DESCRIPTION

TITLE OF INVENTION: HIGHLY OIL-ABSORPTIVE SODIUM BICARBONATE POWDER

TECHNICAL FIELD

[0001]

The present invention relates to a sodium bicarbonate powder having a high oil absorption.

Priority is claimed on Japanese Patent Application No. 2024-040356, filed March 14, 2024, the content of which is incorporated herein by reference.

BACKGROUND ART

[0002]

Sodium bicarbonate is used in a wide range of fields, such as for foods, feeds, deodorants, pharmaceuticals, and treatment of incineration exhaust gas. Although these types of sodium bicarbonate are handled as powders, there has been a problem in that they easily cake during storage. When caking occurs, operations such as discharging the sodium bicarbonate from a tank during transportation or from a silo in which the sodium bicarbonate is stored, and weighing the sodium bicarbonate, are hindered. For this reason, methods for preventing caking of a sodium bicarbonate powder have been proposed.

[0003]

Patent Document 1 discloses a caking-resistant sodium bicarbonate in which a part or all of a sodium carbonate content present on surfaces of sodium bicarbonate particles is sodium sesquicarbonate, and such sodium bicarbonate is obtained by treating sodium bicarbonate particles at a relative humidity of 50% to 90% and a temperature of

20°C to 70°C.

Citation List

Patent Documents

[0004]

Patent Document 1: Japanese Unexamined Patent Application, First Publication No. 2003-104722

SUMMARY OF INVENTION

Technical Problem

[0005]

In Patent Document 1, a caking-resistant sodium bicarbonate is obtained by changing a surface composition of sodium bicarbonate particles that have once been obtained. However, in order to convert sodium bicarbonate into sodium sesquicarbonate, a treatment at a high humidity for a long period of time is required, and there has been a problem in that, when the treatment is performed excessively at a high temperature and a high humidity for a long period of time, the entire particle surface becomes sodium carbonate, so that the chemical properties change.

Furthermore, even with the caking-resistant sodium bicarbonate of Patent Document 1, the improvement in caking resistance (moisture resistance) has still not been sufficient.

The present invention has been made in view of the above circumstances, and an object thereof is to provide a sodium bicarbonate powder that is excellent in moisture resistance and deodorizing properties.

Solution to Problem

[0006]

As a result of intensive studies, the present inventors have found that the above

problem can be solved by adjusting an oil absorption or an apparent density of a sodium bicarbonate powder, and have completed the present invention. The present invention includes the aspects described below.

[1] A sodium bicarbonate powder having an oil absorption of 40 mL/100 g or more.

[2] The sodium bicarbonate powder according to [1], in which a crystallite size of a (210) plane is 75 nm or less, and a crystallite size of a (121) plane is 70 nm or less.

[3] The sodium bicarbonate powder according to [1] or [2], in which a ratio (D210/D121) of a crystallite size (D210) of a (210) plane to a crystallite size (D121) of a (121) plane is 0.60 to 1.00.

[4] A sodium bicarbonate powder having an apparent density of 0.32 g/mL or less.

[5] The sodium bicarbonate powder according to [4], in which a crystallite size of a (210) plane is 75 nm or less, and a crystallite size of a (121) plane is 70 nm or less.

[6] The sodium bicarbonate powder according to [4] or [5], in which a ratio (D210/D121) of a crystallite size (D210) of a (210) plane to a crystallite size (D121) of a (121) plane is 0.60 to 1.00.

[7] A method for producing sodium bicarbonate, the method including supplying fine bubbles of a gas containing carbon dioxide to an aqueous solution of sodium hydroxide or an aqueous solution of sodium carbonate to obtain sodium bicarbonate.

[8] A method for producing sodium bicarbonate, the method including spraying an aqueous solution of sodium bicarbonate with a spray dryer to obtain sodium bicarbonate.

[9] A sodium bicarbonate powder having an oil absorption of 40 mL/100 g or more and an apparent density of 0.32 g/mL or less.

[10] The sodium bicarbonate powder according to [9], in which a crystallite size of a (210) plane is 75 nm or less, and a crystallite size of a (121) plane is 70 nm or less.

[11] The sodium bicarbonate powder according to [9] or [10], in which a ratio (D210/D121) of a crystallite size (D210) of a (210) plane to a crystallite size (D121) of a (121) plane is 0.60 to 1.00.

[12] The sodium bicarbonate powder according to any one of [1] to [6], [10], and [11], having an oil absorption of 100 mL/100 g or more.

[13] The sodium bicarbonate powder according to any one of [1] to [6], [10], and [11], having an apparent density of 0.10 g/mL or less.

[14] The sodium bicarbonate powder according to any one of [1] to [6] and [10] to [13], having an average particle diameter (d50) of 12 μm to 50 μm.

[15] The sodium bicarbonate powder according to any one of [1] to [6] and [10] to [14], in which a crystallite size of a (210) plane is 60 nm or less, or 45 nm or less, and a crystallite size of a (121) plane is 55 nm or less.

Advantageous Effects of Invention

[0007]

According to the present invention, it is possible to provide a sodium bicarbonate powder that can be produced by a simple method and that is excellent in moisture resistance and deodorizing properties.

BRIEF DESCRIPTION OF DRAWINGS

[0008]

[FIG. 1] A schematic diagram showing an example of an apparatus for producing the sodium bicarbonate powder of the present invention.

