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(54) **ANTI-FLAKING AGENT AND LUBRICANT COMPOSITION COMPRISING THE SAME**

(57) The present invention provides an anti-flaking agent comprising at least one selected from the group consisting of (A) a compound having a specific volume resistivity of $1.0 \times 10^{10} \Omega \cdot \text{cm}$ or less, and (B) a compound in which a percentage of the number of carbon atoms having an aromatic ring structure is 40% or more among all carbon atoms constituting a molecule, each in an amount exceeding 0.1% by mass based on a total mass of the anti-flaking agent. The present invention also provides a lubricant composition containing the anti-flaking agent.

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Description

[Technical Field]

5 **[0001]** The present invention relates to a novel anti-flaking agent which can be contained in a lubricant applicable to a metal surface of e.g. a rolling bearing. The present invention also relates to a lubricant composition containing the anti-flaking agent.

[Background Art]

10 **[0002]** A peculiar early abnormal flaking involving formation of white etching area occurring on the rolling surface of a rolling bearing has been a problem since the mid-1980s because it reduces the fatigue life of the rolling bearing. Such flaking is called white flaking, white band flaking, brittle flaking, hydrogen brittle flaking, or hydrogen embrittlement flaking.

15 **[0003]** Although the mechanism of how such flaking takes place has not yet been elucidated, Patent Literature 1 introduces a hydrogen hypothesis, for example. Specifically, the hypothesis is as follows: when grease is used under a high load, the grease decomposes to generate hydrogen; the hydrogen penetrates into the steel material of the rolling bearing and reacts with carbide at the grain boundaries; and as a result, the steel material becomes brittle. Patent Literature 1 reports that, when a grease composition contains a specific compound containing at least one sulfur atom such as a thiazole derivative, a sulfurized oil and/or fat, or a sulfurized olefin, it is possible to deal with the problem of white band flaking, that is, the intrusion of hydrogen generated by decomposition of the lubricant into the metal.

20 **[0004]** The mechanism of how flaking takes place is also explained from the viewpoint of the formation of a new metal surface. Specifically, the mechanism is as follows: when the metal transfer surface wears, a new surface is easily formed by the wear; the newly formed surface brings about catalysis to chemically decompose the grease; and as a result, a large amount of hydrogen is generated, and the generated hydrogen penetrates into the steel to finally produce cracks on the metal surface. Patent Literature 2 reports an additive which is a passivating oxidizer such as a nitrite, where the additive is added to the grease to oxidize the metal surface and suppress the catalytic activity of the surface, thereby suppressing the generation of hydrogen due to the decomposition of the lubricant. Patent Literature 3 reports a technique of combining a passivating oxidizer with an organic sulfonate. Patent Literature 4 reports a technique of allowing grease to contain a specific amount of an azo compound. Patent Literature 5 reports a technique that suppresses the generation of hydrogen from grease by using a phenyl ether-based synthetic oil as the base oil of the grease.

[Citation List]

[Patent Literature]

35 **[0005]**

[Patent Literature 1] International Publication No. WO2015/016376

[Patent Literature 2] Japanese Patent Application Publication No. Hei 3-210394

40 [Patent Literature 3] Japanese Patent Application Publication No. Hei 5-263091

[Patent Literature 4] Japanese Patent Application Publication No. 2002-130301

[Patent Literature 5] Japanese Patent Application Publication No. Hei 3-250094

[Summary of Invention]

45 **[0006]** Meanwhile, it is known that plasma is generated in a minute range of several μm to several mm on the friction surface (Nakayama, K., Yagasaki, F., Tribology Letters (2018)). Such plasma is called "triboplasma." Discharge luminescence and electric corrosion also take place on an elastohydrodynamic lubrication (EHL) thin film of grease formed on rolling bearings. From these facts, there is a report suggesting that discharge plasma is generated on an EHL thin film (Nakayama and Tanaka: Manuscript Preparation for Tribology Conference, Tokyo (2016) A2).

[0007] The present inventors considered that the suppression of triboplasma generation could prevent white band flaking of e.g. a rolling bearing.

55 **[0008]** In view of the above, an object of the present invention is to provide an anti-flaking agent capable of suppressing white band flaking of e.g. a rolling bearing, and a lubricant composition containing the anti-flaking agent.

