METHODS FOR CONVERTING PLASTIC TO WAX

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Abstract

Methods for converting plastic to wax are provided. In one embodiment, a method for converting a waste plastic to wax includes introducing the waste plastic into a chamber and adding hydrogen to the chamber. The method includes heating the waste plastic and hydrogen sufficiently to thermally depolymerize the waste plastic to form a wax product comprising paraffin and olefin compounds.
METHODS FOR CONVERTING PLASTIC TO WAX

TECHNICAL FIELD

[0001] The technical field generally relates to methods for forming wax, and more particularly relates to methods for processing plastic to convert the plastic to wax.

BACKGROUND

[0002] Waxes are broadly divided into several well established groups including paraffin waxes (normally obtained from petroleum oil distillates), microcrystalline wax (usually obtained from residual lubricating oil fractions), and polyethylene waxes (typically manufactured from low molecular weight, high-density raw materials). Each of these wax types has been found to have specific physical properties making them especially attractive for particular utilities. For example, polyethylene waxes are often used in the formulation of colorants for plastics, in polyvinyl chloride lubricants, in adhesives, and in inks to decrease friction. Polyethylene waxes may further be used as release agents or as slip agents.

[0003] Polyethylene wax compositions contain a variety of polyethylene. For the most part, polyethylenes employed in polyethylene waxes have weight average molecular weights in the range of about 1500 grams per mole (g/mol) to about 20,000 g/mol. High grade polyethylene waxes may be obtained by the controlled polymerization of ethylene to obtain desired properties such as molecular weight, melting point, viscosity and hardness. Recently, there has been a rise in the use of lower grade polyethylene waxes that are typically derived from the thermal decomposition of polyethylene resin. Such lower grade products have become popular for use in application or locations where product quality is secondary to cost. However, polyethylene waxes derived from the thermal decomposition of polyethylene resin are typically inferior in quality, e.g., they exhibit undesirable color, low molecular weight, and are inconsistent across production lots.

[0004] Accordingly, it is desirable to provide a low cost method for producing polyethylene wax with improved properties. Further, it is desirable to provide a method for converting waste plastic into wax with desired properties. Furthermore, other desirable features and characteristics will become apparent from the subsequent detailed description and the appended claims, taken in conjunction with the accompanying drawings and the foregoing technical field and background.

BRIEF SUMMARY

[0005] Methods for converting plastic to wax are provided. In an exemplary embodiment, a method for converting a waste plastic to wax includes introducing the waste plastic into a chamber and adding hydrogen to the chamber. The method includes heating the waste plastic and hydrogen sufficiently to thermally depolymerize the waste plastic to form a wax product comprising paraffin and olefin compounds.

[0006] In another embodiment, a method for converting plastic to wax includes contacting the plastic with hydrogen. Further, the method includes heating the plastic and the hydrogen to thermally degrade the plastic to form a wax product with a Saybolt color (ASTM D156) of at least about 0.

[0007] In another embodiment, a method is provided for converting waste plastic to polyethylene wax. The method includes melting the waste plastic. Hydrogen is dissolved into the waste plastic. The waste plastic is thermally depolymerized in the presence of the hydrogen to form a polyethylene wax product comprising paraffin and olefin compounds.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Embodiments of methods for converting plastic to wax will hereinafter be described in conjunction with the following drawing figures, wherein like numerals denote like elements, and wherein:

[0009] FIG. 1 is a schematic diagram of a method for converting plastic to wax in accordance with an exemplary embodiment herein;

[0010] FIG. 2 is a schematic diagram of a method for converting plastic to wax in accordance with an alternate embodiment herein; and

[0011] FIG. 3 is a schematic diagram of a method for converting plastic to wax in accordance with another alternate embodiment herein.

DETAILED DESCRIPTION OF DRAWINGS

[0012] The following detailed description is merely exemplary in nature and is not intended to limit the methods for converting plastic to wax. Furthermore, there is no intention to be bound by any theory presented in the preceding background or the following detailed description.

