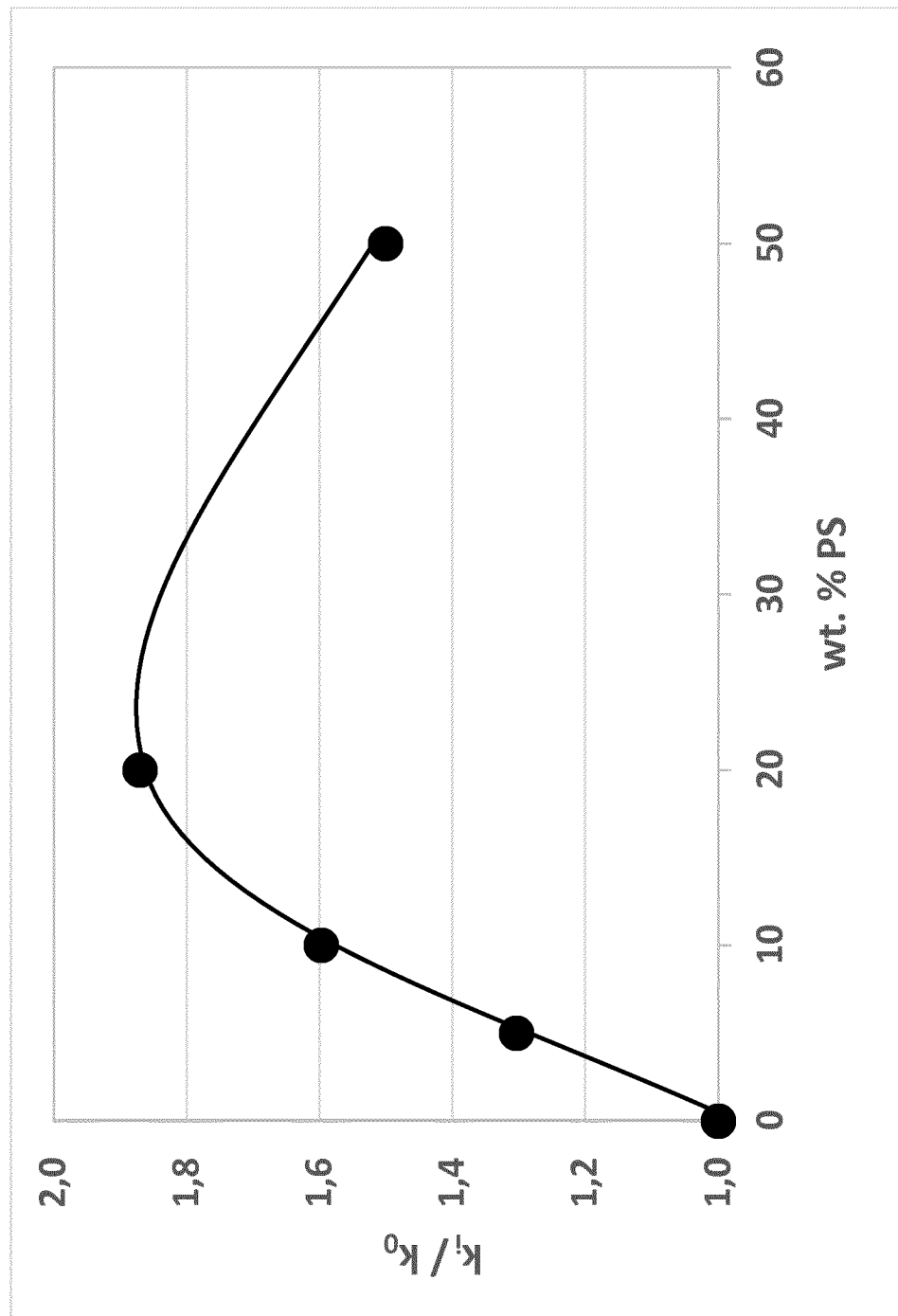


Figure 3

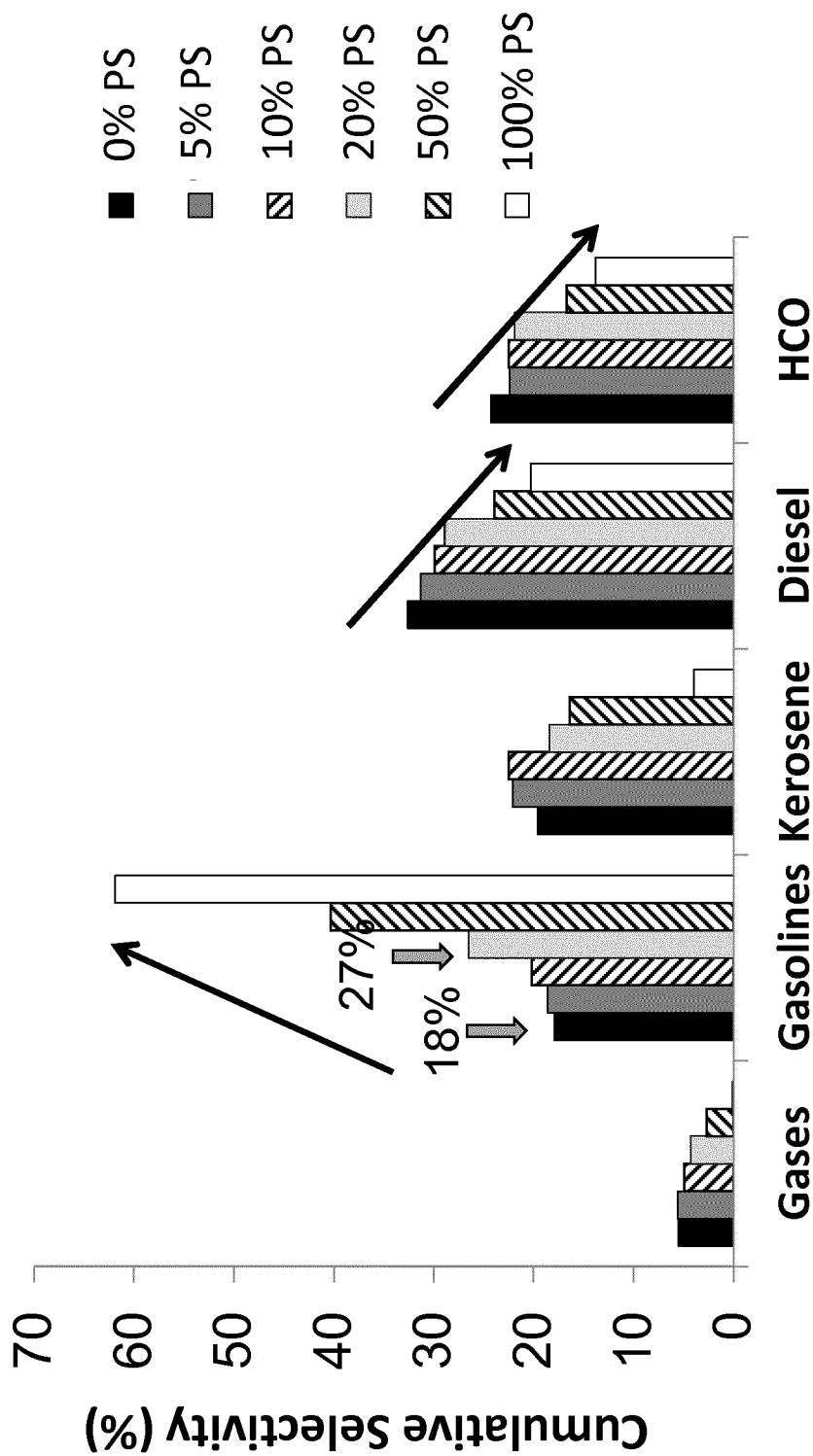


Figure 4

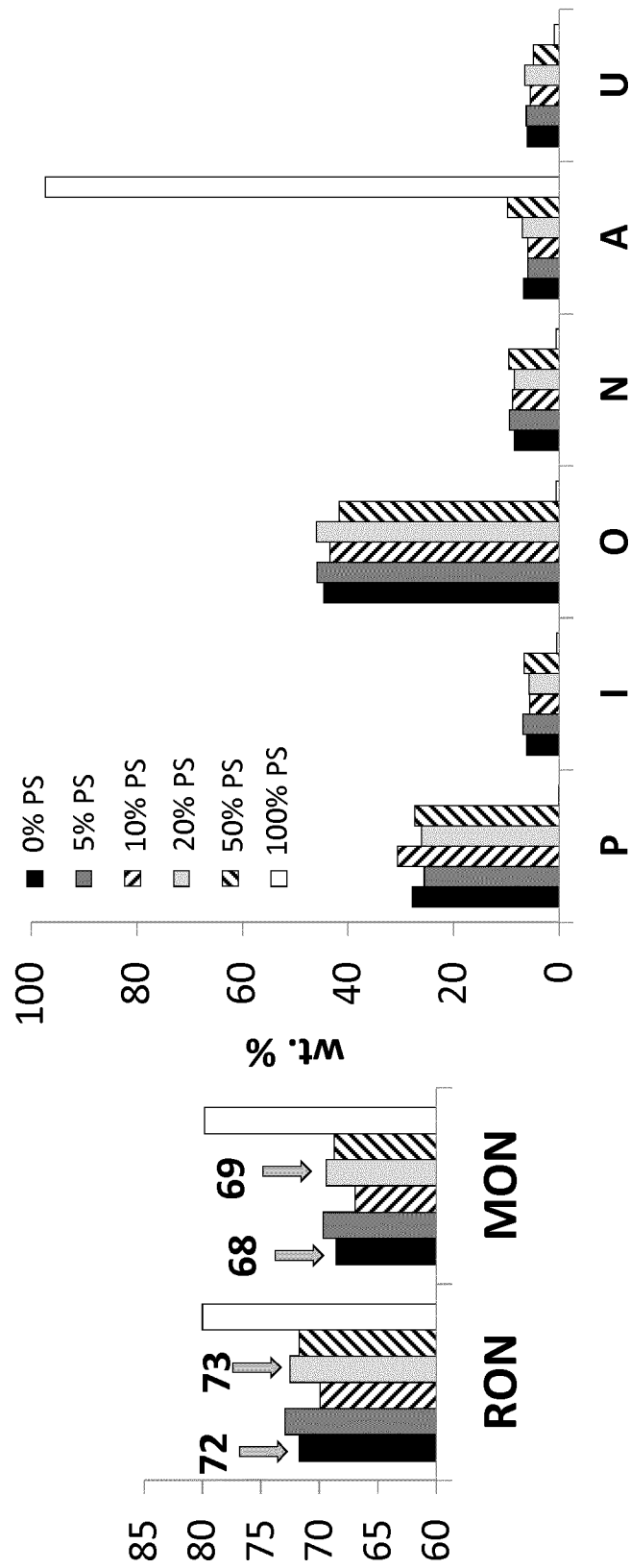


Figure 5

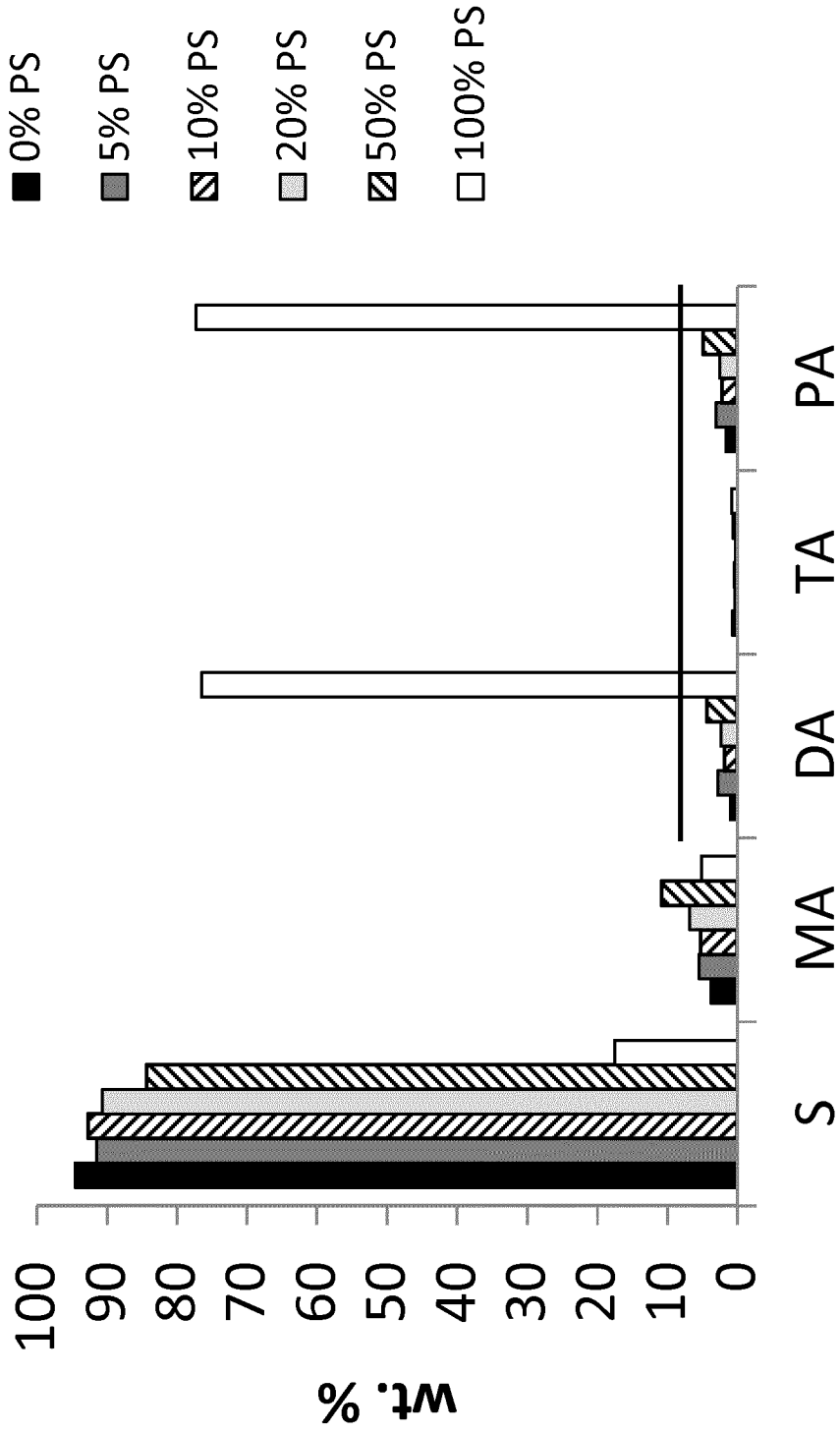


Figure 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/081304

A. CLASSIFICATION OF SUBJECT MATTER
INV. C10G1/10
ADD.
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
C10G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|-----------|--|-----------------------|
| X | WO 2015/128033 A1 (SAUDI BASIC IND CORP [SA]; SABIC GLOBAL TECHNOLOGIES BV [NL]; WARD AND) 3 September 2015 (2015-09-03) example 1 | 1-14 |
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Further documents are listed in the continuation of Box C.

See patent family annex.

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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/081304

| C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT | | |
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International application No

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