

**MILD CATALYTIC METHOD TO SELECTIVELY PRODUCE METHANE GAS
FUEL FROM PLASTIC WASTE**

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of priority of Singapore application No. 10202302519X filed on 8 September 2023, the contents of it being hereby incorporated by reference in its entirety for all purposes.

TECHNICAL FIELD

[0002] The present disclosure generally relates to a catalytic method of producing methane gas fuel from plastic waste. In particular, the present disclosure relates to a catalytic method of producing methane gas fuel from plastic waste under mild conditions, in the presence of a Rh-based catalyst.

BACKGROUND

[0003] The widespread applications of plastics in automotive, packaging, building, construction and single-use protective equipment such as masks have led to a rapid increase in plastic usage and the generation of plastic waste. However, plastic waste cannot be easily broken down by microorganisms and must be destroyed by incineration, a process that emits greenhouse gases, including carbon dioxide, contributing to global warming. This issue is particularly pressing for small countries like Singapore, which have limited land for landfills. Addressing the problem of plastic waste is crucial for reducing environmental harm and one possible way is to transform it into valuable products that are required by the society, such as methane gas fuel.

[0004] Currently, natural gas is imported to generate electricity for daily activities. The use of methane gas fuel produced from plastic waste can reduce the demand for imported natural gas, ensuring stability in the nation's electricity supply. Moreover, methane cracking can generate hydrogen gas, which can be utilized to produce sustainable aviation fuel and electricity.

However, conventional methods for converting plastic waste into methane gas typically involve pyrolysis, which requires harsh reaction conditions, including heating plastic waste in the absence of oxygen to a temperature ranging from 400°C to 600°C.

[0005] It is therefore desirable to provide a method of producing methane gas fuel from plastic waste which seeks to address at least one of the problems described hereinabove, or at least to provide an alternative.

SUMMARY

[0006] In accordance with a first aspect of the present disclosure, a catalytic method of producing methane gas fuel from plastic waste is provided. The method comprises subjecting plastic waste to hydrogenolysis under mild conditions in the presence of a Rh-based catalyst to obtain methane gas fuel, wherein the mild conditions include heating the plastic waste at a temperature of less than 300°C, under 2×10^6 Pa of hydrogen pressure, and within 3 hours; and wherein the Rh-based catalyst is rhodium supported on a material selected from the group consisting of carbon, titanium dioxide (TiO_2) and lanthanum phosphate ($\text{La}(\text{PO}_4)_3$).

[0007] In some embodiments, the hydrogenolysis is performed in the absence of a solvent.

[0008] In accordance with a second aspect of the present disclosure, a Rh-based catalyst for use in producing methane gas fuel from plastic waste is provided. The Rh-based catalyst comprises rhodium supported on a material selected from the group consisting of carbon, titanium dioxide (TiO_2) and lanthanum phosphate ($\text{La}(\text{PO}_4)_3$).

DESCRIPTION

[0009] The following description sets forth exemplary methods, parameters, and the like. The embodiments are described in sufficient detail to enable those skilled in the art to practise the invention. Other embodiments may be utilized, and structural and logical changes may be made without departing from the scope of the invention. The various embodiments are not

necessarily mutually exclusive, as some embodiments can be combined with one or more other embodiments to form new embodiments.

[0010] Features that are described in the context of an embodiment may correspondingly be applicable to the same or similar features in the other embodiments. Features that are described in the context of an embodiment may correspondingly be applicable to the other embodiments, even if not explicitly described in these other embodiments. Furthermore, additions and/or combinations and/or alternatives as described for a feature in the context of an embodiment may correspondingly be applicable to the same or similar feature in the other embodiments.

[0011] In the context of various embodiments, the articles “a”, “an” and “the” as used with regard to a feature or element include a reference to one or more of the features or elements.

[0012] In the context of various embodiments, the term “about” or “approximately” as applied to a numeric value encompasses the exact value and a reasonable variance, e.g. within 10% of the specified value.

[0013] As used herein, the term “and/or” includes any and all combinations of one or more of the associated listed items.

