[0021]

The compound represented by the formula (ii) (hereafter also called "compound (ii)") employs a phosphorus-containing ligand as a neutral donor for imparting electronic and three-dimensional characteristics. As a result, the compound (ii) can achieve an excellent low melting point, high volatility, and thermal stability, can introduce phosphorus atoms into a phosphorus-containing film, and can be applied to a solid electrolyte for a solid-state battery.

[0021a]

In one aspect, there is provided compound represented by the formula (ii), wherein in the formula (ii), E_1 and E_2 are independently a carbon atom, a silicon atom, a germanium atom, or a tin atom; Z_1 and Z_2 are independently a single bond or a divalent linking group; R_{21} to R_{28} are independently a hydrogen atom or a C1-10 alkyl group having a constituent atom optionally substituted with a heteroatom; however, all of R_{21} to R_{28} may not be a hydrogen atom; D_2 is a monodentate or bidentate neutral ligand structure; x2 is 0 or an integer of 1 or greater; and y2 is an integer of 1 or greater, however, if none of the carbon atoms constituting R_{23} to R_{26} is substituted with a heteroatom, x2 is a number of 1 or greater and y2 is a number of 1 or greater.

[0022]

In one embodiment, E_1 and E_2 in the compound (ii) are preferably a carbon atom or a silicon atom;

Z_1 and Z_2 are preferably a methylene group or an ethylene group;

R_{21}, R_{22}, R_{27}, and R_{28} are preferably a methyl group, an ethyl group, an n-propyl group, an i-propyl group, an n-butyl group, an i-butyl group, or a t-butyl group;

R_{22} to R_{26} are preferably a hydrogen atom, a methyl group, or an ethyl group;

D_2 is preferably a chain or cyclic ether, a chain or cyclic thioether, or a tertiary amine;

x2 is preferably 0 or 1; and y2 is preferably 1.

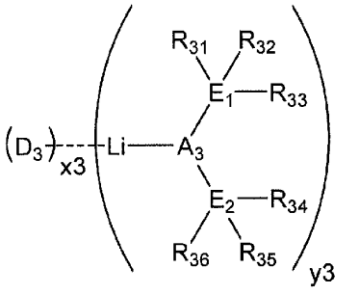
[0023]

By specifically having this structure, the compound (ii) can achieve a low melting point, high volatility, and a high level of thermal stability.

[0024]

In a further embodiment, this compound is preferably represented by the following formula (iii).

[CHEMICAL EXPRESSION 4]



(iii)

(In the formula (iii), A_3 is a phosphorus atom, a boron atom, or an aluminum atom;

E_1 and E_2 are defined the same as in the formula (1);

R_{31} to R_{36} are independently a hydrogen atom or a C1–10 alkyl group having a constituent atom optionally substituted with a heteroatom; however, all of R_{31} to R_{36} may not be a hydrogen atom;

D_3 is a monodentate or bidentate neutral ligand structure;

x3 is 0 or an integer of 1 or greater; and y2 is an integer of 1 or greater.)

[0024a]

In another aspect, there is provided a compound, represented by formula (iii), wherein in the formula (iii), A_3 is a boron atom, or an aluminum atom; E_1 and E_2 are independently a carbon atom, a silicon atom, a germanium atom, or a tin atom; R_{31} to R_{36} are independently a hydrogen atom or a C1–10 alkyl group having a constituent atom optionally substituted with a heteroatom; however, all of R_{31} to R_{36} may not be a hydrogen atom; D_3 is a monodentate or bidentate neutral ligand structure; and x3 is 0 or an integer of 1 or greater; and y2 is an integer of 1 or greater.

[0025]

The compound represented by the formula (iii) (hereafter also called "compound (iii)") can achieve a low melting point, high volatility, and a high level of thermal stability by introduction of a bulky ligand. Development into a solid electrolyte for a solid-state battery can furthermore be anticipated as a result of introduction of phosphorus atoms, boron atoms or aluminum atoms.

[0026]

In one embodiment, A_3 in the compound (iii) is preferably a phosphorus atom;

E_1 and E_2 are preferably a silicon atom;

R_{31} to R_{36} are preferably a methyl group, an ethyl group, an n-propyl group, or an i-propyl group;