[Solution to Problems]

[0009] The present inventors measured the amount of hydrogen generated using a candidate compound for a base oil accounting for a large percentage of the lubricant composition or the grease composition, and have found that a compound having a specific volume resistivity of $1.0 \times 10^{10} \Omega\text{-cm}$ or less can effectively suppress hydrogen generation. Based on this knowledge, the present inventors have completed an invention which can effectively prevent white band flaking of e.g. a rolling bearing.

[0010] Specifically, the present invention provides the following anti-flaking agent.

[1] An anti-flaking agent comprising at least one selected from the group consisting of

(A) a compound having a specific volume resistivity of $1.0 \times 10^{10} \Omega\text{-cm}$ or less, and
 (B) a compound in which a percentage of the number of carbon atoms having an aromatic ring structure is 40% or more among all carbon atoms constituting the compound,
 each in an amount exceeding 0.1% by mass based on a total mass of the anti-flaking agent, wherein the compounds are none of dimethyl malonate, dimethyl succinate, dimethyl glutarate, dimethyl adipate, dimethyl suberate, and dimethyl sebacate.

[2] The anti-flaking agent according to 1 described above, wherein the compound (A) is at least one selected from the group consisting of compounds having a dielectric constant ϵ of 3.0 or more at 500 MHz and 1 GHz.

[3] The anti-flaking agent according to 1 described above, wherein the compound (A) is at least one selected from the group consisting of compounds having a Hansen solubility parameter polar term δ_p of 3.5 or more.

[4] The anti-flaking agent according to 1 to 3 described above, wherein the compound (A) is at least one selected from the group consisting of polyvalent esters, glycols, sulfur-containing compounds, phosphorus-containing compounds, nitrogen-containing compounds, antistatic agents, ionic liquids, liquid crystals, SP compounds, NS compounds, and fatty acid amine salts.

[5] The anti-flaking agent according to any one of 1 to 4 described above, wherein the compound (A) is a diester of an aliphatic monoalcohol having 6 or less carbon atoms with an alicyclic fatty acid having 3 to 10 carbon atoms or aromatic dibasic acid having 3 to 10 carbon atoms.

[6] The anti-flaking agent according to any one of 1 to 5 described above, wherein the compound (A) is a polyvalent ester selected from the group consisting of dimethyl phthalate, dimethyl maleate, diethyl malonate, dibutyl malonate, and dihexyl malonate.

[7] The anti-flaking agent according to any one of 1 to 4 described above, wherein the compound (A) is an antistatic agent selected from the group consisting of poly(oxyethylene)alkylamines, poly(oxyethylene)alkylamides, poly(oxyethylene)alkyl ethers, poly(oxyethylene)alkyl phenyl ethers, glycerin aliphatic esters, sorbitan aliphatic esters, alkylsulfonates, alkylbenzene sulfonates, alkyl phosphates, quaternary ammonium chlorides, quaternary ammonium sulfates, quaternary ammonium nitrates, alkylbetaines, alkyl imidazolines, alkylalanines, polyvinyl benzyl, polyacrylic, amine derivatives, succinic acid derivatives, partial esters of poly(oxyalkylene)glycol and polyhydric alcohol, ammonium compounds of alkyl naphthalene sulfonic acid, polyalkyl sulfones, and neutralized salts of alkyl aryl sulfonic acid and alkyl amine.

[8] The anti-flaking agent according to any one of 1 to 7 described above, wherein the compound (B) is at least one selected from the group consisting of phenyl ethers, alkylbenzenes, and alkylnaphthalenes.

The present invention also provides the following lubricant composition.

[9] A lubricant composition comprising the compound according to any one of 1 to 8 described above.

[10] The lubricant composition according to 9 described above, further comprising at least one conventional base oil selected from the group consisting of mineral oils and synthetic oils.

[11] The lubricant composition according to 10 described above, wherein the base oil is at least one selected from the group consisting of mineral oils, synthetic hydrocarbon oils, and ether oils.

[12] The lubricant composition according to any one of 9 to 11 described above, wherein a content of the compound exceeds 0.1% by mass based on a total mass of the composition.

[13] The lubricant composition according to any one of 9 to 11 described above, wherein a content of the compound exceeds 1% by mass based on a total mass of the composition.

[14] The lubricant composition according to any one of 9 to 11 described above, wherein a content of the compound is 2% by mass or more based on a total mass of the composition.

[15] The lubricant composition according to any one of 9 to 11 described above, wherein a content of the compound is 3% by mass or more based on a total mass of the composition.