[0014] By “comprising” it is meant including, but not limited to, whatever follows the word “comprising”. Thus, use of the term “comprising” indicates that the listed elements are required or mandatory, but that other elements are optional and may or may not be present.

[0015] By “consisting of” is meant including, and limited to, whatever follows the phrase “consisting of”. Thus, the phrase “consisting of” indicates that the listed elements are required or mandatory, and that no other elements may be present.

[0016] The present disclosure relates to a highly selective catalytic method for producing methane gas fuel from plastic waste.

[0017] The term “plastic waste” as used herein refers to discarded, unused, or unwanted plastic material that has reached the end of its useful life and is no longer needed. This can include items such as plastic packaging, bottles, bags, containers, and other single-use plastic

products that are disposed of after use. Plastics are made from a wide range of organic polymers including, but are not limited to, polypropylene (PP), polyethylene (PE), polyvinyl chloride (PVC), polystyrene (PS), polyethylene terephthalate (PET), etc. In some preferred embodiments, the plastic waste is polypropylene (PP).

[0018] The term “methane gas fuel” as used herein refers to saturated hydrocarbon with a chemical formula CH_4 .

[0019] According to a first aspect, the catalytic method comprises subjecting plastic waste to hydrogenolysis under mild conditions in the presence of a Rh-based catalyst to obtain methane gas fuel, wherein the mild conditions include heating the plastic waste at a temperature of less than 300°C , under 2×10^6 Pa (20 bar) of hydrogen pressure, and within 3 hours; and wherein the Rh-based catalyst is rhodium supported on a material selected from the group consisting of carbon, titanium dioxide (TiO_2) and lanthanum phosphate ($\text{La}(\text{PO}_4)_3$).

[0020] The term “carbon” as used herein refers to mesoporous carbon, with pore sizes ranging from 2 to 50 nm.

[0021] In some embodiments, the lanthanum phosphate exists in crystalline form. Lanthanum phosphate is employed as a catalyst support due to its thermal stability and chemical inertness under reaction conditions.

[0022] The term “Rh-based catalyst” as used herein refers to a catalyst primarily consists of rhodium (Rh) as the active metal component. In some embodiments, the Rh-based catalyst comprises rhodium nanoparticles. In other embodiments, the Rh-based catalyst comprises agglomerates of rhodium nanoparticles.

[0023] In some embodiments, the hydrogenolysis is performed in the absence of a solvent. Performing hydrogenolysis without a solvent helps to reduce operational costs and increase efficiency as there are no solvent waste to be disposed of after the generation of the methane gas fuel by the method of the present disclosure.

[0024] In some embodiments, the catalyst has a metal loading ranging from 0.5 to 3 wt%, based on the total weight of the catalyst. In some embodiments, the amount of Rh (rhodium) loaded onto the support material to amount of support material is in a ratio of 1:20 to 1:5.

[0025] In some embodiments, the plastic waste is a single source plastic selected from the group consisting of polypropylene (PP), polyethylene (PE), polyvinyl chloride (PVC), polystyrene (PS) and polyethylene terephthalate (PET). In some preferred embodiments, the plastic waste is polypropylene (PP).

[0026] The method of the present disclosure yields gaseous products comprising mainly methane gas fuel and other gaseous products containing carbon compounds ranging from C₂-C₄. The method achieves a relatively high yield of 94% to 98% of gaseous products (Table 1, entries 6, 18 and 20), with the remainder comprising oil products and solid residue. In some embodiments, the method produces 71% to 81% w/w of methane gas fuel from the plastic waste. The remaining gaseous products consist mainly of ethane gas.

[0027] Unlike the conventional methods, the method of the present disclosure achieves a relatively higher yield of methane gas fuel using mild reaction conditions. This is in contrast to some conventional methods that may require harsher conditions (for example, a temperature of more than 500°C) and longer reaction times to achieve similar results. The technology of the present disclosure provides an alternative approach to managing plastics waste, supporting the achievement of a 'zero waste' goal.

