

DESCRIPTION

Title of Invention

ACIDIC EXHAUST GAS TREATMENT AGENT, ACIDIC EXHAUST GAS TREATMENT METHOD, AND ACIDIC EXHAUST GAS TREATMENT EQUIPMENT

Technical Field

[0001] The present invention relates to an acidic exhaust gas treatment agent, an acidic exhaust gas treatment method, and acidic exhaust gas treatment equipment, which are applied to treat acidic exhaust gas generated from combustion facilities such as thermal power plants and incineration facilities.

Background Art

[0002] The combustion exhaust gas generated in thermal power, waste incineration or the like contains harmful acidic substances such as hydrogen chloride, sulfur oxides, and nitrogen oxides. Accordingly, the acidic exhaust gas containing the acidic substances is treated by various methods to remove the acidic substances.

[0003] Among the acidic substances, hydrogen chloride and sulfur oxides are commonly treated by a dry method in which an alkaline agent such as slaked lime is used to neutralize them and the products are collected in a dust collector, or by a wet method in which a neutralization treatment is performed in a scrubber.

Nitrogen oxides are commonly treated by a selective catalytic reduction (SCR) method in which a reductant such as ammonia or urea is mixed with the combustion exhaust gas and then the nitrogen oxides are decomposed into nitrogen and water with a catalyst including vanadium, platinum or the like loaded on a carrier such as ceramic, or by a selective non-catalytic reduction (SNCR) method in which a reductant such as ammonia or urea is sprayed directly into an incinerator to decompose the nitrogen oxides.

[0004] However, the treatment by the above neutralization treatment involves a treatment step for the neutralization products and also requires a separate treatment for the nitrogen oxides.

In addition, a problem with the treatment of nitrogen oxides by SCR or

SNCR is the use of reductants and catalysts, as well as the cost of equipment, energy, or the like for such treatment.

[0005] To address these problems, the present inventors proposed an efficient and less expensive method for treating the acidic exhaust gas by using carbonate-type Mg-Al layered double hydroxide (see PTL1).

Citation List

Patent Literature

[0006] PTL1: JP 2016190199 A

Summary of Invention

Technical Problem

[0007] However, even by the treatment method described in PTL1, the removal treatment of nitric oxide was not always sufficient.

Therefore, in the treatment of acidic exhaust gas using layered double hydroxide, there has been a need to improve the efficiency in removing nitric oxide.

[0008] The present invention has been developed under these circumstances, and an object thereof is to provide an acidic exhaust gas treatment agent, an acidic exhaust gas treatment method, and acidic exhaust gas treatment equipment that can enhance the efficiency in removing nitric oxide more than before when treating acidic exhaust gas generated from combustion facilities such as thermal power plants and incineration facilities by using layered double hydroxide.

Solution to Problem

[0009] The present invention is based on the finding that a complex of Mg-Al layered double hydroxide (hereinafter, also referred to as Mg-Al LDH) with manganese oxide or the like delivers excellent performance in removing nitric oxide.

[0010] Thus, the present invention provides the following [1] to [7].

[1] An acidic exhaust gas treatment agent comprising a complex of Mg-Al layered double hydroxide with at least one of manganese oxide and a permanganate compound.

[2] The acidic exhaust gas treatment agent according to [1],

wherein the complex is at least one of manganese dioxide-composite Mg-Al layered double hydroxide and permanganate-type Mg-Al layered double hydroxide.

[3] The acidic exhaust gas treatment agent according to [1] or [2], comprising carbonate-type Mg-Al layered double hydroxide.

[0011] [4] A method for treating acidic exhaust gas by using the acidic exhaust gas treatment agent according to any one of [1] to [3], the method comprising the steps of: (1) bringing the acidic exhaust gas into contact with the acidic exhaust gas treatment agent to adsorb an acidic substance in the acidic exhaust gas; (2) desorbing the acidic substance adsorbed on the acidic exhaust gas treatment agent in step (1) to regenerate the acidic exhaust gas treatment agent; and (3) recovering the acidic substance desorbed from the acidic exhaust gas treatment agent in step (2).

