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.

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.

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, 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 ~~(1)~~; and

a coating film ~~(2)~~, wherein

the coating film ~~(2)~~ covers at least part of a surface of the positive electrode active material particle ~~(1)~~,

the coating film ~~(2)~~ 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.

2. The composite particle according to claim 1, wherein

a covering rate is 83% or more, and

the covering rate is measured by X-ray photoelectron spectroscopy.

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

4. A positive electrode comprising:

a composite particle ~~(5)~~; and

a sulfide-based solid electrolyte, wherein

the composite particle ~~(5)~~ includes a positive electrode active material particle ~~(1)~~ and a coating film ~~(2)~~,

the coating film ~~(2)~~ covers at least part of a surface of the positive electrode active material particle ~~(1)~~,

the composite particle ~~(5)~~ satisfies a relationship of the following expression (1):

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

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.

5. The positive electrode according to claim 4, wherein

the composite particle ~~(5)~~ has a covering rate of 83% or more, and

the covering rate is measured by X-ray photoelectron spectroscopy.

6. The positive electrode according to claim 4 or 5, wherein the composite particle ~~(5)~~ includes phosphorus in a mass fraction from 6.1 to 6.5%.

7. An all-solid-state battery comprising the positive electrode ~~(10)~~ according to any one of claims 4 to 6.

8. A method of producing a composite particle, the method comprising:

(a) preparing a mixture by mixing a coating liquid and a positive electrode active material particle ~~(1)~~; and

(b) producing a composite particle ~~(5)~~ 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.

9. The method of producing a composite particle according to claim 8, wherein the phosphoric acid compound includes diphosphorus pentoxide in a mass fraction of 72% or more, with the remainder being made up of water.

10. The method of producing a composite particle according to claim 8 or 9, wherein the phosphoric acid compound includes at least one selected from the group consisting of metaphosphoric acid and polyphosphoric acid.

11. The method of producing a composite particle according to any one of claims 8 to 10, wherein the coating liquid satisfies a relationship of the following expression (2):

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

where

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

n_P represents a molarity of phosphorus in the coating liquid.

12. The method of producing a composite particle according to any one of claims 8 to 11, wherein the (b) includes forming the composite particle ~~(5)~~ by spray drying.