[0028] According to a second aspect of the present disclosure, a Rh-based catalyst for use in producing methane gas fuel from plastic waste is provided. The Rh-based catalyst comprises rhodium supported on a material selected from the group consisting of carbon, titanium dioxide (TiO₂) and lanthanum phosphate (La(PO₄)₃).

[0029] In some embodiments, the carbon is mesoporous carbon, with pore sizes ranging from 2 to 50 nm.

[0030] In some embodiments, the Rh-based catalyst comprises rhodium nanoparticles. In other embodiments, the Rh-based catalyst comprises of agglomerates of rhodium nanoparticles.

[0031] In some embodiments, the Rh-based catalyst is rhodium supported on lanthanum phosphate, represented by Rh1/LaP₃. In other embodiments, the Rh-based catalyst is rhodium supported on carbon, represented by Rh1/carbon. In other embodiments, the Rh-based catalyst is rhodium supported on titanium dioxide, represented by Rh1/TiO₂.

[0032] In some embodiments, the catalyst is prepared by mixing a rhodium(III) nitrate (Rh(NO₃)₃) solution precursor with carbon and subjecting the mixture to rotavap to obtain a solid residue. The solid residue is dried before it is calcined in a furnace to obtain Rh/ carbon. The final active catalyst, Rh1/carbon, is then obtained by the reduction of the solid catalyst under H₂ gas.

[0033] In some embodiments, the catalyst is prepared by mixing a rhodium(III) nitrate (Rh(NO₃)₃) solution precursor with titanium dioxide (TiO₂) and subjecting the mixture to rotavap to obtain a solid residue. The solid residue is dried before it is calcined in a furnace to obtain Rh/ TiO₂. The final active catalyst, Rh1/TiO₂, is then obtained by the reduction of the solid catalyst under H₂ gas.

[0034] In some embodiments, the catalyst is prepared by mixing a rhodium(III) nitrate (Rh(NO₃)₃) solution precursor with lanthanum phosphate (La(PO₄)₃) and subjecting the mixture to rotavap to obtain a solid residue. The solid residue is dried before it is calcined in a furnace to obtain Rh/ LaP₃. The final active catalyst, Rh1/LaP₃, is then obtained by the reduction of the solid catalyst under H₂ gas.

[0035] In some embodiments, the catalyst has a metal loading ranging from 0.5 to 3 wt% based on the total weight of the catalyst. This metal loading is several times lower than some catalysts known in the state of the art.

[0036] The catalyst of the present disclosure offers several advantages including, its reusability while maintaining high selectivity and yield of methane gas fuel. The methane gas

fuel can be used to generate hydrogen gas which can be used to facilitate the hydrocracking of polypropylene to produce sustainable aviation fuel.

[0037] The catalyst and method of the present disclosure offer a significant breakthrough in the conversion of plastic waste into valuable fuels. Achieving an impressive yield of 71% to 81% w/w of methane gas fuel from plastic waste, this technology holds promise for reducing plastic waste and contributing to a circular economy. The method also reduces overall operating costs and streamlines production of methane gas fuel.

[0038] To facilitate a better understanding of the present disclosure, the following examples of specific embodiments are given. In no way should the following examples be read to limit or define the entire scope of the disclosure. One skilled in the art will recognize that the examples set out below are not an exhaustive list of the embodiments of this disclosure.

EXAMPLES

Example 1

[0039] Preparation of the catalyst, Rh1/LaP₃

[0040] The catalyst, Rh1/LaP₃, was prepared by the addition of Rh(NO₃)₃ (0.3 mmol) solution precursor to 20 mL of deionized water in a round bottom flask and stirred for 30 mins. Lanthanum phosphate (LaP₃) (1g) was subsequently added to the solution and the mixture was stirred for 3 hours at room temperature. The mixture was then subjected to rotavap to remove the deionized water to obtain a solid residue. The solid residue was dried in the oven at 80 °C overnight. The dried solid was then calcined in a box furnace at 500 °C, 10 K/min for 3 hours to obtain Rh1/ LaP₃. The final active catalyst, Rh1/LaP₃ was then obtained by the reduction of the solid catalyst under H₂ gas at 300 °C, 1 °C/min for 30 mins.

