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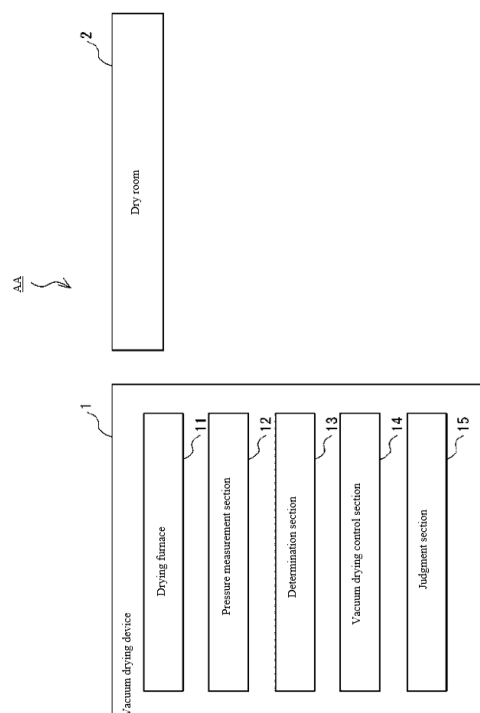
(54) [Title of Invention] Vacuum drying device, vacuum drying system, vacuum drying method and manufacturing method of battery electrodes

(57) [Abstract]

[Problem to be Solved] To complete vacuum drying in the optimal state.

[Means for Solving the Problem] The vacuum drying device 1 is equipped with a drying furnace 11, a pressure measurement section 12, a determination section 13, a vacuum drying control section 14, and a judgment section 15, and it performs vacuum drying on battery electrodes arranged inside the drying furnace 11. The pressure measurement section 12 measures the pressure inside the drying furnace 11. The determination section 13 determines whether the pressure measured by the pressure measurement section 12 is below the target pressure. The vacuum drying control section 14 continues the vacuum drying for a first period of time after it has been determined by the determination section 13 that the pressure measured by the pressure measurement section 12 is below the target pressure. The judgment section 15 concludes that the vacuum drying of the battery electrodes is complete when it is determined by the determination section 13 that the pressure measured by the pressure measurement section 12 is below the target pressure after the first period of time has elapsed.

[Selected representative diagram] Fig. 1



[Scope of Patent Claims]

[Claim 1]

A vacuum drying device that performs vacuum drying on an object to be dried arranged in a drying furnace, comprising:
a pressure measurement means for measuring the pressure inside the aforementioned drying furnace;

a determination means for determining whether the pressure measured by the aforementioned pressure measurement means has decreased to below or less than a predetermined target pressure;

a vacuum drying control means that continues vacuum drying for a predetermined first period of time after it has been determined by the aforementioned determination means that the pressure measured by the aforementioned pressure measurement means is below or less than the aforementioned target pressure; and

10 a judgment means that judges that the vacuum drying of the aforementioned object to be dried is complete when the pressure measured by the aforementioned pressure measurement means is determined by the aforementioned determination means to be below or less than the aforementioned target pressure after the aforementioned first period of time has elapsed.

[Claim 2]

A vacuum drying device described in Claim 1, comprising a time-counting means for measuring the time since the start of the vacuum drying of the aforementioned object to be dried, wherein during the period until the time measured by the aforementioned time-counting means exceeds a predetermined second period of time, the determination by the aforementioned determination means is suspended.

[Claim 3]

20 A vacuum drying device described in Claim 1 or 2, wherein if the environment in which the aforementioned object to be dried is placed after the completion of vacuum drying is referred to as the predetermined environment, the aforementioned target pressure is set lower than the saturation vapor pressure at the dew point in the aforementioned predetermined environment.

[Claim 4]

A vacuum drying device described in Claim 3, wherein if the dew point (in degrees Celsius) in the aforementioned predetermined environment is denoted as t , and predetermined constants are denoted as a and b , the saturation vapor pressure e at the dew point in the aforementioned predetermined environment is determined using the following mathematical formula (1):

[Mathematical formula 1]

$$e = 6.1078 \times 10^{\frac{a \times t}{b+t}} \cdot \cdot \cdot \quad (1)$$

[Claim 5]

30 A vacuum drying device described in Claim 3 or 4, wherein how much lower than the saturation vapor pressure at the dew point in the aforementioned predetermined environment the aforementioned target pressure is set is determined according to the material of the aforementioned object to be dried.

[Claim 6]

A vacuum drying device described in any one of Claims 1 to 5, wherein the aforesaid determination means performs abnormality detection of the aforementioned vacuum drying device based on the pressure measured by the aforementioned pressure measurement means, and if an abnormality is detected, outputs an indication of the abnormality.

[Claim 7]

A vacuum drying device described in any one of Claims 1 to 6, wherein the objects to be dried are battery electrodes.