[5] The method according to [4], wherein a treatment cycle comprising steps (1) to (3) is repeatedly performed, and in step (1) of at least one of the treatment cycles after the second treatment cycle, the acidic exhaust gas treatment agent regenerated in step (2) of at least one of the treatment cycles before the treatment cycle is used for at least part of the acidic exhaust gas treatment agent.

[0012] [6] Equipment for treating acidic exhaust gas by using the acidic exhaust gas treatment agent according to any one of [1] to [3], the equipment comprising: means (1) for bringing the acidic exhaust gas into contact with the acidic exhaust gas treatment agent to adsorb an acidic substance in the acidic exhaust gas; means (2) for desorbing the acidic substance adsorbed on the acidic exhaust gas treatment agent in means (1) to regenerate the acidic exhaust gas treatment agent; and means (3) for recovering the acidic substance desorbed from the acidic exhaust gas treatment agent in means (2).

[7] The method according to [4], wherein the manganese dioxide-composite Mg-Al layered double hydroxide is produced, without requiring a reduction process, by adding Mg-Al oxide to a potassium permanganate aqueous solution, filtering the resulting mixture to obtain a precipitate, and drying the precipitate.

Advantageous Effects of Invention

[0013] The use of the acidic exhaust gas treatment agent of the present invention makes it possible to remove and treat acidic exhaust gases

simultaneously, the acidic exhaust gases including hydrogen chloride, sulfur oxides, and nitrogen oxides and generated from combustion facilities such as thermal power plants and incineration facilities. In particular, the use of the acidic exhaust gas treatment agent of the present invention achieves more improved efficiency in removing nitric oxide than the use of conventional layered double hydroxides.

According to the acidic exhaust gas treatment method of the present invention using the acidic exhaust gas treatment agent, acidic exhaust gas can be efficiently removed with a smaller amount of treatment agent than before, and the acidic exhaust gas treatment agent can also be recycled.

In addition, by using the acidic exhaust gas treatment equipment of the present invention, the acidic exhaust gas treatment method can be suitably performed, and thus it is possible to treat acidic exhaust gas more efficiently and at lower cost than before.

Brief Description of Drawings

[0014] [Fig. 1] Fig. 1 is a graph showing changes with time in a NO_x concentration of a gas at the outlet of a reaction tube in the test for evaluating the performance in acidic exhaust gas treatment in Examples.

[Fig. 2] Fig. 2 is a powder X-ray diffraction diagram of a product in Synthesis Example 1.

[Fig. 3] Fig. 3 is a powder X-ray diffraction diagram of a product in Synthesis Example 2.

[Fig. 4] Fig. 4 is a powder X-ray diffraction diagram of CO_3 -type Mg-Al LDH.

[Fig. 5] Fig. 5 is a XPS spectrum of a product in Synthesis Example 1.

[Fig. 6] Fig. 6 is a XPS spectrum of a product in Synthesis Example 2.

Description of Embodiments

[0015] The acidic exhaust gas treatment agent of the present invention, and the acidic exhaust gas treatment method and an acidic exhaust gas treatment equipment using the treatment agent will be described in detail below.

[0016] [Acidic exhaust gas treatment agent]

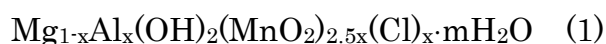
The acidic exhaust gas treatment agent of the present invention comprises a complex of Mg-Al LDH with at least one of manganese oxide and a permanganate compound (hereinafter, also referred to as a Mn-O compound).

Thus, the use of a complex of Mg-Al LDH with a compound of manganese and oxygen (Mn-O compound) as an acidic exhaust gas treatment agent makes it possible to improve the efficiency in removing nitric oxide compared with the use of a conventional layered double hydroxide such as Mg-Al LDH.

