The composite particle satisfies a relationship of the following expression (1):

$C_{Li}/C_P \leq 2.5$ (1)

where C_{Li} represents a concentration of lithium element calculated from a peak area of a Li 1s spectrum measured by X-ray photoelectron spectroscopy, and C_P represents a concentration of phosphorus element calculated from a peak area of a P 2p spectrum measured by X-ray photoelectron spectroscopy.

Therefore, in one aspect, there is provided a composite particle comprising: a positive electrode active material particle; and a coating film, wherein the coating film covers at least part of a surface of the positive electrode active material particle, the coating film includes a phosphorus compound, and a relationship of the following expression (1): $C_{Li}/C_P \leq 2.5$ (1) is satisfied, where C_{Li} represents a concentration of lithium element calculated from a peak area of a Li 1s spectrum measured by X-ray photoelectron spectroscopy, and C_P represents a concentration of phosphorus element calculated from a peak area of a P 2p spectrum measured by X-ray photoelectron spectroscopy, wherein a covering rate is 83% or more, the covering rate is measured by X-ray photoelectron spectroscopy, and the covering rate is calculated by the following expression (3): $\theta = P / (P + M) \times 100$ (3) where θ represents the covering rate, P represents a concentration of phosphorus element, and M represents a concentration of a constituent element of the positive electrode active material particle other than lithium element or oxygen element.

Conventionally, a coating film that includes a niobium compound ($LiNbO_3$) is well known. A coating film that includes a niobium compound may be capable of decreasing initial resistance of a battery. However, it tends to have a great post-endurance-test resistance increment.

According to a novel finding of the present disclosure, a coating film that includes a phosphorus compound tends to have a small post-endurance-test resistance increment. However, a conventional film material (Li_3PO_4) tends to have a high initial resistance.

A coating film is required to have Li-ion conductivity. The higher the Li-ion

conductivity is, the more decreased the initial resistance is expected to be. By using X-ray photoelectron spectroscopy (XPS), it is possible to identify the composition of a particle surface (namely, the composition of the coating film). It seems that a conventional film material (Li_3PO_4) has a particle surface composition ratio (C_{Li}/C_P) of 3 or more. In general, it is expected that the higher the particle surface composition ratio (C_{Li}/C_P) (the richer in Li), the higher the Li-ion conductivity and the lower the initial resistance.

However, according to a novel finding of the present disclosure, when the particle surface composition ratio (C_{Li}/C_P) is 2.5 or less, initial resistance may be markedly decreased.

2. The composite particle may have a covering rate of 83% or more, for example. The covering rate is measured by X-ray photoelectron spectroscopy.

The detailed mechanism for the decrease of initial resistance at the time when the expression (1) above is satisfied is unknown. According to a novel finding of the

present disclosure, when the expression (1) above is satisfied, the covering rate tends to be high. There is a possibility that the composition ratio (C_{Li}/C_P) affects the covering rate and, as a result, causes a decrease of initial resistance.

3. The composite particle may include phosphorus in a mass fraction from 6.1 to 6.5%.

4. A positive electrode includes a composite particle and a sulfide-based solid electrolyte. The composite particle includes a positive electrode active material particle and a coating film. The coating film covers at least part of a surface of the positive electrode active material particle. The composite particle satisfies a relationship of the expression (1) above.

In another aspect, there is provided a positive electrode comprising: a composite particle; and a sulfide-based solid electrolyte, wherein the composite particle includes a positive electrode active material particle and a coating film, the coating film covers at least part of a surface of the positive electrode active material particle, the composite particle satisfies a relationship of the following expression (1): $C_{Li}/C_P \leq 2.5$ (1) where C_{Li} represents a concentration of lithium element calculated from a peak area of a Li 1s spectrum measured by X-ray photoelectron spectroscopy, and C_P represents a concentration of phosphorus element calculated from a peak area of a P 2p spectrum measured by X-ray photoelectron spectroscopy, wherein a covering rate is 83% or more, the covering rate is measured by X-ray photoelectron spectroscopy, and the covering rate is calculated by the following expression (3): $\theta = P / (P + M) \times 100$ (3) where θ represents the covering rate, P represents a concentration of phosphorus element, and M represents a concentration of a constituent element of the positive electrode active material particle other than lithium element or oxygen element.

5. The composite particle may have a covering rate of 83% or more, for example. The covering rate is measured by X-ray photoelectron spectroscopy.

6. The composite particle may include phosphorus in a mass fraction from 6.1 to 6.5%, for example.

7. An all-solid-state battery comprises the above-described positive electrode.

In another aspect, there is provided an all-solid-state battery comprising the positive electrode as disclosed herein.