[Claim 8]

40 A vacuum drying system comprising a vacuum drying device according to any one of Claims 1 to 7, and a dry room where the aforementioned object to be dried is placed after the completion of vacuum drying by the aforementioned vacuum drying device, wherein after the vacuum drying of the aforementioned object to be dried is determined to be complete by the aforementioned judgment means, the object to be dried is transferred from the aforementioned drying furnace to the aforementioned dry room.

[Claim 9]

A vacuum drying method for performing vacuum drying on an object to be dried arranged in a drying furnace, comprising:
a first step of measuring the pressure inside the aforementioned drying furnace;

a second step of determining whether the pressure measured in the aforementioned first step has decreased to below or less than a predetermined target pressure;

a third step of continuing vacuum drying for a predetermined first period of time after it is determined in the aforementioned second step that the pressure measured in the aforementioned first step is below or less than the aforementioned target pressure;

a fourth step of measuring the pressure inside the aforementioned drying furnace after the aforementioned first period of time has elapsed;

a fifth step of determining whether the pressure measured in the aforementioned fourth step has decreased to below or less than the aforementioned target pressure;

10 a sixth step of determining that the vacuum drying of the aforementioned object to be dried is complete when the pressure measured in the aforementioned fourth step is determined in the aforementioned fifth step to be below or less than the aforementioned target pressure; and

a seventh step of transferring the object to be dried, which is judged to have completed vacuum drying in the aforementioned sixth step, from the aforementioned drying furnace to an area adjusted to a predetermined environment.

[Claim 10]

The vacuum drying method described in Claim 9, further comprising an eighth step of measuring the time since the start of vacuum drying of the aforementioned object to be dried, wherein during the period until the time measured in the aforementioned eighth step exceeds a predetermined second period of time, the determination in the aforementioned second step is suspended.

[Claim 11]

20 The vacuum drying method described in Claim 9 or 10, wherein the aforementioned target pressure is set lower than the saturation vapor pressure at the dew point in the aforementioned predetermined environment.

[Claim 12]

The vacuum drying method described in Claim 11, wherein if the dew point (in degrees Celsius) in the aforementioned predetermined environment is denoted as t , and predetermined constants are denoted as a and b , the saturation vapor pressure e at the dew point in the aforementioned predetermined environment is determined using the following mathematical formula (2):

[Mathematical formula 2]

$$e = 6.1078 \times 10^{\frac{a \times t}{b+t}} \cdot \cdot \cdot \quad (2)$$

[Claim 13]

30 A vacuum drying method described in Claim 11 or 12, wherein how much lower than the saturation vapor pressure at the dew point in the aforementioned predetermined environment the aforementioned target pressure is set is determined according to the material of the aforementioned object to be dried.

[Claim 14]

A vacuum drying method described in Claim 9 to 13, wherein in the second step, the abnormality detection of the vacuum drying device that is used to perform vacuum drying on the aforementioned object to be dried is performed based on the pressure measured in the aforementioned first step.

[Claim 15]

A vacuum drying method described in any one of Claims 9 to 14, wherein the object to be dried are battery electrodes.

[Claim 16]

40 A manufacturing method of battery electrodes for performing vacuum drying on battery electrodes arranged in a drying furnace, comprising:

a first step of measuring the pressure inside the aforementioned drying furnace;

a second step of determining whether the pressure measured in the aforementioned first step has decreased to below or less than a predetermined target pressure;

a third step of continuing vacuum drying for a predetermined first period of time after it is determined in the aforementioned second step that the pressure measured in the aforementioned first step is below or less than the aforementioned target pressure;

a fourth step of measuring the pressure inside the aforementioned drying furnace after the aforementioned first period of time has elapsed;

a fifth step of determining whether the pressure measured in the aforementioned fourth step has decreased to below or less than the aforementioned target pressure;

a sixth step of determining that the vacuum drying of the aforementioned battery electrodes is complete when the pressure measured in the aforementioned fourth step is determined in the aforementioned fifth step to be below or less than the aforementioned target pressure; and

a seventh step of transferring the battery electrodes, which are judged to have completed vacuum drying in the aforementioned sixth step, from the aforementioned drying furnace to an area adjusted to a predetermined environment.

[Detailed Explanation of the Invention]

[Technical Field]

[0001]

This invention relates to a vacuum drying device, a vacuum drying system, a vacuum drying method, and a manufacturing method for battery electrodes.

[Background Technology]

[0002]

Conventional techniques have been proposed for performing vacuum drying on objects to be dried (for example, refer to Patent Document 1).

[Existing Technology Document]

[Patent Document]

[0003]

[Patent Document 1] Japanese Unexamined Patent Application Publication Official Gazette No. 2005-140536.

[Overview of the Invention]

[Problems to be Solved by the Invention]

[0004]

The methods described in Patent Document 1, as well as those shown in the literature referenced therein, aim to accurately determine the completion of vacuum drying, thereby suppressing occurrences of excessive drying and insufficient drying. Although this challenge of optimally completing vacuum drying has existed historically, various improvements continue to be made, and no satisfactory technology for determining the completion of vacuum drying has emerged so far. In particular, when drying electrodes for secondary batteries such as lithium-ion batteries, if the electrodes are not sufficiently dried, there is a risk that the batteries produced using those electrodes will fail to demonstrate the desired performance.