The reason for this is presumably as follows: the Mg-Al LDH itself does not readily adsorb nitric oxide, but the catalytic action of the complexed Mn-O compound causes nitric oxide to be oxidized into nitrogen dioxide and further readily oxidized into nitrate ions, which are readily adsorbed on the complex of Mg-Al LDH.

[0017] Manganese may have an oxidation number from +2 to +7, but a higher oxidation number is preferable in view of its action as an oxidation catalyst. In view of, for example, easiness of synthesis, the complex is preferably, for example, manganese dioxide-composite Mg-Al layered double hydroxide (hereinafter also referred to as MnO₂-composite Mg-Al LDH) with manganese having the oxidation number of +4, or permanganate-type Mg-Al layered double hydroxide (hereinafter referred to as MnO₄-type Mg-Al LDH) with manganese having the oxidation number of +7. The complex may be a single type or may include two or more types.

[0018] The structural formula of MnO₂-composite Mg-Al LDH is represented by the following formula (1), and the structural formula of MnO₄-type Mg-Al LDH is represented by the following formula (2).



In the formulas (1) and (2), usually, $x = 0.20$ to 0.40 and $m = 1$ to 12 .

[0019] The acidic exhaust gas treatment agent preferably comprises carbonate-type Mg-Al layered double hydroxide (hereinafter, also referred to as CO₃-type Mg-Al LDH).

As described in PTL 1, CO₃-type Mg-Al LDH is a compound that can be suitably used for the treatment of acidic exhaust gas and can efficiently remove acidic compounds other than nitric oxide contained in the acidic exhaust gas, such as hydrogen chloride, sulfur dioxide, and nitrogen dioxide. Thus, it is preferable to use it in combination with the above-described complex.

In this case, the ratio of the content of the complex and CO₃-type Mg-Al LDH in the acidic exhaust gas treatment agent is not particularly limited, and is set appropriately in accordance with component composition of the acidic exhaust

gas, such as the amount of nitric oxide contained in the acidic exhaust gas to be treated.

[0020] The CO_3 -type Mg-Al LDH occurs as hydrotalcite in a naturally occurring clay mineral. However, when synthesizing it, the synthesis method is not particularly limited and a known method (e.g., the method described in PTL 1) can be used.

For example, it can be obtained by dropping an aqueous solution of magnesium nitrate ($\text{Mg}(\text{NO}_3)_2$) and aluminum nitrate ($\text{Al}(\text{NO}_3)_3$) mixed at $\text{Mg}/\text{Al} = 2/1$ (molar ratio) into a sodium carbonate (Na_2CO_3) aqueous solution while maintaining a pH of 10.5. Specifically, it can be synthesized by the method shown in Examples described later.

[0021] The MnO_2 -composite Mg-Al LDH and MnO_4 -type Mg-Al LDH can also be synthesized by utilizing the anion exchange function by intercalation of CO_3 -type Mg-Al LDH as a starting material compound, but the synthesis method is not particularly limited thereto.

For example, the CO_3 -type Mg-Al LDH is calcined at 500°C to obtain Mg-Al oxide, and it is then added to and mixed with a potassium permanganate (KMnO_4) aqueous solution to synthesize a MnO_4 -type Mg-Al LDH, in which permanganate ions (MnO_4^-) are incorporated.

Furthermore, MnO_4 -type Mg-Al LDH is transformed into MnO_2 -composite Mg-Al LDH in potassium permanganate (KMnO_4) aqueous solution.

The MnO_4 -type Mg-Al LDH can also be added to and mixed with manganese chloride (MnCl_2) aqueous solution to synthesize MnO_2 -composite Mg-Al LDH.

[0022] The acidic exhaust gas treatment agent may include agents other than layered double hydroxides, such as calcium hydroxide (slaked lime), calcium oxide, sodium bicarbonate (baking soda), sodium carbonate, dolomite hydroxide, light burnt dolomite, aluminum hydroxide, aluminum oxide, magnesium hydroxide, and magnesium oxide, as long as they do not impair the effect of the present invention. However, when the acidic exhaust gas treatment agent is regenerated and used for reuse in the acidic exhaust gas treatment method described later, it is preferable that these agents should not be contained therein in view of purity and recovery operations of regenerated products.