[FIG. 2] A schematic diagram showing another example of an apparatus for producing the sodium bicarbonate powder of the present invention.

[FIG. 3] A schematic diagram showing still another example of an apparatus for producing the sodium bicarbonate powder of the present invention.

[FIG. 4-1] A diagram for explaining a procedure of a moisture resistance test method in the Examples.

[FIG. 4-2] A diagram for explaining a procedure of a moisture resistance test method in the Examples.

DESCRIPTION OF EMBODIMENTS

[0009]

In the present specification, a numerical range expressed with “to” means a numerical range having the numerical values preceding and following “to” as the lower limit value and the upper limit value.

[0010]

The present invention will be described below; however, the present invention is not limited by the exemplifications in the following description.

<<Sodium Bicarbonate Powder>>

The sodium bicarbonate powder of the present embodiment has an oil absorption of 40 mL/100 g or more, or an apparent density of 0.32 g/mL or less. A case where the oil absorption is 40 mL/100 g or more and the apparent density is 0.32 g/mL or less is also one preferable example of the present embodiment.

<Oil Absorption>

The oil absorption is preferably 60 mL/100 g or more, and more preferably 100 mL/100 g or more. When the oil absorption is equal to or more than the above lower limit value, a sodium bicarbonate powder excellent in moisture resistance and deodorizing properties is obtained. The upper limit value of the oil absorption is not limited, but may usually be set to 200 mL/100 g or less.

The oil absorption is a value measured in accordance with JIS K 5101-13-1.

[0011]

<Apparent Density>

The apparent density is preferably 0.25 g/mL or less, and more preferably 0.10 g/mL or less. When the apparent density is equal to or less than the above upper limit value, a sodium bicarbonate powder excellent in moisture resistance and deodorizing properties is obtained. The lower limit value of the apparent density is not limited, but may usually be set to 0.04 g/mL or more.

The apparent density is a value measured using an apparent density measuring instrument conforming to the provisions of JIS K 5101-12-1.

[0012]

<Crystallite Size>

In the sodium bicarbonate powder of the present embodiment, a crystallite size of a (210) plane is preferably 75 nm or less, and a crystallite size of a (121) plane is preferably 70 nm or less.

The crystallite size of the (210) plane is more preferably 60 nm or less, and still more preferably 45 nm or less. When the crystallite size of the (210) plane is equal to or less than the above upper limit value, the moisture resistance and the deodorizing properties of the sodium bicarbonate powder can be further improved. The lower limit value of the crystallite size of the (210) plane is not particularly limited, but may usually be set to 20 nm or more.

The crystallite size of the (121) plane is more preferably 55 nm or less, and still more preferably 40 nm or less. When the crystallite size of the (121) plane is equal to or less than the above upper limit value, the moisture resistance and the deodorizing properties of the sodium bicarbonate powder can be further improved. The lower limit

value of the crystallite size of the (121) plane is not particularly limited, but may usually be set to 15 nm or more.

In addition, a ratio (D210/D121) of the crystallite size (D210) of the (210) plane to the crystallite size (D121) of the (121) plane is preferably 0.60 to 1.00, and more preferably 0.70 to 0.90. When the ratio (D210/D121) is within the above range, the moisture resistance and the deodorizing properties of the sodium bicarbonate powder can be still further improved. The crystallite size of the (210) plane and the crystallite size of the (121) plane are determined as follows: among peaks derived from $NaHCO_3$ in an X-ray diffraction pattern, the diffraction peaks attributed to the (210) plane and the (121) plane are selected as peaks that do not overlap with other peaks and that have a relatively high relative intensity, and the crystallite size for each of the crystal planes is determined using the Scherrer equation shown below.

$$D = K\lambda/\{(B - B0)\cos\theta\}$$

Here, D is the crystallite size (nm), and K is the Scherrer constant, for which 0.89 is used. λ is the wavelength (nm) of the X-rays, for which 0.1542 nm of the Cu-Kα radiation is used. B is the full width at half maximum (rad) of each diffraction peak, and B0 is an instrumental function, for which the full width at half maximum (rad) of a peak obtained by measuring an α-alumina sintered body having a crystallite size of 1 μm or more is used. θ is the diffraction angle (rad) of each diffraction peak.

The full width at half maximum (rad) is preferably 0.2 to 0.3.

[0013]

<d50 of Sodium Bicarbonate Powder>

An average particle diameter (d50) of the sodium bicarbonate powder of the

present embodiment is preferably 1 μm to 100 μm, more preferably 5 μm to 50 μm, and still more preferably 12 μm to 50 μm. When the average particle diameter is within the above range, it becomes easier to improve the moisture resistance and the deodorizing properties of the sodium bicarbonate powder.

The d50 of the sodium bicarbonate powder is a volume-based cumulative 50% diameter (median diameter) determined by a laser diffraction/scattering method. That is, the d50 is a particle diameter at a point at which the cumulative volume reaches 50% on a cumulative curve which is obtained by measuring a particle size distribution by a laser diffraction/scattering method and taking the total volume of a population of particles as 100%.

[0014]

<<Method for Producing Sodium Bicarbonate Powder>>

The sodium bicarbonate powder of the present invention can be obtained, for example, by the following two methods.