Example 2

[0041] Preparation of the catalyst, Rh1/carbon

[0042] The catalyst, Rh1/carbon, was prepared by the addition of Rh(NO₃)₃ (0.3 mmol) solution precursor to 20 mL of deionized water in a round bottom flask and stirred for 30 mins.

Carbon (1g) was subsequently added to the solution and the mixture was stirred for 3 hours at room temperature. The mixture was then subjected to rotavap to remove the deionized water to obtain a solid residue. The solid residue was dried in the oven at 80 °C overnight. The dried solid was then calcined in the box furnace at 500 °C, 10 K/min for 3 hours to obtain Rh1/ carbon. The final active catalyst, Rh1/carbon was then obtained by the reduction of the solid catalyst under H₂ gas at 300 °C, 1 °C/min for 30 mins.

Example 3

[0043] Preparation of the catalyst, Rh1/TiO₂

[0044] The catalyst, Rh1/TiO₂, was prepared by the addition of Rh(NO₃)₃ (0.3 mmol) solution precursor to 20 mL of deionized water in a round bottom flask and stirred for 30 mins. TiO₂ (1g) was subsequently added to the solution and the mixture was stirred for 3 hours at room temperature. The mixture was then subjected to rotavap to remove the deionized water to obtain a solid residue. The solid residue was dried in the oven at 80 °C overnight. The dried solid was then calcined in the box furnace at 500 °C, 10 K/min for 3 hours to obtain Rh1/ TiO₂. The final active catalyst, Rh1/TiO₂ was then obtained by the reduction of the solid catalyst under H₂ gas at 300 °C, 1 °C/min for 30 mins.

Example 4

[0045] Preparation of catalysts supported on lanthanum phosphate

[0046] Other catalysts supported on lanthanum phosphate (La(PO₄)₃) were prepared. The catalysts were prepared by adding ammonium molybdate tetrahydrate, ((NH₄)₆Mo₇O₂₄·4H₂O) (0.20 mmol) to 20 mL of deionized water in a round bottom flask and stirring the mixture for about 30 mins to fully dissolve the precursor. 1 g of lanthanum phosphate was added to the solution and the mixture was stirred for 3 hours at room temperature. The mixture was then subjected to rotavap to remove the deionized water to obtain a solid residue. The solid residue was dried in an oven at 80 °C overnight. The dried solid was then calcined in the box furnace at 500 °C, 10 K/min for 3 hours to obtain MoO_x/LaP₃ (Table 1, entry 8).

[0047] $\text{Rh}(\text{NO}_3)_3$ (0.3 mmol) solution precursor was added to 20 mL of deionized water in a round bottom flask and stirred for about 30 mins. 1 g of $\text{MoO}_x/\text{LaP}_3$ was added to the solution and the mixture was stirred for 3 hours at room temperature. The mixture was then subjected to rotavap to remove the deionized water to obtain a solid residue. The solid residue was dried in the oven at 80 °C overnight. The dried solid was then calcined in the box furnace at 500 °C, 10 K/min for 3 hours to obtain $\text{Rh1MoO}_x/\text{LaP}_3$ (Table 1, entry 1). The final catalyst $\text{Rh1MoO}_x/\text{LaP}_3$ was obtained by the reduction of $\text{Rh1MoO}_x/\text{LaP}_3$ under hydrogen gas at 300 °C, at 1°C/min for 30 mins.