[0023] [Acidic exhaust gas treatment method]

A method for treating acidic exhaust gas by using the acidic exhaust gas

treatment agent is not particularly limited, but the acidic exhaust gas treatment agent (hereinafter, simply referred to as the treatment agent) is preferably applied to the acidic exhaust gas treatment method of the present invention.

The acidic exhaust gas treatment method of the present invention comprises the steps of: (1) bringing acidic exhaust gas into contact with the treatment agent to adsorb an acidic substance in the acidic exhaust gas; (2) desorbing the acidic substance adsorbed on the treatment agent in step (1) to regenerate the treatment agent; and (3) recovering the acidic substance desorbed from the treatment agent in step (2).

According to the treatment method described above, the regenerated treatment agent can be reused. The acidic substance is, for example, dissolved in water to be recovered as an acid (aqueous solution), and the acid can be used for industrial applications and the like.

[0024] In step (1), nitric oxide is oxidized by the complex in the treatment agent, and an acidic substance in the acidic exhaust gas is also adsorbed on the treatment agent by, for example, anion exchange in which the acidic substance is introduced between the layers of layered double hydroxide.

[0025] In step (2), the acidic substance adsorbed on the treatment agent is then desorbed from the treatment agent by, for example, reversible anion exchange. The anion exchange in this case can be performed by mixing and stirring with various aqueous solutions, for example, in the same manner as in the synthetic methods of CO₃-type Mg-Al LDH, MnO₂-composite Mg-Al LDH, and MnO₄-type Mg-Al LDH, thereby easily regenerating the treatment agent.

Since the treatment agent regenerated in this manner is reusable, the treatment cost of the acidic exhaust gas can be reduced.

[0026] In step (3), the acidic substance desorbed from the treatment agent in step (2) is recovered. For example, the acidic substance can be dissolved in water to be recovered as an acid (aqueous solution), and the acid can also be used for industrial applications and the like.

Therefore, the treatment method of the present invention has excellent recyclability not only for the treatment agent but also for the acidic exhaust gas to be treated.

[0027] In the treatment method, a treatment cycle comprising steps (1) to (3) can be repeatedly performed, and in that case, it is preferable in step (1) of at least one of the treatment cycles after the second treatment cycle to use the

treatment agent regenerated in step (2) of at least one of the treatment cycles before that treatment cycle for at least part of the treatment agent.

Therefore, when the treatment method is repeatedly performed, the reuse of the treatment agent regenerated in a previous process can reduce the total amount of treatment agent required to treat acidic exhaust gas, thereby reducing the treatment cost of acidic exhaust gas.

[0028] The method for treating acidic exhaust gas of the present invention as described above has excellent work efficiency since various acidic substances in the acidic exhaust gas can be removed and treated simultaneously with a single treatment agent. In particular, the use of the complex as a treatment agent makes it possible to enhance the efficiency in removing nitric oxide more than before.

In addition, no neutralization products are produced during the treatment, and thus the load of treatment of the waste generated by the treatment can be decreased.

[0029] [Acidic exhaust gas treatment equipment]

Equipment for treating acidic exhaust gas by using the acidic exhaust gas treatment agent is not particularly limited, but the treatment agent is preferably applied to the acidic exhaust gas treatment equipment of the present invention.

The acidic exhaust gas treatment equipment of the present invention comprises means (1) for bringing the acidic exhaust gas into contact with the treatment agent to adsorb an acidic substance in the acidic exhaust gas; means (2) for desorbing the acidic substance adsorbed on the treatment agent in means (1) to regenerate the treatment agent; and means (3) for recovering the acidic substance desorbed from the treatment agent in means (2).

[0030] Means (1) can be configured, for example, by providing a container holding the treatment agent with a flow passage for acidic exhaust gas.