[0013] Methods for processing plastic to convert the plastic to wax are provided. As used herein “plastic” refers to thermoplastic polyolefins. Thermoplastic polyolefins include polyethylenes, for example polyethylene with the formula \((C_2H_4)_n\), where \(n\) is typically from 50 to 100, and polypropylenes, such as polypropylenes with the formula \((C_3H_6)_m\), where \(m\) is typically from 50 to 100, or a mixture of thermoplastic polyolefins. The methods disclosed herein enable improved control over the reaction of the plastic and the properties of the resulting wax product. In an exemplary embodiment, the feed plastic is low density polyethylene (LDPE) plastic waste. For example, the feed plastic may be polyethylene films or bags from post-consumer recycle or post-industrial recycle processes.

[0014] The methods provided herein utilize thermal degradation to crack the long chain units of the feed plastic to form olefins and paraffins. More specifically, exemplary methods provided herein thermally depolymerize the feed plastic to form olefins and paraffins. The thermal processing of the plastic is performed in a controlled hydrogen environment. It is theorized that the hydrogen environment inhibits further reaction of the resulting olefins and prevents the olefins from forming compounds that exhibit non-white colors and other undesirable properties. As a result, the product may be obtained with a near white color. The American Society for Testing and Materials (ASTM) recommended test for measuring near white colors of petroleum products uses the Saybolt method under ASTM D156. The Saybolt method provides an empirical definition of the color of a clear petroleum liquid based on a scale of ~16 (darkest) to ~30 (lightest). The number is derived by finding the height of a column of the sample that, when viewed through the length of the column, visually matches a filter standard provided by ASTM D156. For testing, the wax sample is melted to 80°C ~176°C above its congealing point and is poured into an appropriate chromometer column. As described herein, an exemplary product wax is near water white and has a Saybolt color (ASTM D156) of
about +25 to about +30, for example about +30 to about +30, such as about +30. In an exemplary embodiment, the Saybolt color (ASTM D156) of the product wax is at least about 0, for example at least about +5, such as at least about +10. An exemplary product has a Saybolt color (ASTM D156) of at least about +15, for example at least about +18, such as about +20.

[0015] FIG. 1 is a simplified process flow diagram illustrating an embodiment of a method for converting plastic to wax by thermal degradation in a hydrogen environment. This process flow diagram has been simplified in that it does not show pieces of mechanical apparatus normally found on such a process including pumps, pressure, temperature and flow rate monitoring and control systems.

[0016] In FIG. 1, a plastic processing apparatus 10 converts a plastic feedstock 12 into a wax product 14, for example, a polyethylene wax. As noted above, the plastic feedstock 12 may be formed from waste plastic, such as films or bags from post-consumer recycle or post-industrial recycle processes. The plastics forming the feedstock 12 may be restricted to a single type of plastic, such as polyethylene or polypropylene, or may include a mixture of plastic compounds, such as polyethylene and polypropylene.

[0017] As shown, the plastic feedstock 12 and a purge gas 18 are fed to a reaction zone 20. The purge gas 18 includes an inert gas or gases. In an exemplary embodiment, the purge gas 18 is substantially pure hydrogen. In other embodiments, the purge gas 18 is a mixture of hydrogen and an inert gas. For example, the purge gas 18 may be a mixture of hydrogen and nitrogen, such as a mixture with a hydrogen partial pressure of at least about 0.5 atmospheres (atm), for example least about 0.8 atm, such as about 1 atm.

[0018] The purge gas 18 may be introduced to the reaction zone 20 before, after, or simultaneously with the introduction of the plastic feedstock 12 to the reaction zone. Despite the order of feeding the plastic feedstock 12 and the purge gas 18 to the reaction zone 20, the plastic feedstock 12 is considered to be introduced to a hydrogen environment in the reaction zone 20 when the ambient air is purged from the reaction zone 20 by the purge gas 18 and the plastic feedstock 12 is received in the reaction zone 20. After introducing the plastic feedstock 12 to the hydrogen environment, the process may continue with melting the plastic feedstock 12.