[0048] The $\text{Rh2MoO}_x/\text{LaP}_3$ catalyst (Table 1, entry 2) was prepared by adding ammonium molybdate tetrahydrate, $((\text{NH}_4)_6\text{Mo}_7\text{O}_{24} \cdot 4\text{H}_2\text{O})$ (0.20 mmol) to 20 mL of deionized water in a round bottom flask and stirring the mixture for about 30 mins to fully dissolve the precursor. 1 g of lanthanum phosphate was added to the solution and the mixture was stirred for 3 hours at room temperature. The mixture was then subjected to rotavap to remove the deionized water to obtain a solid residue. The solid residue was dried in an oven at 80 °C overnight. The dried solid was then calcined in the box furnace at 500 °C, 10 K/min for 3 hours to obtain $\text{MoO}_x/\text{LaP}_3$. $\text{Rh}(\text{NO}_3)_3$ (0.22 mmol) solution precursor was added to 20 mL of deionized water in a round bottom flask and stirred for about 30 mins. 1 g of $\text{MoO}_x/\text{LaP}_3$ was added to the solution and the mixture was stirred for 3 hours at room temperature. The mixture was then subjected to rotavap to remove the deionized water to obtain a solid residue. The solid residue was dried in the oven at 80 °C overnight. The dried solid was then calcined in the box furnace at 500 °C, 10 K/min for 3 hours to obtain $\text{Rh2MoO}_x/\text{LaP}_3$. The final catalyst $\text{Rh2MoO}_x/\text{LaP}_3$ was obtained by the reduction of $\text{Rh2MoO}_x/\text{LaP}_3$ under hydrogen gas at 300 °C, at 1°C/min for 30 mins.

[0049] The $\text{Rh3MoO}_x/\text{LaP}_3$ catalyst (Table 1, entry 3) was prepared by adding ammonium molybdate tetrahydrate, $((\text{NH}_4)_6\text{Mo}_7\text{O}_{24} \cdot 4\text{H}_2\text{O})$ (0.20 mmol) to 20 mL of deionized water in a round bottom flask and stirring the mixture for about 30 mins to fully dissolve the precursor. 1 g of lanthanum phosphate was added to the solution and the mixture was stirred for 3 hours at

room temperature. The mixture was then subjected to rotavap to remove the deionized water to obtain a solid residue. The solid residue was dried in an oven at 80 °C overnight. The dried solid was then calcined in the box furnace at 500 °C, at 10 K/min for 3 hours to obtain $\text{MoO}_x/\text{LaP}_3$. $\text{Rh}(\text{NO}_3)_3$ (0.18 mmol) solution precursor was added to 20 mL of deionized water in a round bottom flask and stirred for about 30 mins. 1 g of $\text{MoO}_x/\text{LaP}_3$ was added to the solution and the mixture was stirred for 3 hours at room temperature. The mixture was then subjected to rotavap to remove the deionized water to obtain a solid residue. The solid residue was dried in the oven at 80 °C overnight. The dried solid was then calcined in the box furnace at 500 °C, 10 K/min for 3 hours to obtain $\text{Rh}_3\text{MoO}_x/\text{LaP}_3$. The final catalyst $\text{Rh}_3\text{MoO}_x/\text{LaP}_3$ was obtained by the reduction of $\text{Rh}_3\text{MoO}_x/\text{LaP}_3$ under hydrogen gas at 300 °C, at 1°C/min for 30 mins.

[0050] The $\text{Rh}_4\text{MoO}_x/\text{LaP}_3$ catalyst (Table 1, entry 4) was prepared by adding ammonium molybdate tetrahydrate, $((\text{NH}_4)_6\text{Mo}_7\text{O}_{24} \cdot 4\text{H}_2\text{O})$ (0.20 mmol) to 20 mL of deionized water in a round bottom flask and stirring the mixture for about 30 mins to fully dissolve the precursor. 1 g of lanthanum phosphate was added to the solution and the mixture was stirred for 3 hours at room temperature. The mixture was then subjected to rotavap to remove the deionized water to obtain a solid residue. The solid residue was dried in an oven at 80 °C overnight. The dried solid was then calcined in the box furnace at 500 °C, 10 K/min for 3 hours to obtain $\text{MoO}_x/\text{LaP}_3$. $\text{Rh}(\text{NO}_3)_3$ (0.08 mmol) solution precursor was added to 20 mL of deionized water in a round bottom flask and stirred for about 30 mins. 1 g of $\text{MoO}_x/\text{LaP}_3$ was added to the solution and the mixture was stirred for 3 hours at room temperature. The mixture was then subjected to rotavap to remove the deionized water to obtain a solid residue. The solid residue was dried in the oven at 80 °C overnight. The dried solid was then calcined in the box furnace at 500 °C, 10 K/min for 3 hours to obtain $\text{Rh}_4\text{MoO}_x/\text{LaP}_3$. The final catalyst $\text{Rh}_4\text{MoO}_x/\text{LaP}_3$ was obtained by the reduction of $\text{Rh}_4\text{MoO}_x/\text{LaP}_3$ under hydrogen gas at 300 °C, at 1°C/min for 30 mins.