[0005]

Therefore, this invention has been developed in light of the aforementioned issues, with the aim of completing vacuum drying under optimal conditions.

[Means for Solving the Problems]

[0006]

This invention proposes the following measures to solve the aforementioned problems. Moreover, to facilitate understanding, reference numerals corresponding to embodiments of this invention are provided, but the invention is not limited to these embodiments.

[0007]

(1) This invention is a vacuum drying device (for example, corresponding to the vacuum drying device 1 in Fig. 1) for performing vacuum drying on an object to be dried (for example, corresponding to the battery electrodes mentioned later) arranged in a drying furnace (for example, corresponding to the drying furnace 11 in Fig. 1). It comprises: a pressure measurement means (for example, corresponding to the pressure measurement section 12 in Fig. 1) for measuring the pressure inside the aforementioned drying furnace; a determination means (for example, corresponding to the determination section 13 in Fig. 1) for determining whether the pressure measured by the aforementioned pressure measurement means has decreased to below or less than a predetermined target pressure; a vacuum drying control means (for example, corresponding to the vacuum drying control section 14 in Fig. 1) for continuing vacuum drying for a predetermined first period after it is determined by the aforementioned determination means that the pressure measured by the aforementioned pressure measurement means is below or less than the aforementioned target pressure; and a judgment means (for example, corresponding to the judgment

section 15 in Fig. 1) for determining that the vacuum drying of the aforementioned object to be dried is complete when the pressure measured by the aforementioned pressure measurement means after the aforementioned first period is determined by the aforementioned determination means to be below or less than the aforementioned target pressure.

[0008]

According to this invention, the pressure measurement means is used to measure the pressure inside the drying furnace. In addition, the determination means is employed to ascertain whether the pressure measured by the pressure measurement means has fallen below or is less than the target pressure. Moreover, the vacuum drying control means continues vacuum drying over the first period of time once the pressure measurement means indicates that the pressure has dropped below or is less than the target pressure as determined by the determination means. For this reason, even after it is determined that the pressure inside the drying furnace has fallen below or is less than the target pressure, the vacuum drying will still continue over the first period of time, allowing for a suppression of drying insufficiencies without being greatly affected by the accuracy of the target pressure setting.

[0009]

In addition, according to this invention, by setting the first period of time, it is possible to prevent the duration of vacuum drying from becoming excessively prolonged, thereby suppressing the occurrence of excessive drying.

[0010]

In addition, according to this invention, if, after the first period of time has elapsed, the pressure measured by the pressure measurement means is determined by the determination means to have decreased below or less than the target pressure, it is concluded that the vacuum drying of the object to be dried is complete. As a result, even during the period when vacuum drying continues over the first period of time, if an unforeseen circumstance leads to the object being inadequately dried, it can be determined that the vacuum drying is not yet complete, thus preventing a misjudgment that the vacuum drying has been completed despite insufficient drying.

[0011]

(2) This invention proposes a vacuum drying device concerning (1), which includes time-counting means (for example, corresponding to the time-counting section 16 in Fig. 3) for measuring the time since the commencement of vacuum drying of the aforementioned object to be dried. During the period until the time measured by the aforementioned time-counting means exceeds a predetermined second period of time, the determination made by the aforementioned determination means is suspended.

[0012]

According to this invention, in the vacuum drying device of (1), the time-counting means measures the time since the start of vacuum drying of the object to be dried, and during the period until the time measured by the time-counting means exceeds the second period of time, the determination made by the determination means is suspended. Therefore, by setting the second period of time, it is possible to suspend the determination made by the determination means during a period when it is certain that the vacuum drying of the object to be dried is not yet complete.

[0013]

(3) This invention proposes a vacuum drying device concerning (1) or (2), wherein the environment where the aforementioned object to be dried will be placed after the completion of vacuum drying is referred to as a predetermined environment (for example, corresponding to the dry room 2 in Fig. 1). In this case, the pressure set as the aforementioned target pressure is lower than the saturation vapor pressure at the dew point in the aforementioned predetermined environment.

[0014]

According to this invention, in the vacuum drying device of (1) or (2), where the object to be dried will be placed in a predetermined environment after the completion of vacuum drying, the target pressure is set to be lower than the saturation vapor pressure at the dew point in the predetermined environment. Consequently, the accuracy of the target pressure as a criterion for determining the completion of vacuum drying can be improved, allowing for a more reliable suppression of inadequate drying and enabling a reduction in the first period of time during which vacuum drying is continued.