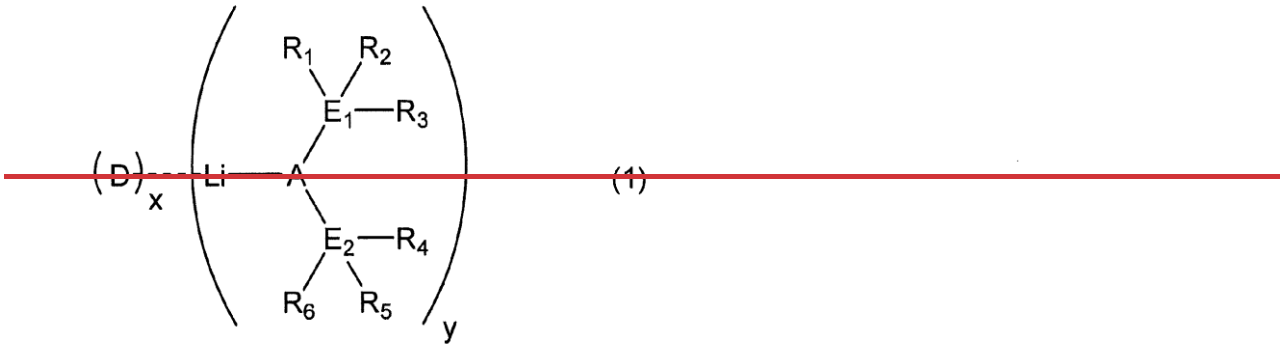
D_3 is preferably N,N,N',N'-tetramethylethylenediamine, N,N,N',N'-tetraethylethylenediamine, N,N,N',N'-tetramethyl-1,3-diaminopropane, or N,N,N',N",N"-pentamethyldiethylenetriamine;

DOCUMENT TITLE: CLAIMS

CLAIM 1

~~A compound represented by the following formula (1).~~

~~[CHEMICAL EXPRESSION 1]~~



~~(In the formula (1), A is a nitrogen atom, a phosphorus atom, a boron atom, or an aluminum atom;~~

~~E_1 and E_2 are independently a carbon atom, a silicon atom, a germanium atom, or a tin atom;~~

~~R_1 to R_6 are independently a hydrogen atom or a C1-10 hydrocarbon group having a constituent atom optionally substituted with a heteroatom; however, all of R_1 to R_6 may not be a hydrogen atom;~~

~~D is a monodentate or polydentate neutral ligand structure;~~

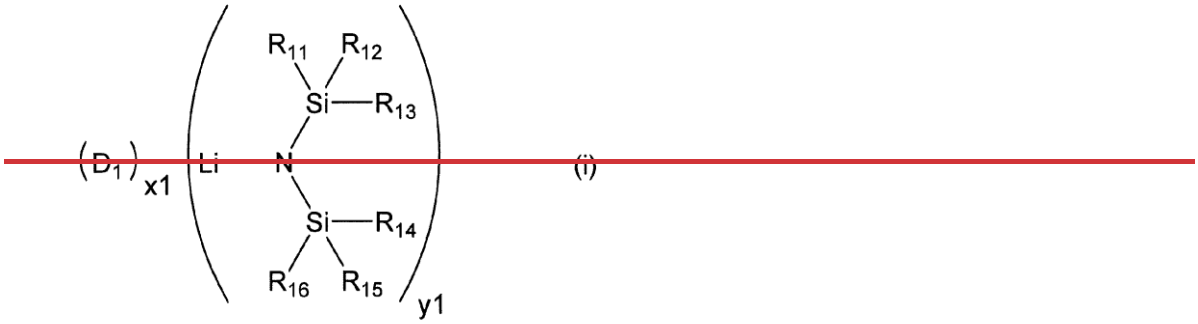
~~x is 0 or an integer of 1 or greater, and y is an integer of 1 or greater; however, if A is a nitrogen atom and none of the carbon atoms constituting R_1 to R_6 is substituted with a heteroatom, x is a number of 1 or greater and y is a number of 1 or greater; and~~

~~if there are more than one of A, E_1, E_2, and R_1 to R_6, these may be the same or different.)~~

~~CLAIM 2~~

~~The compound according to claim 1, represented by the following formula (i).~~

~~[CHEMICAL EXPRESSION 2]~~



~~(In the formula (i), R_{11} to R_{16} are independently a hydrogen atom or a C1-10 alkyl group having a constituent atom optionally substituted with a heteroatom; however, all of R_{11} to R_{16} may not be a hydrogen atom;~~

~~D_1 is a bidentate or tridentate neutral ligand structure; and~~

~~x1 and y1 are independently an integer of 1 or greater.)~~

~~CLAIM 3~~

~~The compound according to claim 2, wherein R_{11} to R_{16} are all methyl groups;~~

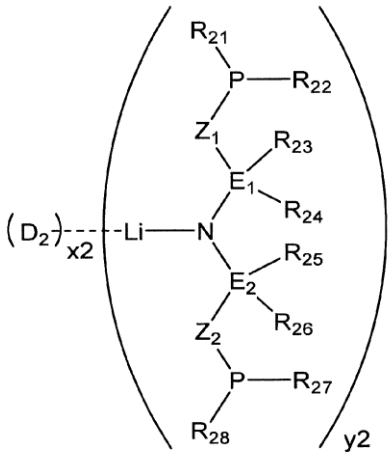
~~D_1 is 1,2-diethoxyethane, diethylene glycol dimethyl ether, N,N,N',N'-tetramethylethylenediamine, N,N,N',N'-tetraethylethylenediamine, N,N,N',N'-tetramethyl-1,3-diaminopropane, or N,N,N',N",N"-pentamethyldiethylenetriamine; and~~