[0051] The Rh₅MoO_x/LaP₃ catalyst (Table 1, entry 5) was prepared by adding ammonium molybdate tetrahydrate, ((NH₄)₆Mo₇O₂₄·4H₂O) (0.20 mmol) to 20 mL of deionized water in a round bottom flask and stirring the mixture for about 30 mins to fully dissolve the precursor. 1 g of lanthanum phosphate was added to the solution and the mixture was stirred for 3 hours at room temperature. The mixture was then subjected to rotavap to remove the deionized water to obtain a solid residue. The solid residue was dried in an oven at 80 °C overnight. The dried solid was then calcined in the box furnace at 500 °C, 10 K/min for 3 hours to obtain MoO_x/LaP₃. Rh(NO₃)₃ (0.05 mmol) solution precursor was added to 20 mL of deionized water in a round bottom flask and stirred for about 30 mins. 1 g of MoO_x/LaP₃ was added to the solution and the mixture was stirred for 3 hours at room temperature. The mixture was then subjected to rotavap to remove the deionized water to obtain a solid residue. The solid residue was dried in the oven at 80 °C overnight. The dried solid was then calcined in the box furnace at 500 °C, 10 K/min for 3 hours to obtain Rh₅MoO_x/LaP₃. The final catalyst Rh₅MoO_x/LaP₃ was obtained by the reduction of Rh₅MoO_x/LaP₃ under hydrogen gas at 300 °C, at 1 °C/min for 30 mins.

Example 5

[0052] Preparation of catalysts supported on other materials

[0053] Other catalysts supported on meso-Si were prepared by the addition of ammonium molybdate tetrahydrate, ((NH₄)₆Mo₇O₂₄·4H₂O) (0.20 mmol) to 20 mL of deionized water in a round bottom flask and stirred for 30 mins to fully dissolve the precursor. Meso-Si (1g) was subsequently added to the solution and the mixture was stirred for 3 hours at room temperature. The mixture was then subjected to rotavap to remove the deionized water to obtain a solid residue. The solid residue was dried in the oven at 80 °C overnight. The dried solid was then calcined in the box furnace at 500 °C, 10 K/min for 3 hours to obtain MoO_x/ meso-Si. Rh(NO₃)₃ (0.3, 0.08 mmol) solution precursor was added to 20 mL of deionized water in a round bottom flask and stirred for 30 mins. MoO_x/ meso-Si (1g) was subsequently added to the solution and the mixture was stirred for 3 hours at room temperature. The mixture was then subjected to

rotavap to remove the deionized water to obtain a solid residue. The solid was dried in the oven at 80 °C overnight. The dried solid was then calcined in the box furnace at 500 °C, 10 K/min for 3 hours to obtain Rh1MoO_x/ meso-Si (Table 1, entry 14) and Rh4MoO_x/ meso-Si (Table 1, entry 15). The final active catalyst, was then obtained by the reduction of the solid catalyst under H₂ gas at 300 °C, 1 °C/min for 30 mins.