[0015]

In addition, it is conceivable to find the optimal value of the target pressure by repeating the procedures for appropriately setting the target pressure and measuring the moisture content contained in the object to be dried or evaluating its performance after the completion of vacuum drying. Therefore, according to this invention, in the vacuum drying device of (1) or (2), the

target pressure is set to be lower than the saturation vapor pressure at the dew point in the predetermined environment. Thus, when finding the optimal value of the target pressure, the initial value of the target pressure can be set using the saturation vapor pressure at the dew point in the predetermined environment as a reference. Accordingly, it becomes possible to set a more appropriate initial value for the target pressure compared to the situation where there is no reference, thus reducing the number of times these two procedures need to be repeated and enabling the optimal value of the target pressure to be determined in a shorter time.

[0016]

(4) This invention proposes a vacuum drying device concerning (3), wherein the dew point (in degrees Celsius) in the aforementioned predetermined environment is denoted as t , and the predefined constants are denoted as a and b . The saturation vapor pressure e at the dew point in the aforementioned predetermined environment is determined using the following mathematical formula (1).

[0017]

[Mathematical formula 1]

$$e = 6.1078 \times 10^{\frac{a \times t}{b+t}} \cdot \cdot \cdot \quad (1)$$

[0018]

According to this invention, in the vacuum drying device of (3), the saturation vapor pressure at the dew point in the predetermined environment can be determined using the aforementioned mathematical formula (1), known as the Tetens formula, without employing a complex method.

[0019]

(5) This invention proposes a vacuum drying device concerning (3) or (4), which determines how much lower than the aforementioned saturation vapor pressure at the dew point in the aforesaid predetermined environment the aforementioned target pressure should be set, depending on the material of the object to be dried.

[0020]

After the completion of vacuum drying, the object to be dried will absorb moisture during the period it is placed in the predetermined environment, depending on the material of the object to be dried. Therefore, according to this invention, in the vacuum drying device of (3) or (4), the decision of how much lower than the saturation vapor pressure at the dew point in the predetermined environment the target pressure should be set is made according to the material of the object to be dried. This allows for the setting of the target pressure based on the hygroscopicity of the object to be dried in the predetermined environment.

[0021]

(6) This invention proposes a vacuum drying device concerning any one of (1) to (5), wherein the aforementioned determination means detects abnormalities in the vacuum drying device based on the pressure measured by the aforementioned pressure measurement means and outputs an indication of the abnormality when such an abnormality is determined.

[0022]

According to this invention, in any one of the vacuum drying devices from (1) to (5), the determination means performs abnormality detection of the vacuum drying device based on the pressure measured by the pressure measurement means, and if an abnormality is judged to exist, it issues an output indicating the abnormality. As a result, it becomes possible to detect and output abnormalities in the vacuum drying device while determining the completion of vacuum drying.

[0023]

(7) This invention proposes a vacuum drying device regarding any one of (1) to (6), wherein the objects to be dried are battery electrodes.

[0024]

According to this invention, in any one of the vacuum drying devices from (1) to (6), the object to be dried is specified as a battery electrode. This helps to suppress the occurrence of insufficient drying of the battery electrodes.

[0025]

(8) This invention proposes a vacuum drying system that includes any one of the vacuum drying devices from (1) to (7) and a dry room where the aforementioned object to be dried is placed after the completion of vacuum drying (for example,

corresponding to the dry room 2 in Fig. 1), wherein the object to be dried will be transferred from the aforementioned drying furnace to the aforementioned dry room after it has been judged as having completed vacuum drying by the aforementioned judgment means.

[0026]

According to this invention, in a vacuum drying system comprising any one of the vacuum drying devices from (1) to (7) and the dry room where the object to be dried is placed after the completion of vacuum drying, the object to be dried will be transferred from the drying furnace to the dry room after the judgment means has determined that the vacuum drying of the object to be dried has been completed. This allows for the vacuum drying device to perform vacuum drying on a new object to be dried after transferring the object to be dried from the drying furnace to the dry room.

[0027]

(9) This invention relates to a vacuum drying method that performs vacuum drying on an object to be dried (for example, corresponding to the battery electrodes described later) placed in a drying furnace (for example, corresponding to the drying furnace 11 in Fig. 1). The method includes a first step of measuring the pressure inside the aforementioned drying furnace; a second step of determining whether the pressure measured in the aforementioned first step has decreased to below or less than a predetermined target pressure; a third step of continuing vacuum drying for a predetermined first period of time after it is determined in the aforementioned second step that the pressure measured in the aforementioned first step is below or less than the aforementioned target pressure; a fourth step of measuring the pressure inside the aforementioned drying furnace after the aforementioned first period of time has elapsed; a fifth step of determining whether the pressure measured in the aforementioned fourth step has decreased to below or less than the aforementioned target pressure; a sixth step of determining that the vacuum drying of the aforementioned object to be dried is complete when the pressure measured in the aforementioned fourth step is determined in the aforementioned fifth step to be below or less than the aforementioned target pressure; and a seventh step of transferring the object to be dried, which is judged to have completed vacuum drying in the aforementioned sixth step, from the aforementioned drying furnace to an area adjusted to a predetermined environment (for example, corresponding to the dry room 2 in Fig. 1).