~~x1 and y1 are 1.~~

~~CLAIM 4~~

~~The~~ A compound ~~according to claim 1,~~ represented by the following formula (ii~~).~~):

[CHEMICAL EXPRESSION 3]



(ii)

(wherein In in the formula (ii), E_1 and E_2 are independently a carbon atom, a silicon atom, a germanium atom, or a tin atom defined the same as in the formula (1);

Z_1 and Z_2 are independently a single bond or a divalent linking group;

R_{21} to R_{28} are independently a hydrogen atom or a C1–10 alkyl group having a constituent atom optionally substituted with a heteroatom; however, all of R_{21} to R_{28} may not be a hydrogen atom;

D_2 is a monodentate or bidentate neutral ligand structure;

x2 is 0 or an integer of 1 or greater; and y2 is an integer of 1 or greater, however, if none of the carbon atoms constituting R_{23} to R_{26} is substituted with a heteroatom, x2 is a number of 1 or greater and y2 is a number of 1 or greater.)

CLAIM 52

The compound according to claim 41, wherein E_1 and E_2 are a carbon atom or a silicon atom;

Z_1 and Z_2 are a methylene group or an ethylene group;

R_{21}, R_{22}, R_{27}, and R_{28} are a methyl group, an ethyl group, an n–propyl group, an i–propyl group, an n–butyl group, an i–butyl group, or a t–butyl group;

R_{22} R_{23} to R_{26} are a hydrogen atom, a methyl group, or an ethyl group;

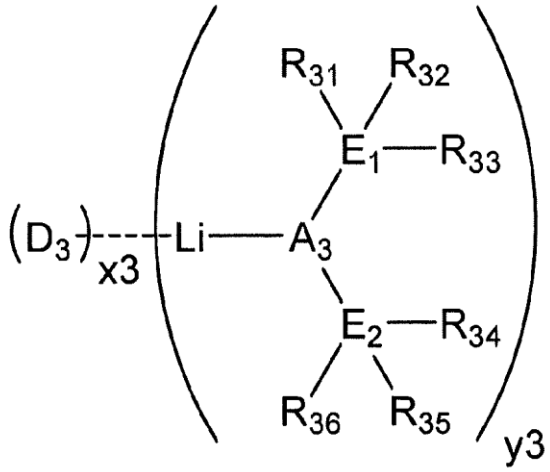
D_2 is a chain or cyclic ether, a chain or cyclic thioether, or a tertiary amine;

x2 is 0 or 1; and y2 is 1.

CLAIM ~~6~~3

~~The~~ A compound ~~according to claim 1~~, represented by the following formula (iii).

[CHEMICAL EXPRESSION 4]



(iii)

~~(In~~ wherein in the formula (iii), A_3 is ~~a phosphorus atom,~~ a boron atom, or an aluminum atom;

E_1 and E_2 are independently a carbon atom, a silicon atom, a germanium atom, or a tin atom~~defined the same as in the formula (1)~~;

R_{31} to R_{36} are independently a hydrogen atom or a C1–10 alkyl group having a constituent atom optionally substituted with a heteroatom; however, all of R_{31} to R_{36} may not be a hydrogen atom;

D_3 is a monodentate or bidentate neutral ligand structure;

x3 is 0 or an integer of 1 or greater; and y2 is an integer of 1 or greater.~~)~~

CLAIM ~~7~~4

The compound according to claim ~~6~~3, wherein ~~A_3 is a phosphorus atom;~~

E_1 and E_2 are a silicon atom;

R_{31} to R_{36} are a methyl group, an ethyl group, an n–propyl group, or an i–propyl group;

D_3 is N,N,N',N'-tetramethylethylenediamine, N,N,N',N'-tetraethylethylenediamine, N,N,N',N'-tetramethyl-1,3-diaminopropane, or N,N,N',N",N"-pentamethyldiethylenetriamine;

x3 is 0 or 1; and y3 is 1.

CLAIM ~~8~~5

The compound according to any one of claims 1 to ~~7~~4, which is a liquid at 25° C, or a temperature demonstrating a vapor pressure of 133.3 Pa is 100° C or less.

CLAIM ~~9~~6

The compound according to any one of claims 1 to ~~8~~5, wherein a region having 95% or greater weight loss at 300° C or less is present according to thermogravimetric analysis.

CLAIM ~~10~~7

The compound according to any one of claims 1 to ~~9~~6, which is for thin film vapor deposition.

CLAIM ~~11~~8

A method for producing a lithium-containing film comprising the steps of:

preparing a reaction chamber having at least one substrate placed inside;

introducing a gas containing the vaporized compound according to any one of claims 1 to ~~10~~ 7 into the reaction chamber: and

forming a lithium-containing film on at least a portion of the surface of the substrate using a vapor deposition process for contacting the substrate with the gas.

CLAIM ~~12~~9

The method for producing a lithium-containing film according to claim ~~11~~8, wherein the vapor deposition process is carried out at 200° C or less.