Means (2) can be configured, for example, as an immersion tank in which the treatment agent taken out from the container after circulation of the acidic exhaust gas can be immersed in various aqueous solutions according to the chemical species to be complexed with the Mg-Al LDH and mixed and stirred therewith in the same method as the synthesis methods of CO₃-type Mg-Al LDH, MnO₂-composite Mg-Al LDH, and MnO₄-type Mg-Al LDH described above.

Means (3) can be configured, for example, as an aqueous solution-holding tank which can recover the acidic substance as an acid (aqueous solution) by

dissolving it in water.

[0031] The acidic exhaust gas treatment equipment can be attached to combustion equipment in thermal power generation, waste incineration or the like. For example, when treating acidic exhaust gas generated in a waste incinerator, the acidic exhaust gas treatment equipment can be installed following a boiler, exhaust gas cooler, and dust collector, which are sequentially installed in the combustion exhaust gas system of the incinerator main body. The treated exhaust gas from the acidic exhaust gas treatment equipment can be led to the chimney by an induced draft fan or the like, and then released into the atmosphere from the chimney.

Examples

[0032] The present invention will be described in detail below, but the present invention is not limited by the following Examples.

[0033] [Synthesis Example 1] Synthesis of MnO_2 composite Mg-Al LDH

A mixed aqueous solution with a magnesium concentration of 0.33 mol/L and an aluminum concentration of 0.17 mol/L (magnesium/aluminum = 2/1 (molar ratio)) was prepared using magnesium nitrate hexahydrate and aluminum nitrate nonahydrate.

The mixed aqueous solution was dropped into sodium carbonate aqueous solution with a concentration of 0.1 mol/L at 30°C while stirring. At this point, the pH was maintained at 10.5 by dropping a sodium hydroxide aqueous solution with a concentration of 1.25 mol/L.

After the drop was completed, the mixture was stirred at 30°C for 1 hour. After that, the mixture was filtered to obtain a precipitate, and the precipitate was washed repeatedly, and then dried at 40°C for 40 hours under reduced pressure to obtain CO_3 -type Mg-Al LDH.

The resulting CO_3 -type Mg-Al LDH was calcined at 500°C for 2 hours. The resulting product was added to a potassium permanganate aqueous solution with a concentration of 0.2 mol/L under a nitrogen gas stream, and the mixture was stirred at 30°C for 6 hours. After that, the mixture was filtered to obtain a precipitate, and the precipitate was washed repeatedly, and then dried at 40°C for 40 hours under reduced pressure. The resulting product was added to a manganese chloride aqueous solution with a concentration of 0.1 mol/L under nitrogen gas stream, and the mixture was stirred at 30°C for 3 hours. After

that, the mixture was filtered to obtain a precipitate, and the precipitate was washed repeatedly, and then dried at 40°C for 40 hours under reduced pressure to obtain MnO₂-composite Mg-Al LDH

(Mg_{0.62}Al_{0.38}(OH)₂(MnO₂)_{0.95}(Cl)_{0.38}·1.13H₂O).

[0034] [Synthesis Example 2] Synthesis of MnO₂ composite Mg-Al LDH

A mixed aqueous solution with a magnesium concentration of 0.33 mol/L and an aluminum concentration of 0.17 mol/L (magnesium/aluminum = 2/1 (molar ratio)) was prepared using magnesium nitrate hexahydrate and aluminum nitrate nonahydrate.

The mixed aqueous solution was dropped into sodium carbonate aqueous solution with a concentration of 0.1 mol/L at 30°C while stirring. At this point, the pH was maintained at 10.5 by dropping a sodium hydroxide aqueous solution with a concentration of 1.25 mol/L.

After the drop was completed, the mixture was stirred at 30°C for 1 hour. After that, the mixture was filtered to obtain a precipitate, and the precipitate was washed repeatedly, and then dried at 40°C for 40 hours under reduced pressure to obtain CO₃-type Mg-Al LDH.