[0028]

According to this invention, similar effects as those mentioned above can be achieved.

[0029]

(10) This invention proposes a vacuum drying method concerning the vacuum drying method of (9), which further includes an eighth step of measuring the time since the start of vacuum drying of the object to be dried, and during the period until the time measured in the eighth step exceeds a predetermined second period of time, it is characterized by suspending the determination made in the second step.

[0030]

According to this invention, similar effects as those mentioned above can be achieved.

[0031]

(11) This invention proposes a vacuum drying method regarding the vacuum drying methods of (9) or (10), wherein the aforementioned target pressure is set to a pressure lower than the saturation vapor pressure at the dew point in the aforementioned predetermined environment.

[0032]

According to this invention, similar effects as those mentioned above can be achieved.

[0033]

(12) This invention proposes a vacuum drying method regarding the vacuum drying method of (11), wherein when the dew point (in degrees Celsius) in the aforementioned predetermined environment is denoted as t , and predetermined constants are represented as a and b , the saturation vapor pressure e at the dew point in the aforementioned predetermined environment is determined using the following mathematical formula (2).

[0034]

[Mathematical formula 2]

$$e = 6.1078 \times 10^{\frac{a \times t}{b+t}} \cdot \cdot \cdot \quad (2)$$

[0035]

According to this invention, similar effects as those mentioned above can be achieved.

[0036]

(13) This invention proposes a vacuum drying method concerning the vacuum drying methods of (11) or (12), wherein how much lower the target pressure is set from the saturation vapor pressure at the dew point in the aforementioned predetermined environment is determined depending on the material of the object to be dried.

[0037]

10 According to this invention, similar effects as those mentioned above can be achieved.

[0038]

(14) This invention proposes a vacuum drying method regarding any one of the vacuum drying methods from (9) to (13), which includes performing abnormality detection of the vacuum drying device that dries the object to be dried based on the pressure measured in the first step during the second step.

[0039]

According to this invention, similar effects as those mentioned above can be achieved.

[0040]

(15) This invention proposes a vacuum drying method concerning any one of the vacuum drying methods from (9) to (14), wherein the objects to be dried are battery electrodes.

20 [0041]

According to this invention, similar effects as those mentioned above can be achieved.

[0042]

(16) This invention is a manufacturing method of battery electrodes that performs vacuum drying on battery electrodes placed in a drying furnace (for example, corresponding to the drying furnace 11 in Fig. 1). The method includes a first step of measuring the pressure inside the aforementioned drying furnace; a second step of determining whether the pressure measured in the aforementioned first step has decreased to below or less than a predetermined target pressure; a third step of continuing vacuum drying for a predetermined first period of time after it is determined in the aforementioned second step that the pressure measured in the aforementioned first step is below or less than the aforementioned target pressure; a fourth step of measuring the pressure inside the aforementioned drying furnace after the aforementioned first period of time has elapsed; a fifth step of determining whether the pressure measured in the aforementioned fourth step has decreased to below or less than the aforementioned target pressure; a sixth step of determining that the vacuum drying of the aforementioned battery electrodes is complete when the pressure measured in the aforementioned fourth step is determined in the aforementioned fifth step to be below or less than the aforementioned target pressure; and a seventh step of transferring the battery electrodes, which is judged to have completed vacuum drying in the aforementioned sixth step, from the aforementioned drying furnace to an area adjusted to a predetermined environment (for example, corresponding to the dry room 2 in Fig. 1).

30 [0043]

According to this invention, similar effects as those mentioned above can be achieved when manufacturing battery electrodes.

[Effects of the Invention]

40 [0044]

According to this invention, vacuum drying can be completed under optimal conditions.

[Brief Description of Drawings]

[0045]

[Fig. 1] It is a block diagram of the vacuum drying device according to the first embodiment of this invention.

[Fig. 2] It is a diagram showing the state of water changing according to temperature and pressure.

[Fig. 3] It is a block diagram of the vacuum drying device according to the second embodiment of this invention.

[Embodiments of the Invention]

[0046]

Below, the embodiments of this invention will be described in detail using the Drawings. Please note that the components in the following embodiments can be appropriately replaced with existing components and various combinations with other existing components are possible. Therefore, the description of the following embodiments does not limit the scope of the invention as stated in the Scope of Patent Claims.

[0047]

<First Embodiment>

10 Fig. 1 is a block diagram of the vacuum drying system AA according to the first embodiment of this invention. The vacuum drying system AA includes a vacuum drying device 1 that performs vacuum drying on battery electrodes, and a dry room 2 where the battery electrodes are placed after the completion of vacuum drying by the vacuum drying device 1.