<First Method>

The first method is a method in which bubbles of a gas containing carbon dioxide are supplied to an aqueous solution of sodium hydroxide to perform carbonation and bicarbonation, thereby obtaining sodium bicarbonate. The bubbles are preferably fine bubbles, which are described later. That is, it is preferable that fine bubbles of a gas containing carbon dioxide be formed and supplied to an aqueous solution of sodium hydroxide or an aqueous solution of sodium carbonate.

A concentration of the sodium hydroxide in the aqueous solution is not particularly limited as long as it is equal to or less than a saturation concentration of sodium hydroxide, and is preferably 4% to 20%, and more preferably 8% to 15%. When the concentration is equal to or more than the above lower limit value, the aqueous

sodium bicarbonate solution obtained by the carbonation and the bicarbonation becomes supersaturated, and sodium bicarbonate precipitates to form a sodium bicarbonate slurry, from which a sodium bicarbonate powder is obtained by subsequent filtration and drying, which is preferable. When the concentration is equal to or less than the above upper limit value, there is an advantage in that a viscosity of the sodium bicarbonate slurry does not become excessively high and the slurry is easy to handle.

The term “fine bubbles” is a general term for microbubbles having a diameter of 1 μm to 100 μm and nanobubbles having a diameter of less than 1 μm. When a large number of microbubbles are generated in water, a cloudy phenomenon appears. On the other hand, since nanobubbles are extremely small, water remains transparent. By forming a gas containing carbon dioxide into fine bubbles, a gas-liquid interface with the aqueous solution of sodium hydroxide or the aqueous solution of sodium carbonate becomes large, and a dissolution rate of the carbon dioxide can be increased. As a result, substantially the entire amount of the supplied carbon dioxide can react with the sodium hydroxide or the sodium carbonate, so that the carbon dioxide can be reacted without loss, and crystallization of sodium bicarbonate can be performed at an extremely high rate. By performing the crystallization of sodium bicarbonate at an extremely high rate, fine crystals of sodium bicarbonate precipitate, and a sodium bicarbonate powder having a large oil absorption and a small apparent density is obtained.

[0015]

An apparatus for producing such fine bubbles is not particularly limited, and examples thereof include the following.

(Example 1) An apparatus that supplies gas to a suction side of a pressure pump and converts the gas drawn into the pressure pump into fine bubbles by a mixing blade rotating at high speed in the pressure pump. A specific example thereof includes “Vortex

turbo mixer pump" (trade name) manufactured by Nikuni Co., Ltd.

(Example 2) An apparatus in which a low-pressure portion is formed in a liquid flow by the Venturi effect (by narrowing a flow passage through which a pressurized liquid flows to increase a flow rate and create a low-pressure portion), and gas is supplied to the low-pressure portion and formed into fine bubbles. Specific examples thereof include "YJ nozzle" (trade name) manufactured by EnviroVision Co., Ltd. and "Aqua Transfer Nozzle" (trade name) manufactured by Water Navi Co., Ltd.

(Example 3) An apparatus that radially ejects water from a disk rotating at high speed to form a negative-pressure portion in a central portion, draws in gas, and forms fine bubbles. A specific example thereof includes "Spinor" (trade name) manufactured by Water Navi Co., Ltd.

[0016]

A temperature of the aqueous solution of sodium hydroxide or the aqueous solution of sodium carbonate at the time of supplying the fine bubbles of the gas containing carbon dioxide is not particularly limited, and is preferably 0°C to 80°C. The lower the temperature, the higher the solubility of the carbon dioxide in the aqueous solution of sodium hydroxide or the aqueous solution of sodium carbonate; a temperature of 0°C or higher is preferable because there is no risk of freezing. On the other hand, the higher the temperature, the lower the solubility of the carbon dioxide in the aqueous solution of sodium hydroxide or the aqueous solution of sodium carbonate; a temperature of 80°C or lower is preferable because a generation rate of the alkali metal carbonate is unlikely to become slow. The temperature of the aqueous solution is more preferably 20°C to 60°C, and still more preferably 30°C to 50°C.

[0017]

The gas containing carbon dioxide is not particularly limited as long as a

concentration of the carbon dioxide is 10 vol% or more, and is not limited to a mixed gas of carbon dioxide and air or nitrogen gas, such as exhaust gas from a combustion furnace, exhaust gas from a glass melting furnace, or gas generated by neutralization of a carbonate; a high-purity carbon dioxide gas and the like may also be mentioned. A preferable range of the carbon dioxide concentration is 30 vol% or more, and more preferably 50 vol% or more.

[0018]

In addition, the bubbles of the gas containing carbon dioxide preferably have a size such that a d50 is 100 μm or less and a d90 is 150 μm or less. Bubbles having such a size can be obtained by appropriately adjusting conditions of a known fine-bubble preparation method.

The size of the bubbles can be measured, for example, using a particle size analyzer (trade name: Particle Track) employing FBRM (Focused Beam Reflectance Measurement) manufactured by Mettler-Toledo K.K. In the present specification, the distribution of the size of the bubbles is represented by a 10% diameter (d10), a 50% diameter (median diameter, d50), and a 90% diameter (d90) on a cumulative distribution curve of bubble volume with respect to bubble size.

In addition, from the viewpoint of more reliably achieving the effects of the present invention, the d50 is preferably 50 μm to 90 μm, and more preferably 60 μm to 80 μm, and the d90 is preferably 100 μm to 150 μm, and more preferably 100 μm to 130 μm.