[0054] Other catalysts supported on meso-Al-Si, respectively were prepared by the addition of ammonium molybdate tetrahydrate, ((NH₄)₆Mo₇O₂₄·4H₂O) (0.20 mmol) to 20 mL of deionized water in a round bottom flask and stirred for 30 mins to fully dissolve the precursor. Meso-Al-Si (1g) was subsequently added to the solution and the mixture was stirred for 3 hours at room temperature. The mixture was then subjected to rotavap to remove the deionized water to obtain a solid residue. The solid residue was dried in an oven at 80 °C overnight. The dried solid was then calcined in a box furnace at 500 °C, 10 K/min for 3 hours to obtain MoO_x/ meso-Al-Si. Rh(NO₃)₃ (0.3, 0.08 mmol) solution precursor was added to 20 mL of deionized water in a round bottom flask and stirred for 30 mins. MoO_x/ meso-Al-Si (1g) was subsequently added to the solution and the mixture was stirred for 3 hours at room temperature. The mixture was then subjected to rotavap to remove the deionized water to obtain a solid residue. The solid was dried in the oven at 80 °C overnight. The dried solid was then calcined in the box furnace at 500 °C, 10 K/min for 3 hours to obtain RhMoO_x/ meso-Al-Si. The final active catalyst, Rh1MoO_x/meso-Al-Si (Table 1, entry 10) and Rh4MoO_x/meso-Al-Si (Table 1, entry 11), was then obtained by the reduction of the solid catalyst under H₂ gas at 300 °C, 1 °C/min for 30 mins.

Example 6

[0055] Converting polypropylene (PP) waste into methane gas fuel

[0056] The hydrogenolysis of polypropylene (PP) waste was performed in a 160 mL Parr autoclave with an overhead mechanical stirrer attached to an impeller. Polypropylene (PP) (approx. 0.9 to 1.1 g) was added to the catalyst, Rh1/LaP₃ (approx. 0.9 – 1.1 g) and was

subjected to three cycles of purging with argon and hydrogen gas. The Parr reactor was then pressurized with H₂ (20 bar) and heated at 300 °C for 3 hours with stirring. The reactor was allowed to cool slowly, and the pressure difference was noted before the gas in the headspace of the reactor was collected in a gas bag. 20 mL of dichloromethane (DCM) was added to the crude mixture and the liner was washed with DCM to prevent any loss of oil product. The resulting mixture was then filtered to remove the solid residue. The solid residue was dried in an oven at 70 °C overnight. The solid residue was subjected to pyrolysis gas chromatography-mass spectrometry analysis to obtain the distribution of hydrocarbons. The gas collected was analyzed by GC-FID and GC-TCD for quantification. Any clear liquid filtrate was subjected to rotavap to remove all DCM present to obtain a colorless oil product and the final mass of the oil was recorded. A known quantity of internal standard, octacosane (avg. 0.01 mmol) was added to the oil mixture (0.2-0.3 g) in 3 mL of DCM. The oil product was subsequently analysed by GC-MS, GC-FID, pyrolysis gas chromatography-mass spectrometry and high temperature gel Permeation chromatography (HT-GPC). These procedures were repeated using the other catalysts. The results obtained are as shown in Table 1.

[0057] These procedures were repeated using the other catalysts. The results are as shown in Table 1.

[0058] Table 1: Catalytic conversion of polypropylene

Entry	Catalyst	Conversion (%)	Yield (%)		
			Gas	Oil	Solid Residue
1	Rh1MoO ₄ /LaP ₃	98	88	10	2
2	Rh2MoO ₄ /LaP ₃	97	88	9	3
3	Rh3MoO ₄ /LaP ₃	97	59	37	3
4	Rh4MoO ₄ /LaP ₃	89	11	78	11
5	Rh5MoO ₄ /LaP ₃	37	6	31	63
6	Rh1/LaP ₃	99	98	0.97	0.87
7	Rh4/LaP ₃	91	36	55	9
8	MoO ₃ /LaP ₃	7	4	3	93
9	LaP ₃	55	7	49	45

10	Rh1MoO _x /meso-Al-Si	100	78	22	0
11	Rh4MoO _x /meso-Al-Si	96	2	94	4
12	Rh4MoO _x /Al-SBA-15	98	26	72	2
13	Rh4/meso-Al-Si	92	38	54	8
14	Rh1MoO _x /meso-Si	100	38	62	0
15	Rh4MoO _x /meso-Si	80	10	70	20
16	Rh1/meso-Si	100	51	49	0
17	Rh4/meso-Si	91	7	84	9
18	Rh1/carbon	100	95	5	0
19	Rh4MoO _x /carbon	74	10	64	26
20	Rh1/TiO ₂	100	94	6	0