[0048]

The vacuum drying device 1 comprises a drying furnace 11, a pressure measurement section 12, a determination section 13, a vacuum drying control section 14, and a judgment section 15. It performs vacuum drying on the battery electrodes placed inside the drying furnace 11 to remove moisture contained in the battery electrodes.

[0049]

The pressure measurement section 12 measures the pressure inside the drying furnace 11.

[0050]

20 The determination section 13 determines whether the pressure measured by the pressure measurement section 12 has fallen below a predetermined target pressure. The setting of the aforementioned target pressure will be detailed below using Fig. 2.

[0051]

As shown in Fig. 2, the state of water changes according to temperature and pressure. Therefore, first, the dew point (in degrees Celsius) in the dry room 2, where the battery electrodes are placed after vacuum drying is completed, is substituted for t in the following mathematical formula (3) to obtain the saturation vapor pressure e at the dew point in the dry room 2. Moreover, in the mathematical formula (3), a and b are predetermined constants, which are uniquely determined for the case when the moisture in the battery electrodes is water and the case when it is ice.

[0052]

[Mathematical formula 3]

$$e = 6.1078 \times 10^{\frac{a \times t}{b+t}} \cdot \cdot \cdot (3)$$

30 [0053]

Moreover, in the dry room 2, to prevent moisture from adhering to the transported battery electrodes, a threshold based on the dew point of the dry room 2 is set, and environmental adjustments are made through air conditioning to maintain the desired dew point. According to the aforementioned mathematical formula (3), the pressure that serves as the basis for the threshold is determined.

[0054]

Next, a pressure lower than the saturation vapor pressure e at the dew point in the dry room 2 is set as the aforementioned target pressure.

[0055]

40 Here, first, let's consider two cases: one where the target pressure is set higher than the saturation vapor pressure e at the dew point in the dry room 2, and another where the target pressure is set to the saturation vapor pressure e in the dry room 2. In these cases, if the pressure in the drying furnace 11 is equal to or higher than the saturation vapor pressure e at the dew point in the dry room 2, it will be determined that vacuum drying of the battery electrodes is complete, resulting in insufficient drying.

[0056]

Next, let's examine the case where an excessively low pressure is set as the target pressure compared to the saturation vapor pressure e at the dew point in the dry room 2. In this case, excessive drying occurs, and the moisture contained in the

battery electrodes will be less than if the target pressure were appropriately set. However, when this battery electrode is placed in the dry room 2 after completing vacuum drying, the battery electrodes will absorb moisture until they contain the amount of moisture that balances with the saturation vapor pressure in the dry room 2. Therefore, if the target pressure is set to an excessively low pressure compared to the saturation vapor pressure e at the dew point in the dry room 2, it results in inefficiencies in the vacuum drying process compared to setting a proper pressure that is lower than the saturation vapor pressure at the dew point in the dry room 2.

[0057]

However, the hygroscopicity of the battery electrodes varies depending on the material of the battery electrodes. Thus, how much lower the pressure set as the aforementioned target pressure should be compared to the saturation vapor pressure e at the dew point in the dry room 2 is preferably determined based on the material of the battery electrodes.

[0058]

Returning to Fig. 1, the vacuum drying control section 14 continues vacuum drying for a predetermined first period of time after it has been determined by the determination section 13 that the pressure measured by the pressure measurement section 12 has fallen below the aforementioned target pressure. Moreover, the first period of time may either be a predetermined fixed value or a variable value set as needed.

[0059]

First, regarding the case where the first period of time is a fixed value, it is explained as follows. For example, if the accuracy of the target pressure setting is above a predetermined accuracy or if the degree to which the battery electrodes can be easily dried is above a predetermined level, the first period of time may be set short. Conversely, if the accuracy of the target pressure setting is lower than the predetermined accuracy or if the degree to which the battery electrodes can easily dry is below a predetermined level, the first period of time may be set longer. In addition, for instance, as the accuracy of the target pressure setting increases, the first period of time may be set shorter. Furthermore, for example, as the ease of drying of the battery electrodes increases, the first period of time may also be set shorter.

[0060]

Next, let's explain the case where the first period of time is set as a variable value. For example, if the time from when vacuum drying begins until it is determined by the determination section 13 that the pressure measured by the pressure measurement section 12 is below the target pressure exceeds a predetermined time, the first period of time may be set longer to avoid insufficient drying. Conversely, if the time from when vacuum drying begins until it is determined by the determination section 13 that the pressure measured by the pressure measurement section 12 is below the target pressure is less than a predetermined time, the first period of time may be set shorter to avoid excessive drying. In addition, for example, as the time from when vacuum drying begins until it is determined by the determination section 13 that the pressure measured by the pressure measurement section 12 is below the target pressure increases, the aforementioned first period of time may be set longer.

[0061]

The judgment section 15 determines that the vacuum drying of the battery electrodes is complete if, after the first period of time has elapsed, the pressure measured by the pressure measurement section 12 is determined to be below the aforementioned target pressure by the determination section 13. When judgment section 15 concludes that vacuum drying is complete, the vacuum drying device 1 ends the vacuum drying of the battery electrodes located in the drying furnace 11 and transfers the battery electrodes from drying furnace 11 to dry room 2.