By adjusting the size of the bubbles of the gas containing carbon dioxide within such ranges, the dissolution rate of the carbon dioxide can be increased and the crystallization of sodium bicarbonate can be performed at an extremely high rate, so that fine crystals of sodium bicarbonate precipitate and a sodium bicarbonate powder having

a large oil absorption and a small apparent density is obtained. A preferable range of the time required for the crystallization of sodium bicarbonate from the aqueous sodium carbonate solution is 12 hours or less, a more preferable range is 6 hours or less, and a still more preferable range is 3 hours or less.

[0019]

As described above, a slurry of sodium bicarbonate is obtained by supplying the fine bubbles of the gas containing carbon dioxide to the aqueous solution of sodium hydroxide or the aqueous solution of sodium carbonate. Subsequently, this slurry is filtered by a filter such as a centrifugal dewatering machine to obtain a cake of sodium bicarbonate, and this cake is dried and pulverized, whereby a sodium bicarbonate powder is obtained.

[0020]

Hereinafter, the first method will be described with reference to FIG. 1 and FIG. 2; however, this is merely an exemplification, and the present invention is not limited by this exemplification.

FIG. 1 is a schematic diagram showing an example of an apparatus for producing the sodium bicarbonate powder of the present invention (hereinafter also referred to as a “sodium bicarbonate powder production apparatus”), the apparatus being usable for carrying out the first method (hereinafter also referred to as an “apparatus of a first embodiment”). The sodium bicarbonate powder production apparatus 100 exemplified in FIG. 1 is an apparatus that precipitates sodium bicarbonate from an aqueous solution of sodium carbonate by using “Vortex turbo mixer pump” (trade name) manufactured by Nikuni Co., Ltd. as an apparatus for producing fine bubbles of a gas containing carbon dioxide; however, the present invention is not limited by this exemplification.

[0021]

The sodium bicarbonate powder production apparatus 100 includes a crystallization tank 1, and a stirring device 2 is provided in the crystallization tank 1. A liquid 3 in the crystallization tank 1 is initially an aqueous sodium carbonate solution, and while this aqueous sodium carbonate solution is circulated in the crystallization tank 1 through a circulation pipe 5 using a vortex turbo mixer pump 4, carbon dioxide is formed into fine bubbles and introduced through a supply pipe 6 for a gas containing carbon dioxide into a suction side of the vortex turbo mixer pump 4. As the gas containing carbon dioxide is introduced, a pH of the liquid 3 in the crystallization tank decreases, and sodium bicarbonate precipitates, so that the liquid becomes cloudy. Finally, when the pH of the liquid 3 in the crystallization tank becomes 8.5 or lower, the supply of the gas containing carbon dioxide is stopped, and a sodium bicarbonate slurry is obtained. The obtained sodium bicarbonate slurry is sent through a feed pipe 7 to a centrifugal dewatering machine 8, and, when subjected to centrifugal dewatering, a cake 10 of sodium bicarbonate is obtained, with the remainder being a filtrate 9. When the cake 10 of sodium bicarbonate is dried in drying equipment 11, a sodium bicarbonate powder 12 is obtained.

[0022]

FIG. 2 is a schematic diagram showing another example of an apparatus usable for carrying out the first method (hereinafter also referred to as an “apparatus of a second embodiment”). The sodium bicarbonate powder production apparatus 200 exemplified in FIG. 2 is an apparatus that precipitates sodium bicarbonate from an aqueous solution of sodium carbonate by using “YJ nozzle” (trade name) manufactured by EnviroVision Co., Ltd. as an apparatus for producing fine bubbles of a gas containing carbon dioxide; however, the present invention is not limited by this exemplification.

[0023]

The apparatus of the second embodiment differs from the apparatus of the first embodiment in that a YJ nozzle is used instead of the vortex turbo mixer pump as an apparatus for producing fine bubbles of a gas containing carbon dioxide. The liquid 3 in the crystallization tank 1 is supplied to a YJ nozzle 14 by a magnet pump 13. The gas containing carbon dioxide is supplied through a supply pipe 6 to a central portion of the YJ nozzle 14 and is formed into fine bubbles in the YJ nozzle. As a result, a sodium bicarbonate slurry is obtained in the crystallization tank 1, in the same manner as in the apparatus of the first embodiment.

[0024]

<Second Method>

The second method for obtaining the sodium bicarbonate powder of the present invention is a method in which an aqueous solution of sodium bicarbonate is sprayed with a spray dryer to obtain a powder of sodium bicarbonate.

As the conditions for spraying with the spray dryer, for example, the following conditions can be adopted: an inlet temperature of air is generally 100°C to 200°C, and preferably 110°C to 150°C; an outlet temperature of air is generally 60°C to 150°C, and preferably 80°C to 130°C; a spraying air pressure is generally 0.4 MPa to 1.0 MPa, and preferably 0.5 MPa to 0.8 MPa; and an air volume is generally 3 L/min to 20 L/min, and preferably 6 L/min to 15 L/min.

When the inlet temperature of air is equal to or higher than the above lower limit, water can be sufficiently removed from the aqueous solution of sodium bicarbonate, and it is possible to prevent the powder of sodium bicarbonate from failing to precipitate and to prevent the obtained sodium bicarbonate powder from becoming moist, which is preferable. When the inlet temperature of air is equal to or lower than the

above upper limit, thermal decomposition of sodium bicarbonate can be prevented, which is preferable.

[0025]

Hereinafter, the second method will be described with reference to FIG. 3; however, this is merely an exemplification, and the present invention is not limited by this exemplification.