[0019] As shown in FIG. 1, the reaction zone 20 is equipped with a heater 24. In an exemplary embodiment, heater 24 is controlled to operate at a low pretreatment temperature to melt the plastic feedstock 12. For example, the heater 24 may heat the reaction zone 20 to a temperature of about 100°C. to about 150°C., for example about 135°C. The heater 24 may maintain the low pretreatment temperature for a selected duration of time, such as from about 1 minute to about 90 minutes. After the plastic feedstock 12 is melted, the heater 24 is controlled to operate at a high reaction temperature to cause thermal degradation of the melted plastic feedstock 12, i.e., cracking of the plastic feedstock 12 including thermal depolymerization and other cracking processes. For example, the heater 24 may heat the reaction zone 20 including the plastic feedstock 12 and the hydrogen purge gas 18 to a high reaction temperature of about 300°C. to about 500°C., for example about 405°C. The heater 24 may maintain the high reaction temperature for a duration of time sufficient to cause thermal degradation of substantially all of the plastic feedstock 12. As used herein, the phrase “substantially all of the plastic feedstock” means at least about 95 weight percent (wt %) of the plastic feedstock 12. In an exemplary embodiment, the heater 24 maintains the high reaction temperature for a duration of about 1 minute to about 45 minutes, such as 30 minutes. In an exemplary embodiment, the plastic feedstock 12 undergoes thermal depolymerization (one of the thermal degradation processes) rather than random chain scission or side-group elimination. Oxidation of the plastic feedstock 12 is not possible as all oxygen is purged from the reaction zone by the purge gas 18.

[0020] To thermally degrade substantially all of the plastic feedstock 12, hydrogen purge gas 18 is mixed and dissolved into the melted plastic feedstock 12. Therefore, the reaction zone 20 may be provided with an agitator 28 to facilitate dissolution of the hydrogen purge gas 18 into the melted plastic feedstock 12. For a batch process, an agitator 28 may include a static mixer or another mixing mechanism to agitate and mix the melted plastic feedstock 12 and the hydrogen purge gas 18. For a flow through continuous process, an exemplary agitator 28 includes a static mixer 28 through which the mixture of melted plastic feedstock 12 and hydrogen purge gas 18 are extruded.

[0021] Heating the reaction zone 20 to the high reaction temperature for the selected duration causes thermally degradation of substantially all of the plastic feedstock 12 and formation of the wax product 14. An exemplary wax product includes paraffin and olefin compounds and may consist of only paraffins and olefins. The stoichiometric depolymerization cracking reaction typically forms paraffins and olefins in a 1:1 ratio. Further reactions of the olefins may occur, but are typically inhibited by the hydrogen or inert environment. As a result, the wax product 14 may have a paraffin:olefin ratio of about 1:1 to about 1:4:1, for example about 1:1:1. In an exemplary embodiment, the wax product 14 is formed with an average molecular weight of from about 5000 gram per mole (g/mol) to about 15000 g/mol, for example from about 6000 g/mol to about 9000 g/mol.

[0022] In an exemplary embodiment, the reaction zone 20 is provided with a catalyst, such as a depolymerization catalyst. An exemplary depolymerization catalyst may include solid acid catalysts, liquid acid catalysts, radical initiators, hydrolysis catalysts (such as nickel), zeolites, catalysts on supports such as alumina or silica and the like. Alternatively, the walls of the vessel forming the reaction zone 20 may act as a depolymerization catalyst.

[0023] After formation, the wax product 14 may be cooled to ambient temperature within the reaction zone 20 and in the purge gas environment within the reaction zone 20 and under ambient conditions after release of the purge gas, or after removal from the reaction zone 20.

[0024] The apparatus 10 of FIG. 1 may be utilized in a batch process with the reaction zone 20 forming an autoclave or other chamber, or a continuous flow process in which the reaction zone 20 is a flow-through autoclave, a pressurized flow-through reactor and/or an extruder.

[0025] FIG. 2 illustrates an alternate apparatus 10 that may be more conducive to a continuous flow process. Similar to FIG. 1, the plastic processing apparatus 10 of FIG. 2 converts a plastic feedstock 12 into a wax product 14 such as a polyethylene wax. An exemplary plastic feedstock 12 is waste plastic, including films or bags from post-consumer recycle or post-industrial recycle processes. The plastics forming the feedstock 12 may be restricted to a single type of plastic, such as polyethylene or polypropylene, or may include a mixture of plastic compounds.
[0026] As shown, the plastic feedstock 12 and the purge gas 18 are fed separately to the reaction zone 20. An exemplary purge gas 18 includes hydrogen and may include an inert gas or gases. In an exemplary embodiment, the purge gas 18 is substantially pure hydrogen. As used herein, the phrase “substantially pure hydrogen” means that the purge gas has a hydrogen content of at least about 95 wt. %. In certain embodiments, the purge gas has a hydrogen content of at least about 99 wt. %. For example, an exemplary purge gas includes less than 100 parts per million (ppm) of compounds other than hydrogen. In other embodiments, the purge gas 18 is a mixture of hydrogen and an inert gas. For example, the purge gas 18 may be a mixture of hydrogen and nitrogen, such as a mixture with a hydrogen partial pressure of at least about 0.5 atm and the nitrogen partial pressure of about 0.5 atm, such as about 1 atm. An exemplary mixture has a hydrogen partial pressure of at least about 1.5 atm, for example at least about 2.0 atm.