[0062]

According to the vacuum drying system AA and the vacuum drying device 1 described above, the following effects can be achieved.

[0063]

The vacuum drying system AA transfers the battery electrodes from drying furnace 11 to dry room 2 after judgment section 15 determines that the vacuum drying of the battery electrodes is complete. As a result, after transferring the battery electrodes from drying furnace 11 to dry room 2, the vacuum drying device 1 can conduct vacuum drying for new battery electrodes.

[0064]

The vacuum drying device 1 measures the pressure in the drying furnace 11 using pressure measurement section 12, and determination section 13 determines whether the pressure measured by the pressure measurement section 12 is below the target pressure. If it is determined by the determination section 13 that the pressure measured by the pressure measurement section 12 is below the target pressure, the vacuum drying control section 14 continues vacuum drying for the duration of the first period of time. Therefore, even after it has been determined that the pressure in the drying furnace 11 is below the target pressure, vacuum drying continues for the first period of time, which helps suppress the occurrence of insufficient drying regardless of the accuracy of the target pressure setting.

[0065]

10 In addition, by setting the first period of time, the vacuum drying device 1 can prevent the duration of the vacuum drying from becoming excessively long, thereby suppressing the occurrence of excessive drying.

[0066]

Moreover, the vacuum drying device 1 uses the judgment section 15 to determine that the vacuum drying of the battery electrodes is complete if, after the first period of time has elapsed, the pressure measured by the pressure measurement section 12 is determined to be below the target pressure by the determination section 13. Therefore, during the period of continued vacuum drying over the first period of time, if an unexpected situation causes the battery electrodes to remain insufficiently dried, it can be judged that the vacuum drying of the battery electrodes has not been completed, thus preventing a false conclusion that vacuum drying is complete despite insufficient drying.

[0067]

20 In addition, the vacuum drying device 1 sets a pressure lower than the saturation vapor pressure at the dew point in the dry room 2 as the target pressure using determination section 13. As a result, it is possible to improve the accuracy of the target pressure set as the criterion for determining the completion of the vacuum drying, thereby more reliably suppressing the occurrence of insufficient drying and shortening the first period of time during which vacuum drying is continued.

[0068]

30 In addition, by repeating the procedure of appropriately setting the target pressure and measuring the moisture content contained in the object to be dried or evaluating the performance of the object to be dried after the completion of vacuum drying, it is conceivable to find the optimal value of the target pressure. Thus, the vacuum drying device 1 sets a pressure lower than the saturation vapor pressure at the dew point in the dry room 2 as the target pressure. This allows for setting the initial value of the target pressure based on the saturation vapor pressure at the dew point in the dry room 2 when searching for the optimal value of the target pressure. Therefore, it is possible to set a more appropriate value as the initial value of the target pressure compared to setting it without any reference, reducing the number of repetitions of the aforementioned two procedures and allowing for finding the optimal value of the target pressure in a shorter time.

[0069]

In addition, the vacuum drying device 1 can determine the saturation vapor pressure at the dew point in the dry room 2 using the above mathematical formula (1) without employing a complicated method.

[0070]

In addition, the vacuum drying device 1 determines how much lower the target pressure should be set compared to the saturation vapor pressure at the dew point in the dry room 2 according to the material of the battery electrodes. For this reason, it is possible to set the target pressure according to the hygroscopicity of the battery electrodes in the dry room 2.

[0071]

40 Moreover, the electrodes of secondary batteries such as lithium-ion batteries have an electrode active material layer on a metal foil (aluminum or copper), and in their manufacturing process, the electrode active material slurry is applied on the metal foil before undergoing vacuum drying treatment to remove moisture from the electrodes. If the electrodes are not sufficiently dried, the desired performance as a secondary battery cannot be achieved; therefore, it is necessary to ensure adequate drying. For this reason, the vacuum drying device 1 is suitable for vacuum drying the electrodes of secondary batteries.

[0072]

In addition, hygroscopic materials are sometimes used in the aforementioned electrode active materials. Thus, the vacuum drying system AA, which places the battery electrodes in the dry room 2 after the completion of vacuum drying, is suitable for

vacuum drying the electrodes of secondary batteries.

[0073]

<Second Embodiment>

Fig. 3 is a block diagram of the vacuum drying system BB according to the second embodiment of this invention. Vacuum drying system BB differs from vacuum drying system AA, which is the first embodiment of this invention shown in Fig. 1, in that it is equipped with the vacuum drying device 1A instead of the vacuum drying device 1. Moreover, in the vacuum drying system BB, the same reference numerals are used for the components that are identical to those in the vacuum drying system AA, and their descriptions are omitted.