The resulting CO₃-type Mg-Al LDH was calcined at 500°C for 2 hours. The resulting product was added to a potassium permanganate aqueous solution with a concentration of 0.2 mol/L under a nitrogen gas stream, and the mixture was stirred at 30°C for 6 hours. After that, the mixture was filtered to obtain a precipitate, and the precipitate was washed repeatedly, and then dried at 40°C for 40 hours under reduced pressure.

[0035] The phase identification of CO₃-type Mg-Al LDH, MnO₄-type Mg-Al LDH, and MnO₂ composite Mg-Al LDH in Synthesis Examples 1 and 2 was performed by powder X-ray diffractometry (powder XRD). The powder X-ray diffraction diagram for CO₃-type Mg-Al LDH is shown in Fig. 4. An X-ray diffractometer used was the "RINT-2200VHF" manufactured by Rigaku Corporation, and the CuKα radiation (1.5418Å) was used as the characteristic X-ray for the diffractometry. The resulting values in elemental analysis by inductively coupled plasma atomic emission spectrometry (ICP-AES) is also shown for the complex with Mn-O compound. The MnO₄-type Mg-Al LDH and the MnO₂-composite Mg-Al LDH in Synthesis Examples 1 and 2 were identified by determining the oxidation number of Mn using X-ray photoelectron spectroscopy (XPS).

[0036] [Test for evaluating performance in acidic exhaust gas treatment]

(Example 1)

In the reaction tube (an inner diameter of 16 mm) of a tubular electric furnace, 1.0 g of MnO₂-composite Mg-Al LDH obtained in Synthesis Example 1 was filled on glass wool. The preset temperature of the tubular electric furnace was 170°C, and the test gas (carrier gas: nitrogen, nitric oxide gas concentration of 150 volppm, oxygen gas concentration of 10 vol%) was flowed into the reaction tube at a linear velocity of 1.0 m/min, by adjusting the flow rate with a mass flow controller. The change with time (90 minutes) in the NO_x concentration of the outlet gas of the reaction tube was determined with a combustion exhaust gas analyzer (manufactured by Testo K.K.) by the constant potential electrolysis method.

[0037] (Comparative Example 1)

In Example 1, the evaluation test was performed in the same manner as in Example 1, except that MnO₂-composite Mg-AL LDH was changed to the CO₃-type Mg-Al LDH obtained in the synthesis process of Synthesis Example 1.

[0038] A graph of the changes with time in the NO_x concentration of the gas at the outlet of the reaction tubes in Example 1 and Comparative Example 1 is shown in Fig. 1.

The reaction rate of nitric oxide gas in the test gas was determined from the integrated concentration of NO_x concentration, and it was found to be 91.5 vol% in Example 1 and 2.2 vol% in Comparative Example 1.

From these results, it was found that the complex of manganese dioxide with Mg-Al layered double hydroxide was superior to CO₃-type Mg-Al LDH in the performance in removing nitric oxide.

[0039] [Analysis of Existence Ratio of MnO₂-composite Mg-Al LDH in Synthesis Example 1 and Synthesis Example 2]

The powder X-ray diffraction diagrams of the products by Synthesis Examples 1 and 2 are shown in Figs. 2 and 3. The XPS spectra of the products by Synthetic Example 1 and Synthetic Example 2 are shown in Figs. 5 and 6.

From the elemental analysis values, the Mg/Al molar ratios of the products in Synthesis Examples 1 and 2 were 1.9 and 1.6, respectively, which were approximately consistent with the initial Mg/Al molar ratio of 2.0.

The powder X-ray diffraction diagrams in Figs. 2 and 3 both show X-ray peaks assigned to LDH and the surface spacing (d_{003}) of 7.6 Å and 7.5 Å,

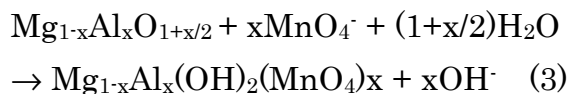
respectively, confirming the LDH structure of both products.