[0027] As illustrated in FIG. 2, the plastic feedstock 12 and purge gas 18 are independently passed through a pretreatment heater 32. In other embodiments, the purge gas 18 is introduced to the plastic feedstock 12 and both are passed through the pretreatment heater 32 together. In either case, the pretreatment heater 32 may heat the plastic feedstock 12 sufficiently to cause melting of the thermoplastic material. In an exemplary embodiment, pretreatment heater 32 is controlled to operate at a low pretreatment temperature to melt the plastic feedstock 12 without causing thermal degradation. For example, the pretreatment heater 32 may heat the plastic feedstock 12 to a temperature of about 100° C. to about 150° C., for example about 135° C. The duration of time needed for the plastic feedstock 12 to pass through the pretreatment heater 32 may be controlled so that the plastic feedstock 12 is substantially completely melted, for example, the duration of time for passage through the pretreatment heater 32 may be from about 1 minute to about 90 minutes.

[0028] In an exemplary embodiment, the pretreatment heater 32 is provided with a pretreatment agitator 36. Specifically, for an embodiment in which the plastic feedstock 12 and hydrogen purge gas 18 are introduced to one another before or in the pretreatment heater 32, the pretreatment agitator 36 may mix and facilitate dissolution of the hydrogen purge gas 18 into the plastic feedstock 12. An exemplary pretreatment agitator 36 is a static mixer through which the plastic feedstock 12 and hydrogen purge gas 18 are extruded.

[0029] While in certain embodiments, the pretreatment heater 32 may be utilized to melt the plastic feedstock 12 and to dissolve hydrogen purge gas 18 into the plastic feedstock 12, it may alternatively be used to preheat the plastic feedstock 12 and hydrogen purge gas 18 without causing melting to lower the heating burden downstream. For example, the pretreatment heater 32 may heat the plastic feedstock to from about 60° C. to about 90° C. For such embodiments, the plastic feedstock 12 and hydrogen purge gas 18 are introduced to the reaction zone 20 and are heated by heater 24 at a low pretreatment temperature to melt the plastic feedstock 12. For example, the heater 24 may heat the reaction zone 20 to a temperature of about 100° C. to about 150° C., for example about 135° C. The heater 24 may maintain the low pretreatment temperature for a selected duration of time, such as from about 1 minute to about 90 minutes. To thermally degrade substantially all of the plastic feedstock 12, hydrogen purge gas 18 is mixed and dissolved into the melted plastic feedstock 12 by agitator 28 such as a blender or other mixing mechanism or a static mixer through which the mixture of melted plastic feedstock 12 and hydrogen purge gas 18 are extruded.

[0030] After the plastic feedstock 12 is melted by pretreatment heater 32 or heater 24 and the hydrogen purge gas 18 is dissolved into the plastic feedstock 12 by agitator 36 or 28, the heater 24 is controlled to operate at a high reaction temperature to cause thermal degradation of the melted plastic feedstock 12. Non-inert gases are purged from the reaction zone 20 by the purge gas 18 to facilitate desired reactions during thermal degradation. The heater 24 may heat the reaction zone 20 including the plastic feedstock 12 and the hydrogen purge gas 18 to a high reaction temperature of about 300° C. to about 500° C., for example about 450° C. The heater 24 may maintain the high reaction temperature for a duration of time sufficient to cause thermal degradation of substantially all of the melted plastic feedstock 12, for example for a duration of about 1 minute to about 45 minutes, such as 30 minutes. In an exemplary embodiment, the plastic feedstock 12 undergoes thermal depolymerization (one of the thermal degradation processes) rather than random chain scission or side-group elimination. Oxidation of the plastic feedstock 12 is not possible as all oxygen is purged from the reaction zone by the purge gas 18.