FIG. 3 is a schematic diagram showing an example of a sodium bicarbonate powder production apparatus used in the second method (hereinafter also referred to as an “apparatus of a third embodiment”). The sodium bicarbonate powder production apparatus 300 exemplified in FIG. 3 is an apparatus that sprays an aqueous solution of sodium bicarbonate with a spray dryer to obtain a powder of sodium bicarbonate; however, the present invention is not limited by this exemplification.

[0026]

A liquid to be sprayed 16 contained in a vessel 15 is supplied by a pump 17 to a two-fluid nozzle 18. High-temperature air 19 is also supplied to the two-fluid nozzle 18, and the liquid to be sprayed 16 is sprayed by the high-temperature air 19 into a spray cylinder 20. The sprayed liquid is dried in the spray cylinder 20 to become a sodium bicarbonate powder. This sodium bicarbonate powder is entrained by the high-temperature air and introduced into a cyclone 21, and is recovered as a sodium bicarbonate powder 23 in a recovery vessel 22. The air that has passed through the cyclone 21 is filtered by a filter 24 and released into the atmosphere.

[0027]

The sodium bicarbonate powder of the present invention and the method for producing the same have been described above; however, the present invention is not limited to the configurations described in the above embodiments, and the configurations

thereof can be appropriately modified within a range that does not depart from the gist of the invention.

[0028]

Applications of the sodium bicarbonate powder of the present invention are not particularly limited; however, since the powder has high reactivity with gases, it is suitable as a deodorant, a neutralizing agent for acidic substances, or a detoxifying agent for incineration exhaust gas. In addition, since the powder is excellent in moisture resistance under a high-humidity environment and is unlikely to cake, it is also suitable for use as an emergency neutralizing agent, a kitchen detergent, and the like.

Examples

[0029]

The present invention is described in detail below by way of Examples, but is not limited thereto. Unless otherwise specified, “part” and “%” mean “part by mass” and “mass%”, respectively.

[0030]

Examples 1 to 3 are examples according to the present invention, and Examples 4 to 6 are Comparative Examples.

[0031]

<<Measurement Methods and Evaluation Methods>>

(Utilization Rate of Carbon Dioxide)

In the first method for producing the sodium bicarbonate powder of the present invention described above (using the apparatuses of the first embodiment and the second embodiment), the ratio, expressed as a percentage, of a calculated value (B) of an amount of carbon dioxide gas required to convert all of the sodium carbonate in the aqueous sodium carbonate solution used into sodium bicarbonate, to an amount (A) of carbon

dioxide gas actually supplied for the precipitation of sodium bicarbonate, was defined as the utilization rate (%) of carbon dioxide during the precipitation of sodium bicarbonate.

Utilization rate of carbon dioxide during precipitation of sodium bicarbonate (%) = Calculated value of amount of carbon dioxide gas required to convert all sodium carbonate into sodium bicarbonate (B, unit: L)/Amount of carbon dioxide gas actually supplied (A, unit: L) × 100

[0032]

(d50 of Sodium Bicarbonate Powder)

Using a Microtrac FRA particle size distribution analyzer manufactured by Nikkiso Co., Ltd., a particle size distribution of sodium bicarbonate particles dispersed in a mixed solvent (methanol = 11%, ethanol = 88%, and isopropanol = 1%) was measured, and a median diameter d50 was determined.

[0033]

(Oil Absorption of Sodium Bicarbonate Powder)

The oil absorption was measured in accordance with JIS K 5101-13-1. Specifically, boiled linseed oil is added to a sodium bicarbonate powder while the powder is kneaded until the entire sodium bicarbonate powder forms a single mass. The oil absorption was expressed as the volume of the boiled linseed oil per 100 g of sodium bicarbonate at the time when the entire sample formed a single mass.

[0034]

(Apparent Density of Sodium Bicarbonate Powder)

The apparent density was measured using an apparent density measuring instrument conforming to the provisions of JIS K 5101-12-1.

[0035]

(Crystallite Size of Sodium Bicarbonate Powder)

Powder X-ray diffraction was performed using an X-ray diffractometer (model: SmartLab) manufactured by Rigaku Corporation. The measurement conditions were as follows: output: 45 kV-200 mA; scanning speed: 20°/min; step width: 0.02°; and scanning range: 10° to 80°.

Among peaks derived from $NaHCO_3$ in the obtained X-ray diffraction pattern, the diffraction peaks attributed to the (210) plane and the (121) plane were selected as peaks that do not overlap with other peaks and that have a relatively high relative intensity, and the crystallite size for each of the crystal planes was determined using the Scherrer equation shown below.

$$D = K\lambda/\{(B - B0)\cos\theta\}$$

Here, D is the crystallite size (nm), and K is the Scherrer constant, for which 0.89 was used. λ is the wavelength (nm) of the X-rays, for which 0.1542 nm of the Cu-Kα radiation was used. B is the full width at half maximum (rad) of each diffraction peak, and B0 is an instrumental function, for which the full width at half maximum (rad) of a peak obtained by measuring an α-alumina sintered body having a crystallite size of 1 μm or more was used. θ is the diffraction angle (rad) of each diffraction peak.

[0036]

(Moisture Resistance of Sodium Bicarbonate Powder)

FIG. 4-1 and FIG. 4-2 show a moisture resistance test method.