From the XPS spectra in Figs. 5 and 6, the peak of Mn(IV) derived from MnO₂ was confirmed. From the peak area, it was confirmed that Mn(IV) was present in an amount of 95% or more based on the total amount of Mn in both cases.

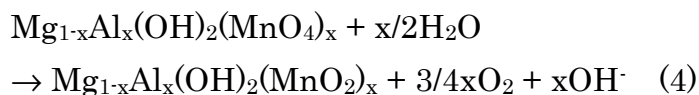
From these results, it was confirmed that as in Synthesis Example 2, it was possible to synthesize MnO₂-composite Mg-Al LDH without the reduction process shown in Synthesis Example 1, specifically, adding to a manganese chloride aqueous solution.

[0040] It is considered that the MnO₂-composite Mg-Al LDH was produced in Synthesis Example 2 as follows.

First, CO₃-type Mg-Al LDH was calcined at 500°C for 2 hours, and then the produced Mg-Al oxide (Mg_{1-x}Al_xO_{1+x/2}) was added to a potassium permanganate aqueous solution with a concentration of 0.2 mol/L under a stream of nitrogen gas, followed by stirring the mixture at 30°C for 6 hours. At that time, MnO₄-type Mg-Al LDH (Mg_{1-x}Al_x(OH)₂(MnO₄)_x) was produced according to formula (3).



Furthermore, the reaction shown in formula (4) occurred to produce MnO₂-type Mg-Al LDH (Mg_{1-x}Al_x(OH)₂(MnO₂)_x) in a potassium permanganate aqueous solution.



CLAIMS

[Claim 1]

An acidic exhaust gas treatment agent comprising a complex of Mg-Al layered double hydroxide with at least one of manganese oxide and a permanganate compound.

[Claim 2]

The acidic exhaust gas treatment agent according to claim 1, wherein the complex is at least one of manganese dioxide-composite Mg-Al layered double hydroxide and permanganate-type Mg-Al layered double hydroxide.

[Claim 3]

The acidic exhaust gas treatment agent according to claim 1 or 2, comprising carbonate-type Mg-Al layered double hydroxide.

[Claim 4]

A method for treating acidic exhaust gas by using the acidic exhaust gas treatment agent according to any one of claims 1 to 3, the method comprising the steps of:

(1) bringing the acidic exhaust gas into contact with the acidic exhaust gas treatment agent to adsorb an acidic substance in the acidic exhaust gas;

(2) desorbing the acidic substance adsorbed on the acidic exhaust gas treatment agent in step (1) to regenerate the acidic exhaust gas treatment agent; and

(3) recovering the acidic substance desorbed from the acidic exhaust gas treatment agent in step (2).

[Claim 5]

The method according to claim 4, wherein a treatment cycle comprising steps (1) to (3) is repeatedly performed, and in step (1) of at least one of the treatment cycles after the second treatment cycle, the acidic exhaust gas treatment agent regenerated in step (2) of at least one of the treatment cycles before the treatment cycle is used for at least part of the acidic exhaust gas treatment agent.

[Claim 6]

Equipment for treating acidic exhaust gas by using the acidic exhaust gas treatment agent according to any one of claims 1 to 3, the equipment comprising:

means (1) for bringing the acidic exhaust gas into contact with the acidic exhaust gas treatment agent to adsorb an acidic substance in the acidic exhaust

gas;

means (2) for desorbing the acidic substance adsorbed on the acidic exhaust gas treatment agent in means (1) to regenerate the acidic exhaust gas treatment agent; and

means (3) for recovering the acidic substance desorbed from the acidic exhaust gas treatment agent in means (2).

[Claim 7]

The method according to claim 4, wherein the manganese dioxide-composite Mg-Al layered double hydroxide is produced, without requiring a reduction process, by adding Mg-Al oxide to a potassium permanganate aqueous solution, filtering the resulting mixture to obtain a precipitate, and drying the precipitate.