[0031] Heating the reaction zone 20 to the high reaction temperature for the selected duration causes thermally degradation of substantially all of the plastic feedstock 12 and formation of the wax product 14. An exemplary wax product includes paraffin and olefin compounds. The stoichiometric depolymerization cracking reaction typically forms paraffins and olefins in a 1:1 ratio. Further reactions of the olefins may occur, but are typically inhibited by the hydrogen or inert environment. As a result, the wax product 14 may have a paraffin:olefin ratio of about 1:1 to about 1:4, for example about 1:1. In an exemplary embodiment, the wax product 14 is formed with an average molecular weight of from about 5000 gram per mole (g/mol) to about 15000 g/mol, for example from about 6000 g/mol to about 9000 g/mol.

[0032] In an exemplary embodiment, the reaction zone 20 in FIG. 2 is provided with a catalyst, such as a depolymerization catalyst. An exemplary depolymerization catalyst may include solid acid catalysts, liquid acid catalysts, radical initiators, hydrogenation catalysts (such as nickel), zeolites, catalysts on supports such as an alumina or silica, and the like. Additionally or alternatively, the walls of the vessel forming the reaction zone 20 may act as a depolymerization catalyst.

[0033] After formation, the wax product 14 may be cooled to ambient temperature within the reaction zone 20 and in the purge gas environment, within the reaction zone 20 and under ambient conditions after release of the purge gas, or after removal from the reaction zone 20.

[0034] FIG. 3 illustrates another embodiment of the apparatus 10 for converting plastic feedstock 12 to a wax product 14. In FIG. 3, only the plastic feedstock 12 passes through the pretreatment heater 32. It may be heated so that it is substantially completely melted, or preheated to lower the heating burden on the downstream heater 24. In an exemplary embodiment, the plastic feedstock 12 is heated to a low pretreatment temperature of about 100° C. to about 150° C., for example about 135° C. The plastic feedstock 12 may have residence time within the pretreatment heater 32 of a selected duration of time, such as from about 1 minute to about 90
minutes. As shown, no agitator is provided with the pretreatment heater 32 as no hydrogen is available to be dissolved into the plastic feedstock 12.

[0035] After the plastic feedstock 12 exits the pretreatment heater 32 it is introduced to the reaction zone 20. As shown, the purge gas 18, such as hydrogen, may be introduced to the plastic feedstock 12 upstream of the reaction zone 20. Alternatively, and as shown in FIG. 1, the purge gas 18 may be fed directly to the reaction zone 20 and introduced to the plastic feedstock 12 there. In either case, the plastic feedstock 12 and purge gas 18 are received in the reaction zone 20. Non-inert gases are purged from the reaction zone 20 by the purge gas 18.

[0036] If the plastic feedstock 12 is not melted by the pretreatment heater 32, the plastic feedstock 12 and hydrogen purge gas 18 are heated by heater 24 at a low pretreatment temperature to melt the plastic feedstock 12. For example, the heater 24 may heat the reaction zone 20 to a temperature of about 100° C. to about 150° C., for example about 135° C. The heater 24 may maintain the low pretreatment temperature for a selected duration of time, such as from about 1 minute to about 90 minutes. To thermally degrade substantially all of the plastic feedstock 12, hydrogen purge gas 18 is mixed and dissolved into the melted plastic feedstock 12 by agitator 28 such as a blender or other mixing mechanism or a static mixer through which the mixture of melted plastic feedstock 12 and hydrogen purge gas 18 are extruded.

[0037] After the plastic feedstock 12 is melted by pretreatment heater 32 or heater 24 and the hydrogen purge gas 18 is dissolved into the plastic feedstock 12 by agitator 28, the heater 24 is controlled to operate at a high reaction temperature to cause thermal degradation of the melted plastic feedstock 12. Non-inert gases are purged from the reaction zone 20 by the purge gas 18 to facilitate desired reactions during thermal degradation. The heater 24 may heat the reaction zone 20 including the plastic feedstock 12 and the hydrogen purge gas 18 to a high reaction temperature of about 300° C. to about 500° C., for example about 405° C. The heater 24 may maintain the high reaction temperature for a duration of time sufficient to cause thermal degradation of substantially all of the melted plastic feedstock 12, for example for a duration of about 1 minute to about 45 minutes, such as 30 minutes. In an exemplary embodiment, the plastic feedstock 12 undergoes thermal depolymerization (one of the thermal degradation processes) rather than random chain scission or side-group elimination. Oxidation of the plastic feedstock 12 is not possible as all oxygen is purged from the reaction zone by the purge gas 18.