First, as shown in FIG. 4-1, 30 g of a sodium bicarbonate powder 26 was placed in a polystyrene resin container 25 (inner diameter: 15 cm, depth: 9 cm), and the container was left to stand for 72 hours in a desiccator in which silica gel had been

placed, whereby the sodium bicarbonate powder was initialized. The environment in the desiccator was a temperature of 25 ± 1°C and a humidity of 23 ± 1% RH.

Next, the container containing this sodium bicarbonate powder was taken out of the desiccator and stored in a constant-temperature and constant-humidity chamber. The constant-temperature and constant-humidity chamber had a temperature of 25 ± 1°C and a humidity of 88 ± 3% RH. Then, the container was taken out of the constant-temperature and constant-humidity chamber every 12 hours, and the caking properties of the sodium bicarbonate powder were examined. FIG. 4-2 shows the test method for the caking properties. The polystyrene resin container containing the sodium bicarbonate powder was rotated at a speed of 15 rpm in a state of being inclined at approximately 30 degrees from the horizontal. When the sodium bicarbonate powder crumbled and fell down, the powder was not caking, and thus the moisture resistance was rated as “Good”. On the other hand, when the sodium bicarbonate powder did not crumble and fall down, the powder was caking, and thus the moisture resistance was rated as “Poor”.

[0037]

(Deodorizing Performance of Sodium Bicarbonate Powder)

The deodorizing performance of the sodium bicarbonate powder against isovaleric acid as an odor component was tested by a gas chromatography method applied mutatis mutandis in accordance with the SEK Mark Textile Product Certification Criteria of the Japan Textile Evaluation Technology Council. Specifically, the test was carried out in the following procedure.

1) 0.1 g of a sodium bicarbonate powder was placed at the bottom of a 500 mL Erlenmeyer flask.

2) Next, 5 μL of an ethanol solution of isovaleric acid (isovaleric acid concentration: 38 ppm) was added dropwise into the Erlenmeyer flask.

3) The Erlenmeyer flask was sealed and left to stand at 20°C for 2 hours, and then a gas concentration of the isovaleric acid in the Erlenmeyer flask was measured by a gas chromatography method.

4) A reduction rate (%) was determined from the concentration (unit: ppm) after 2 hours relative to the initial concentration (unit: ppm) of the isovaleric acid by the following expression, and was taken as the deodorizing performance.

Deodorizing performance (%) = (Initial concentration − Concentration after 2 hours)/Initial concentration × 100

[0038]

(Example 1)

A sodium bicarbonate powder was synthesized using the apparatus 100 of the first embodiment shown in FIG. 1. First, 400 g of sodium carbonate powder and 2000 g of deionized water were charged into the crystallization tank 1 having an internal volume of 6 L and stirred to obtain 2400 g of an aqueous sodium carbonate solution having a concentration of 16.7%. Next, the vortex turbo mixer pump 4 was started, and the aqueous sodium carbonate solution was circulated using the circulation pipe 5. A KTM15ND02S model manufactured by Nikuni Co., Ltd. was used as the vortex turbo mixer pump. The circulation flow rate was 20 L/min. Immediately after the circulation was started, carbon dioxide gas was supplied at a rate of 1.0 L/min to the suction pipe side of the vortex turbo mixer pump 4, and the carbon dioxide was formed into fine bubbles and introduced. After 85 minutes, the liquid in the crystallization tank became a cloudy sodium bicarbonate slurry with a pH of 8.0. The utilization rate of carbon dioxide was 100%.

The obtained sodium bicarbonate slurry was filtered by the centrifugal dewatering machine 8 to form the cake 10 of sodium bicarbonate, which was then dried

in the drying equipment 11 to obtain the sodium bicarbonate powder 12. The amount of the obtained sodium bicarbonate powder was 420 g. The powder was further pulverized with a hammer mill so that the d50 became approximately 10 μm.

The d50 of the obtained sodium bicarbonate powder was 8.9 μm, and the oil absorption was as large as 42 mL/100 g. The apparent density was as small as 0.28 g/mL. As for the crystallite sizes, the crystallite size of the (210) plane was 82 nm, and the crystallite size of the (121) plane was 77 nm. In the moisture resistance test, the powder did not cake even when stored for 60 hours in an environment at a temperature of 25 ± 1°C and a humidity of 88 ± 3% RH. The powder also deodorized 76% of the isovaleric acid.

Various conditions and results are shown in Table 1 and Table 2.

[0039]

(Example 2)

A sodium bicarbonate powder was synthesized using the apparatus 200 of the second embodiment shown in FIG. 2. First, 800 g of sodium carbonate powder and 4000 g of deionized water were charged into the crystallization tank 1 having an internal volume of 6 L and stirred to obtain 4800 g of an aqueous sodium carbonate solution having a concentration of 16.7%. Next, the magnet pump 13 was started, and the aqueous sodium carbonate solution was circulated using the circulation pipe 5. A stainless steel motor pump MM-254 model (trade name) manufactured by Maruhachi Pump Mfg. Co., Ltd. was used as the magnet pump. The circulation flow rate was 20 L/min. Immediately after the circulation was started, carbon dioxide gas was supplied at a rate of 1.0 L/min to the YJ nozzle 14, and the carbon dioxide was formed into fine bubbles and introduced. A YJ-6 inline model (trade name) manufactured by EnviroVision Co., Ltd. was used as the YJ nozzle. After 169 minutes, the liquid in the

sodium bicarbonate precipitation tank became a cloudy sodium bicarbonate slurry with a pH of 8.0. The utilization rate of carbon dioxide was 100%.