[16] The lubricant composition according to any one of 9 to 11 described above, wherein a content of the compound is 40% by mass or less based on a total mass of the composition.

[17] The lubricant composition according to any one of 9 to 16 described above, further comprising a thickener.

[0011] The anti-flaking agent and lubricant composition of the present invention can prevent white band flaking effectively (20% or less as compared with *n*-hexadecane).

[Brief Description of Drawings]

[0012] [Fig. 1] Fig. 1 is a schematic view of an apparatus, used in Examples, for generating hydrogen gas by triboplasma.

[Description of Embodiments]

[Definitions]

[0013] In the present specification, the specific volume resistivity represents a ratio between a DC electric field (V/m) applied to the sample at 25°C and a current per unit cross-sectional area applied to the sample at that time, and is equal to the resistance between opposing faces of a cubic sample with one side being 1 cm. The specific volume resistivity can be measured based on the testing methods of electrical insulating oils specified in JIS C2101.

[0014] In the present specification, the dielectric constant ϵ is a coefficient representing the relationship between the electric charge in the substance and the force given thereby. The dielectric constant ϵ was measured at 25°C with E4991B Impedance Analyzer (Keysight Technologies).

[0015] In the present specification, the "Hansen solubility parameters" are each an index indicating the solubility of a certain solute in a certain solvent, and include three components: the dispersion term (δD), the polar term (δP), and the hydrogen bond term (δH). The dispersion term (δD) represents the effect due to the dispersion force, the polar term (δP) represents the effect due to the force between dipoles, and the hydrogen bond term (δH) represents the effect due to the hydrogen bond force. Details of the definitions and calculation methods for the Hansen solubility parameters are described in the following literature: Charles M. Hansen, "Hansen Solubility Parameters: A Users Handbook," CRC Press, 2007.

[0016] In the present specification, "white band flaking" refers to a peculiar early abnormal flaking involving formation of white etching area. In the present specification, the term "white band flaking" is synonymous with a term called e.g. white flaking, white band flaking, brittle flaking, hydrogen brittle flaking, or hydrogen embrittlement flaking in the art. Normally, for rolling fatigue, the life can be estimated based on the life calculation formula defined in the standards (ISO281, JIS B-1518). However, in the case where white band flaking takes place, the lifetime is reached in a shorter time than the calculated lifetime. In the actual market, it has been reported that the life is reached at about 1/10 to 1/20 of the calculated life. White band flaking is one type of internal origin damage, and shows a specific phenomenon in which a white band is observed when the metal structure after the occurrence is etched with a nital solution.

[Compound Used as Anti-Flaking Agent]

[0017] The compound used in the present invention is a compound having a specific volume resistivity of 1.0×10^{10} Ω -cm or less. The present inventors have found that a compound having such a physical property can suppress hydrogen generation by plasma. Although the experimental methods and results are described in detail in the Examples section, the present inventors systematically examined the influence of the carbon chain length of ester on the amount of hydrogen generated. Then, as regards the length of the carbon chain derived from the dibasic fatty acid constituting the ester with methanol ($R^2OOC-R^1-COOR^2$) (that is, R^1), no hydrogen was generated when the number of carbon atoms was 6 or less. Conversely, when the number of carbon atoms was 8 (that is, when the dibasic acid was sebacic acid), hydrogen was generated. However, the amount generated was only 17% compared with *n*-hexadecane used as a standard substance. It was considered that triboplasma was generated in the case of using dimethyl sebacate. Thus, the specific volume resistivity was measured and found to be 9.0×10^9 Ω -cm. Moreover, when the specific volume resistivity was measured while changing the number of carbon atoms of R^1 , it was found that the specific volume resistivity increased as the number of carbon atoms of R^1 increased.

Table 1

	Number of Carbon Atoms of R^1	Amount of Hydrogen Generated, %*	Specific Volume Resistivity, Ω -cm
Dimethyl Malonate	1	0	6.6×10^7

(continued)

	Number of Carbon Atoms of R ¹	Amount of Hydrogen Generated, %*	Specific Volume Resistivity, Ω·cm
Dimethyl Adipate	4	0	4.0×10^9
Dimethyl Sebacate	8	17	9.0×10^9

* The amount of hydrogen generated for *n*-hexadecane is set to 100.

[0018] On the other hand, the present inventors examined the influence of the length of the carbon chain derived from the alcohol constituting the ester with sebacic acid (that is, R²) on the amount of hydrogen generated. Then, it was found that the specific volume resistivity increased as the number of carbon atoms of R² increased. This tendency was also observed in the case of monoesters.