[0038] Heating the reaction zone 20 to the high reaction temperature for the selected duration causes thermally degradation of substantially all of the plastic feedstock 12 and formation of the wax product 14. An exemplary wax product includes paraffin and olefin compounds. The stoichiometric depolymerization cracking reaction typically forms paraffins and olefins in a 1:1 ratio. Further reactions of the olefins may occur, but are typically inhibited by the hydrogen or inert environment. As a result, the wax product 14 may have a paraffin/olefin ratio of about 1:1 to about 1:4:1, for example about 1:1:1. In an exemplary embodiment, the wax product 14 is formed with an average molecular weight of from about 5000 gram per mole (g/mol) to about 15000 g/mol, for example from about 6000 g/mol to about 9000 g/mol.

[0039] In an exemplary embodiment, the reaction zone 20 in FIG. 3 is provided with a catalyst, such as a depolymerization catalyst. An exemplary depolymerization catalyst may include solid acid catalysts, liquid acid catalysts, radical initiators, hydrogenation catalysts (such as nickel), zeolites, catalysts on supports such as an alumina or silica and the like. Additionally or alternatively, the walls of the vessel forming the reaction zone 20 may act as a depolymerization catalyst.

[0040] After formation, the wax product 14 may be cooled to ambient temperature within the reaction zone 20 and in the purge gas environment, within the reaction zone 20 and under ambient conditions after release of the purge gas, or after removal from the reaction zone 20.

[0041] The following is an example of a process for converting plastic to wax. The example is provided for illustrative purposes only and is not meant to limit the various embodiments contemplated herein in any way.

**EXAMPLES**

[0042] In a first example of an embodiment of a process for converting plastic to wax, 50 grams (g) of low density polyethylene (LDPE) was introduced to a stainless steel autoclave. The autoclave environment was purged with hydrogen at 40 standard cubic centimeters per minute (sccm) and the autoclave was heated to 135° C. for 60 minutes to melt the LDPE. Thereafter, the melted LDPE was heated to 405° C. for 30 minutes causing depolymerization of the LDPE under the continued hydrogen purge. The autoclave was then cooled to ambient temperature and the product wax was recovered. The composition of the product wax formed with hydrogen is set forth below in the TABLE.

[0043] In a second example of an embodiment of a process for converting plastic to wax, 50 or 20 grams (g) of low density polyethylene (LDPE) was introduced to a stainless steel autoclave. The autoclave environment was purged with nitrogen at 40 standard cubic centimeters per minute (sccm) and the autoclave was heated to 135° C. for 60 minutes to melt the LDPE. Thereafter, the melted LDPE was heated to 405° C. for 30 minutes causing depolymerization of the LDPE under the continued nitrogen purge. The autoclave was then cooled to ambient temperature and the product wax was recovered. The composition of the product wax formed without hydrogen and with the autoclave purged with only nitrogen is set forth below in the TABLE.

<table>
<thead>
<tr>
<th>TABLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purge Gas</td>
</tr>
<tr>
<td>LDPE Loading (g)</td>
</tr>
<tr>
<td>Maximum Autoclave Temp.</td>
</tr>
<tr>
<td>Autoclave Time at 405° C</td>
</tr>
<tr>
<td>Product Wax Recovery (%)</td>
</tr>
<tr>
<td>Product Wax Melting Point</td>
</tr>
<tr>
<td>Average Molecular Weight</td>
</tr>
<tr>
<td>Number Average Molecular Weight</td>
</tr>
<tr>
<td>Viscosity (centipoise at 140° C)</td>
</tr>
</tbody>
</table>

[0044] As seen in the TABLE, the process using a hydrogen purge gas results in a product wax having an off white visual color or appearance, which is commercially preferable for certain uses.

[0045] As described herein, methods for converting plastic to wax have been provided. In exemplary embodiments, plas-
tic is depolymerized in a hydrogen environment to form a product wax including paraffins and olefins.