8. A method of producing a composite particle comprises the following (a) and (b):

(a) preparing a mixture by mixing a coating liquid and a positive electrode active material particle; and

(b) producing a composite particle by drying the mixture.

The coating liquid includes a phosphoric acid compound and a solvent. The phosphoric acid compound includes diphosphorus pentoxide in a mass fraction of 72% or more.

In another aspect, there is provided a method of producing a composite particle as disclosed herein, the method comprising: (a) preparing a mixture by mixing a coating liquid and a positive electrode active material particle; and (b) producing a composite particle by drying the mixture, wherein the coating liquid includes a phosphoric acid compound and a solvent, and the phosphoric acid compound includes diphosphorus pentoxide in a mass fraction of 72% or more.

When the coating liquid adhered to the surface of the positive electrode active material particle is dried, a coating film may be produced. The coating liquid includes a phosphoric acid compound. The phosphoric acid compound may be diphosphorus pentoxide (P_2O_5). P_2O_5 is also called "phosphoric anhydride". The phosphoric acid compound may be a derivative of P_2O_5. The derivative of P_2O_5 may be produced by reaction between P_2O_5 and water (hydrolysis). According to a novel finding of the

WHAT IS CLAIMED IS:

1. A composite particle comprising:

a positive electrode active material particle; and

a coating film, wherein

the coating film covers at least part of a surface of the positive electrode active material particle,

the coating film includes a phosphorus compound, and

a relationship of the following expression (1):

$C_{Li}/C_P \leq 2.5$ (1)

is satisfied,

where

C_{Li} represents a concentration of lithium element calculated from a peak area of a Li 1s spectrum measured by X-ray photoelectron spectroscopy, and

C_P represents a concentration of phosphorus element calculated from a peak area of a P 2p spectrum measured by X-ray photoelectron spectroscopy,

wherein a covering rate is 83% or more,

the covering rate is measured by X-ray photoelectron spectroscopy, and

the covering rate is calculated by the following expression (3):

$\theta = P / (P + M) \times 100$ (3)

where

θ represents the covering rate,

P represents a concentration of phosphorus element, and

M represents a concentration of a constituent element of the positive electrode active material particle other than lithium element or oxygen element.

2. The composite particle according to claim 1, wherein phosphorus is included in a mass fraction from 6.1 to 6.5%.

3. A positive electrode comprising:

a composite particle; and

a sulfide-based solid electrolyte, wherein

the composite particle includes a positive electrode active material particle and a coating film,

the coating film covers at least part of a surface of the positive electrode active material particle,

the composite particle satisfies a relationship of the following expression (1):

$C_{Li}/C_P \leq 2.5$ (1)

where

C_{Li} represents a concentration of lithium element calculated from a peak area of a Li 1s spectrum measured by X-ray photoelectron spectroscopy, and

C_P represents a concentration of phosphorus element calculated from a peak area of a P 2p spectrum measured by X-ray photoelectron spectroscopy,

wherein a covering rate is 83% or more,

the covering rate is measured by X-ray photoelectron spectroscopy, and

the covering rate is calculated by the following expression (3):

$\theta = P / (P + M) \times 100$ (3)

where

θ represents the covering rate,

P represents a concentration of phosphorus element, and

M represents a concentration of a constituent element of the positive electrode active material particle other than lithium element or oxygen element.

4. The positive electrode according to claim 3, wherein the composite particle includes phosphorus in a mass fraction from 6.1 to 6.5%.

5. An all-solid-state battery comprising the positive electrode according to claim 3 or 4.

6. A method of producing the composite particle according to claim 1, the method comprising:

(a) preparing a mixture by mixing a coating liquid and a positive electrode active material particle; and

(b) producing a composite particle by drying the mixture, wherein

the coating liquid includes a phosphoric acid compound and a solvent, and

the phosphoric acid compound includes diphosphorus pentoxide in a mass fraction of 72% or more.

7. The method of producing a composite particle according to claim 6, wherein the phosphoric acid compound includes diphosphorus pentoxide in a mass fraction of 72% or more, with the remainder being made up of water.

8. The method of producing a composite particle according to claim 6 or 7, wherein the phosphoric acid compound includes at least one selected from the group consisting of metaphosphoric acid and polyphosphoric acid.

9. The method of producing a composite particle according to any one of claims 6 to 8, wherein the coating liquid satisfies a relationship of the following expression (2):

$0 \leq n_{Li}/n_P < 1.1$ (2)

where

n_{Li} represents a molarity of lithium in the coating liquid, and

n_P represents a molarity of phosphorus in the coating liquid.

10. The method of producing a composite particle according to any one of claims 6 to 9, wherein the (b) includes forming the composite particle by spray drying.