The obtained sodium bicarbonate slurry was filtered by the centrifugal dewatering machine 8 to form the cake 10 of sodium bicarbonate, which was then dried in the drying equipment 11 to obtain the sodium bicarbonate powder 12. The amount of the obtained sodium bicarbonate powder was 850 g. The powder was further pulverized with a hammer mill so that the d50 became approximately 10 μm.

The d50 of the obtained sodium bicarbonate powder was 11.1 μm, and the oil absorption was as large as 46 mL/100 g. The apparent density was as small as 0.29 g/mL. As for the crystallite sizes, the crystallite size of the (210) plane was 93 nm, and the crystallite size of the (121) plane was 85 nm. In addition, the obtained sodium bicarbonate powder was excellent in moisture resistance and deodorizing performance, in the same manner as in Example 1.

Various conditions and results are shown in Table 1 and Table 2.

[0040]

(Example 3)

A sodium bicarbonate powder was synthesized using the apparatus 300 of the third embodiment shown in FIG. 3. 282 g of a sodium bicarbonate powder was added to 3000 g of deionized water and dissolved with stirring to obtain an aqueous sodium bicarbonate solution 16 having a concentration of 8.6%. A mini spray dryer B-290 model manufactured by Nihon BUCHI K.K. was used as the spray dryer apparatus. While the aqueous sodium bicarbonate solution 16 was supplied at a rate of 10 g/min to the two-fluid nozzle 18 having an orifice diameter of 0.7 mm, high-temperature air 19 at 150°C was also supplied, and the solution was sprayed into the spray cylinder 20. Simultaneously with the start of the spraying, a sodium bicarbonate powder was

recovered in the recovery vessel 22 at a lower portion of the cyclone 21. After approximately 5 hours, when the aqueous sodium bicarbonate solution 16 was used up, the spraying was terminated, and the sodium bicarbonate powder in the recovery vessel was recovered. The amount of the obtained sodium bicarbonate powder was 123 g. Since the d50 was approximately 10 μm, pulverization with a hammer mill was not performed.

The d50 of the obtained sodium bicarbonate powder was 14.0 μm, and the oil absorption was as very large as 125 mL/100 g. The apparent density was as very small as 0.08 g/mL. As for the crystallite sizes, the crystallite size of the (210) plane was as very small as 40 nm, and the crystallite size of the (121) plane was as very small as 50 nm. In the moisture resistance test, the powder did not cake even when stored for 84 hours in an environment at a temperature of 25 ± 1°C and a humidity of 88 ± 3% RH. The powder also deodorized 99% of the isovaleric acid and was excellent in deodorizing properties.

Various conditions and results are shown in Table 1 and Table 2.

[0041]

(Example 4)

Physical properties of general-purpose industrial-grade sodium bicarbonate (product name: KF) manufactured by AGC Inc. were evaluated. The d50 was as large as 130.0 μm. The oil absorption was as very small as 14 mL/100 g. The apparent density was as very large as 1.12 g/mL. As for the crystallite sizes, the crystallite size of the (210) plane was as very large as 149 nm, and the crystallite size of the (121) plane was as very large as 157 nm.

In addition, the moisture resistance was very poor, and the powder had caked after 12 hours. The deodorizing performance was also poorer than those of Examples 1 to 3.

Various conditions and results are shown in Table 1 and Table 2.

[0042]

(Example 5)

The general-purpose industrial-grade sodium bicarbonate (product name: KF) manufactured by AGC Inc. used in Example 4 was pulverized with a hammer mill so that the d50 became approximately 10 μm.

The d50 was 13.4 μm. The oil absorption was as small as 30 mL/100 g. The apparent density became as small as 0.35 g/mL. As for the crystallite sizes, the crystallite size of the (210) plane was 93 nm, and the crystallite size of the (121) plane was 98 nm.

In addition, the moisture resistance was very poor, and the powder had caked after 24 hours. The deodorizing performance was also poorer than those of Examples 1 to 3.

Various conditions and results are shown in Table 1 and Table 2.

[0043]

(Example 6)

Physical properties of a commercially available sodium bicarbonate powder produced from trona ore as a raw material were evaluated.

The d50 was 110.9 μm. The oil absorption was as small as 29 mL/100 g. The apparent density was as large as 1.09 g/mL. As for the crystallite sizes, the crystallite size of the (210) plane was 88 nm and the crystallite size of the (121) plane was 76 nm, which were relatively small.

In addition, the moisture resistance was very poor, and the powder had caked after 12 hours. The deodorizing performance was also only 10%, which was very poor as compared with those of Examples 1 to 3.

Various conditions and results are shown in Table 1 and Table 2.