[0059] The reaction conditions employed for converting the plastic waste, polypropylene (PP) into methane gas fuel in the examples described hereinabove include heating the plastic waste at a temperature of less than 300°C, under a hydrogen pressure of 2×10^6 Pa (20 bar) within 3 hours. The results in Table 1 show that the use of Rh1/LaP₃, Rh1/TiO₂ or Rh1/carbon as the catalyst in the hydrogenolysis process can achieve a relatively high yield of 98%, 94% and 95%, respectively of gaseous products. The yield and selectivity of methane gas fuel makes up an average of 71% to 81% w/w of the gaseous products, while the remaining consists mainly of ethane gas. This is one of the highest yields towards the selective production of methane gas fuel from plastic waste among some of the methods known in the state of the art which require much harsher reaction conditions (for example, require a temperature of more than 500°C) and longer reaction time to achieve similar results.

[0060] Although embodiments of the invention have been shown and described, the invention is not limited to the described embodiments. Instead, it would be appreciated by those skilled in the art that various modifications and variations can be made to the embodiments of the invention without departing from the scope of the invention, the scope of which is set forth in the following claims.

Claims

1. A catalytic method of producing methane gas fuel from plastic waste, the method comprising:

subjecting plastic waste to hydrogenolysis under mild conditions in the presence of a Rh-based catalyst to obtain methane gas,

wherein the mild conditions include heating the plastic waste at a temperature of less than 300°C, under 2×10^6 Pa of hydrogen pressure, and within 3 hours; and

wherein the Rh-based catalyst comprises rhodium supported on a material selected from the group consisting of carbon, titanium dioxide (TiO₂) and lanthanum phosphate.

2. The catalytic method of claim 1, wherein the Rh-based catalyst is rhodium supported on lanthanum phosphate, represented by Rh1/LaP₃.

3. The catalytic method of claim 1, wherein the Rh-based catalyst is rhodium supported on carbon, represented by Rh1/carbon.

4. The catalytic method of claim 1, wherein the Rh-based catalyst is rhodium supported on titanium dioxide, represented by Rh1/TiO₂.

5. The catalytic method of claim 1, wherein the hydrogenolysis is performed in the absence of a solvent.

6. The catalytic method of claim 1, wherein the Rh-based catalyst has a metal loading ranging from 0.5 to 3 wt% based on the total weight of the Rh-based catalyst.

7. The catalytic method of claim 1, wherein the plastic waste is a single source plastic selected from the group consisting of polypropylene (PP), polyethylene (PE), polyvinyl chloride (PVC), polystyrene (PS) and polyethylene terephthalate (PET).
8. The catalytic method of claim 1, wherein the method produces 71% to 81% w/w of methane gas fuel from the plastic waste.
9. A Rh-based catalyst for use in producing methane gas fuel from plastic waste, the Rh-based catalyst comprising rhodium supported on a material selected from the group consisting of carbon, titanium dioxide and lanthanum phosphate.
10. The Rh-based catalyst of claim 9, wherein the Rh-based catalyst is rhodium supported on the lanthanum phosphate, represented by Rh1/LaP₃.
11. The Rh-based catalyst of claim 9, wherein the Rh-based catalyst is rhodium supported on the carbon, represented by Rh1/carbon.
12. The Rh-based catalyst of claim 9, wherein the Rh-based catalyst is rhodium supported on the titanium dioxide, represented by Rh1/TiO₂.
13. The Rh-based catalyst of claim 9, wherein the Rh-based catalyst has a metal loading ranging from 0.5 to 3 wt% based on the total weight of the Rh-based catalyst.
14. The Rh-based catalyst of claim 9, wherein the amount of rhodium loaded onto the material to the amount of the material is in a ratio of 1:20 to 1:5.