[0074]

10 The vacuum drying device 1A comprises a drying furnace 11, a pressure measurement section 12, a determination section 13A, a vacuum drying control section 14, a judgement section 15, and a time-counting section 16, and performs vacuum drying on battery electrodes placed inside the drying furnace 11 to remove moisture contained in the battery electrodes.

[0075]

The time-counting section 16 measures the time elapsed since the start of vacuum drying for the battery electrodes.

[0076]

20 The determination section 13A, similarly to the determination section 13, determines whether the pressure measured by the pressure measurement section 12 is below a predetermined target pressure. However, during the period until the time measured by time-counting section 16 exceeds a predetermined second period of time, the determination section 13A suspends the judgment of whether the pressure measured by the pressure measurement section 12 is below the predetermined target pressure. Therefore, the judgment by the determination section 13A will begin after the second period of time has elapsed since the start of vacuum drying for the battery electrodes.

[0077]

In addition, the determination section 13A conducts abnormality detection for the vacuum drying device 1A based on the pressure measured by the pressure measurement section 12, and if an abnormality is detected, it provides an output indicating the abnormality. Specifically, if the pressure measured by the pressure measurement section 12 is higher than a predetermined upper limit pressure or lower than a predetermined lower limit pressure, the determination section 13A judges that an abnormality has occurred in the vacuum drying device 1A and outputs a signal notifying of the abnormal occurrence.

[0078]

30 According to vacuum drying device 1A, in addition to the aforementioned effects that vacuum drying device 1 can achieve, the following effects can also be realized.

[0079]

The vacuum drying device 1A measures the time elapsed since the start of vacuum drying for the battery electrodes using time-counting section 16, and during the period until the time measured by time-counting section 16 exceeds the second period of time, it suspends the judgment by the determination section 13A. For this reason, by setting the second period of time, it can ensure that the determination by the determination section 13A is suspended during the period when it is certain that the vacuum drying of the battery electrodes has not yet been completed.

[0080]

40 In addition, the vacuum drying device 1A conducts abnormality detection for the vacuum drying device 1A based on the pressure measured by the pressure measurement section 12 through the determination section 13A, and if an abnormality is detected, it provides an output indicating the abnormality. For this reason, it is possible to detect and output abnormalities in the vacuum drying device 1A while determining the completion of the vacuum drying.

[0081]

Thus far, the embodiments of this invention have been described in detail with reference to the drawings; however, the specific configuration is not limited to this embodiment and may include designs that do not deviate from the main idea of this invention.

[0082]

For example, in the above-mentioned embodiments, the target of determining the completion of vacuum drying was set as battery electrodes, but this is not limited to the battery electrodes.

[0083]

50 In addition, in the above-mentioned embodiments, the determination sections 13 and 13A were configured to determine

whether the pressure measured by the pressure measurement section 12 is below the target pressure. However, this is not limited to that case, and the determination sections 13 and 13A may also determine whether the pressure measured by the pressure measurement section 12 is less than the target pressure.

[Explanation of Reference Numerals]

[0084]

AA, BB: Vacuum drying system

1, 1A: Vacuum drying device

2: Dry room

11: Drying furnace

12: Pressure measurement section

13, 13A: Determination section

14: Vacuum drying control section

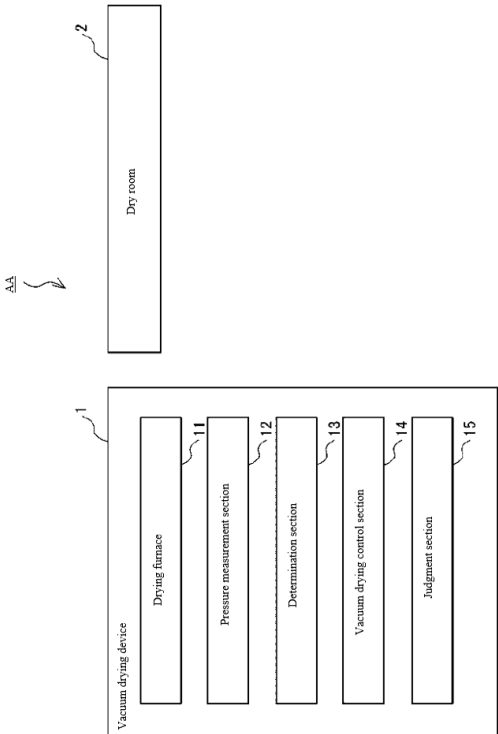
15: Judgment section

16: Time-counting section

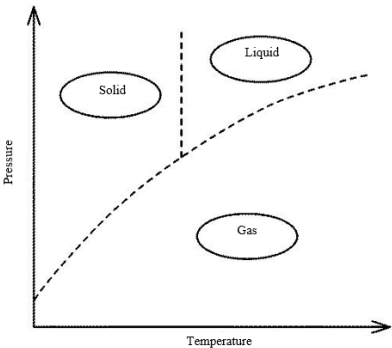
10

20

[Fig. 1]



[Fig. 2]



[Fig. 3]