[0044]

[Table 1]

Example	Sodium bicarbonate powder	Physical properties of the obtained sodium bicarbonate										
					Crystallite size of (210) plane				Crystallite size of (121) plane			
		d50	Oil absorption	Apparent density	Peak position 2θ	B Full width at half maximum	B0	Crystallite size	Peak position 2θ	B Full width at half maximum	B0	Crystallite size
		(μm)	(mL/100 g)	(g/mL)	(deg)	(deg)	(deg)	(nm)	(deg)	(deg)	(deg)	(nm)
Example 1	Synthesized with the apparatus of FIG. 1	8.9	42	0.28	25.53	0.149	0.0502	82	34.43	0.165	0.058	77
Example 2	Synthesized with the apparatus of FIG. 2	11.1	46	0.29	25.55	0.137	0.0502	93	34.45	0.155	0.058	85
Example 3	Synthesized with the apparatus of FIG. 3	14.0	125	0.08	25.53	0.251	0.0502	40	34.45	0.222	0.058	50
Example 4	General-purpose industrial-grade sodium bicarbonate KF manufactured by AGC Inc.	130.0	14	1.12	25.57	0.104	0.0502	149	34.48	0.110	0.058	157
Example 5	Pulverized product of Example 4	13.4	30	0.35	25.56	0.137	0.0502	93	34.47	0.142	0.058	98
Example 6	Commercially available product produced from trona ore as a raw material	110.9	29	1.09	25.61	0.142	0.0502	88	34.51	0.166	0.058	76

[0045]

[Table 2]

Example	Name of sodium bicarbonate powder	Moisture resistance								Deodorizing performance (%)
		After 12 hours	After 24 hours	After 36 hours	After 48 hours	After 60 hours	After 72 hours	After 84 hours	After 96 hours	
Example 1	Synthesized with the apparatus of FIG. 1	Good	Good	Good	Good	Good	Poor	–	–	76
Example 2	Synthesized with the apparatus of FIG. 2	Good	Good	Good	Good	Good	Poor	–	–	79
Example 3	Synthesized with the apparatus of FIG. 3	Good	Good	Good	Good	Good	Good	Good	Poor	99
Example 4	General-purpose industrial-grade sodium bicarbonate KF manufactured by AGC Inc.	Poor	–	–	–	–	–	–	–	71
Example 5	Pulverized product of Example 4	Good	Poor	–	–	–	–	–	–	71
Example 6	Commercially available product produced from trona ore as a raw material	Poor	–	–	–	–	–	–	–	10

REFERENCE SIGNS LIST

[0046]

100, 200, 300 Sodium bicarbonate powder production apparatus

1 Crystallization tank

2 Stirring device

3 Liquid in crystallization tank

4 Vortex turbo mixer pump

5 Circulation pipe

6 Supply pipe for gas containing carbon dioxide

7 Feed pipe

8 Centrifugal dewatering machine

9 Filtrate

10 Cake of sodium bicarbonate

11 Drying equipment

12 Sodium bicarbonate powder

13 Magnet pump

14 YJ nozzle

15 Vessel

16 Liquid to be sprayed

17 Pump

18 Two-fluid nozzle

19 High-temperature air

20 Spray cylinder

21 Cyclone

22 Recovery vessel

23 Sodium bicarbonate powder

24 Filter

25 Polystyrene resin container

26 Sodium bicarbonate powder

CLAIMS

[Claim 1] A sodium bicarbonate powder having an oil absorption of 40 mL/100 g or more.

[Claim 2] The sodium bicarbonate powder according to claim 1, wherein a crystallite size of a (210) plane is 75 nm or less, and a crystallite size of a (121) plane is 70 nm or less.

[Claim 3] The sodium bicarbonate powder according to claim 1, wherein a ratio (D210/D121) of a crystallite size (D210) of a (210) plane to a crystallite size (D121) of a (121) plane is 0.60 to 1.00.

[Claim 4] A sodium bicarbonate powder having an apparent density of 0.32 g/mL or less.

[Claim 5] The sodium bicarbonate powder according to claim 4, wherein a crystallite size of a (210) plane is 75 nm or less, and a crystallite size of a (121) plane is 70 nm or less.

[Claim 6] The sodium bicarbonate powder according to claim 4, wherein a ratio (D210/D121) of a crystallite size (D210) of a (210) plane to a crystallite size (D121) of a (121) plane is 0.60 to 1.00.

[Claim 7] A sodium bicarbonate powder having an oil absorption of 40 mL/100 g or more and an apparent density of 0.32 g/mL or less.

[Claim 8] The sodium bicarbonate powder according to claim 7, wherein a crystallite size of a (210) plane is 75 nm or less, and a crystallite size of a (121) plane is 70 nm or less.

[Claim 9] The sodium bicarbonate powder according to claim 7, wherein a ratio (D210/D121) of a crystallite size (D210) of a (210) plane to a crystallite size (D121) of a (121) plane is 0.60 to 1.00.

[Claim 10] The sodium bicarbonate powder according to any one of claims 1 to 9,

having an oil absorption of 100 mL/100 g or more.

[Claim 11] The sodium bicarbonate powder according to any one of claims 1 to 9, having an apparent density of 0.10 g/mL or less.

[Claim 12] The sodium bicarbonate powder according to any one of claims 1 to 9, having an average particle diameter (d50) of 12 μm to 50 μm.

[Claim 13] The sodium bicarbonate powder according to any one of claims 1 to 9, wherein a crystallite size of a (210) plane is 60 nm or less, or 45 nm or less, and a crystallite size of a (121) plane is 55 nm or less.

[Claim 14] A method for producing sodium bicarbonate, comprising supplying fine bubbles of a gas containing carbon dioxide to an aqueous solution of sodium hydroxide or an aqueous solution of sodium carbonate to obtain sodium bicarbonate.

[Claim 15] A method for producing sodium bicarbonate, comprising spraying an aqueous solution of sodium bicarbonate with a spray dryer to obtain sodium bicarbonate.