[0046] While at least one exemplary embodiment has been presented in the foregoing detailed description, it should be appreciated that a vast number of variations exist. It should also be appreciated that the exemplary embodiment or exemplary embodiments are only examples, and are not intended to limit the scope, applicability, or configuration of the claimed subject matter in any way. Rather, the foregoing detailed description will provide those skilled in the art with a convenient road map for implementing an exemplary embodiment or embodiments. It being understood that various changes may be made in the function and arrangement of elements described in an exemplary embodiment without departing from the scope set forth in the appended claims.

What is claimed is:

1. A method for converting a waste plastic to wax, the method comprising the steps of:
   introducing the waste plastic into a chamber;
   adding hydrogen to the chamber;
   heating the waste plastic and hydrogen sufficiently to thermally depolymerize the waste plastic to form a wax product comprising paraffin and olefin compounds.

2. The method of claim 1 further comprising providing the chamber with a depolymerization catalyst selected from solid acid catalysts, liquid acid catalysts, radical initiators, hydrogenation catalysts, zeolites, and catalysts on supports.

3. The method of claim 1 wherein:
   melting the waste plastic comprises heating the waste plastic to a temperature of about 100°C to about 150°C; and
   heating the waste plastic and hydrogen comprises heating the waste plastic and hydrogen to a temperature of from about 300°C to about 500°C.

4. The method of claim 1 wherein heating the waste plastic and hydrogen comprises forming a polyethylene wax product comprising paraffin and olefin compounds in a paraffin-olefin ratio of at least about 1:1 and having a weight average molecular weight of from about 5000 gram per mole (g/mol) to about 15000 g/mol.

5. The method of claim 1 wherein introducing the waste plastic into a chamber comprises introducing the waste plastic to a chamber in a batch process.

6. The method of claim 1 wherein hydrogen is added to the chamber after the waste plastic is introduced into the chamber.

7. A method for converting a plastic to wax, the method comprising the steps of:
   contacting the plastic with hydrogen; and
   heating the plastic and the hydrogen sufficiently to thermally degrade the plastic to form a wax product with a Saybolt color (ASTM D156) of at least about 0.

8. The method of claim 7 wherein heating the plastic and the hydrogen sufficiently to thermally degrade the plastic comprises forming the wax product with a Saybolt color (ASTM D156) of at least about 20.

9. The method of claim 7 wherein heating the plastic and the hydrogen comprises thermally degrading the plastic to form a wax product having an average molecular weight of from about 5000 gram per mole (g/mol) to about 15000 g/mol.

10. The method of claim 7 wherein heating the plastic and the hydrogen comprises thermally degrading the plastic to form a wax product having an average molecular weight of from about 6000 gram per mole (g/mol) to about 9000 g/mol.

11. The method of claim 7 wherein heating the plastic and the hydrogen comprises thermally degrading the plastic to form a wax product comprising paraffin and olefin compounds in a paraffin-olefin ratio of at least about 1:1.

12. The method of claim 7 wherein heating the plastic and the hydrogen comprises heating the plastic and the hydrogen to a temperature of about 300°C to about 500°C.

13. The method of claim 7 further comprising melting the plastic before contacting the plastic with hydrogen.

14. The method of claim 7 further comprising melting the plastic after contacting the plastic with hydrogen.

15. The method of claim 7 further comprising melting the plastic at a temperature of about 100°C to about 150°C.

16. The method of claim 7 further comprising agitating the plastic after contacting the plastic with hydrogen to promote dissolution of the hydrogen into the plastic.

17. The method of claim 7 wherein contacting the plastic with hydrogen comprises locating the plastic in a hydrogen environment, and wherein the method further comprises maintaining a hydrogen partial pressure in the hydrogen environment of at least about 0.5 atmospheres (atm).

18. The method of claim 7 wherein contacting the plastic with hydrogen comprises:
   introducing the plastic to a chamber; and
   filling the chamber with the hydrogen and an inert gas.

19. The method of claim 7 wherein contacting the plastic with hydrogen comprises locating the plastic in an environment comprising substantially pure hydrogen.

20. A method for converting waste plastic to polyethylene wax, the method comprising the steps of:
   melting the waste plastic;
   dissolving hydrogen into the waste plastic; and
   thermally depolymerizing the waste plastic in the presence of the hydrogen to form a polyethylene wax product comprising paraffin and olefin compounds.

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