Table 2

	Number of Carbon Atoms of R ²	Amount of Hydrogen Generated, %*	Specific Volume Resistivity, Ω·cm
Dimethyl Sebacate	1	17	9.0×10^9
Dihexyl Sebacate	6	95	9.0×10^{11}
Di(2-Ethylhexyl) Sebacate	8	100	2.4×10^{12}

* The amount of hydrogen generated for *n*-hexadecane is set to 100.

[0019] The present inventors have also found that a specific aromatic compound can effectively suppress hydrogen generation even when the compound has a specific volume resistivity exceeding 1.0×10^{10} Ω·cm.

[0020] Therefore, the compound of the present invention is at least one selected from the group consisting of

(A) a compound having a specific volume resistivity of 1.0×10^{10} Ω·cm or less, and

(B) a compound in which a percentage of the number of carbon atoms having an aromatic ring structure is 40% or more among all carbon atoms constituting the compound, wherein the compounds are none of dimethyl malonate, dimethyl succinate, dimethyl glutarate, dimethyl adipate, dimethyl suberate, and dimethyl sebacate.

(Compound (A))

[0021] The compound (A) preferably has a specific volume resistivity of 5.0×10^9 Ω·cm or less.

[0022] In addition, the compound (A) is preferably liquid at 25°C.

[0023] In addition, the compound (A) preferably has a dielectric constant ϵ of 3.0 or more at 500 MHz (25°C) and 1 GHz (25°C).

[0024] In addition, the compound (A) preferably has a Hansen solubility parameter polar term δ_p of 3.5 or more.

[0025] The term δ_p is expressed by the following formula, and δ_p increases as the dielectric constant ϵ increases. Generally, it is said that the dielectric constant ϵ of oil affects electron wave absorption, and it is said that the larger the dielectric constant ϵ and the larger the dielectric loss tangent, the more effectively electron waves can be absorbed, which can be a countermeasure against electron wave noise.

$$\delta_p^2 = \frac{12108}{V^2} \frac{\epsilon - 1}{2\epsilon + n_D^2} (n_D^2 + 2) \mu^2$$

[0026] It has been found that a compound having a specific volume resistivity of 1.0×10^{10} Ω·cm has a δ_p of 3.5 or more. Therefore, it is considered that, when δ_p is 3.5 or more, hydrogen generation can be prevented and white band

flaking can be prevented. The term δp is preferably 4.0 or more. The Hansen solubility parameter polar term δp is preferably 20 or less.

[0027] The term δp is preferably 3.5 or more, and the reason is as follows. Such a value makes it possible to achieve a conductivity to an extent sufficient to prevent charging and a high dielectric constant, and it is therefore considered that white band flaking can be suppressed through suppression of triboelectric generation.

[0028] Specific examples of the compound (A) include polyvalent esters, glycols, sulfur-containing compounds, phosphorus-containing compounds, nitrogen-containing compounds, antistatic agents, ionic liquids, liquid crystals, SP compounds, NS compounds, and fatty acid amine salts.

[0029] The polyvalent ester is selected from diesters, triesters, and tetraesters. A polyvalent ester having 15 or less carbon atoms is preferable. A diester having 15 or less carbon atoms is more preferable. Among others, preferable is a diester of a linear or branched aliphatic monoalcohol having 6 or less and preferably 4 or less carbon atoms with a linear or branched saturated or unsaturated aliphatic dibasic acid having 3 to 10 carbon atoms, a saturated or unsaturated alicyclic dibasic acid having 3 to 10 carbon atoms, or an aromatic dibasic acid having 3 to 10 carbon atoms. Particularly preferable is a diester of a linear or branched aliphatic monoalcohol having 6 or less carbon atoms with a saturated or unsaturated dibasic acid having 3 to 10 carbon atoms. Most preferable is a diester of a linear or branched aliphatic monoalcohol having 4 or less carbon atoms with a saturated or unsaturated dibasic acid having 3 to 10 carbon atoms.

[0030] A specific example of the diester is a diester in which the alcohol is methanol, ethanol, propanol, butanol, or hexanol, and the dibasic acid is malonic acid, succinic acid, glutaric acid, adipic acid, pimelic acid, suberic acid, azelaic acid, sebacic acid, phthalic acid, fumaric acid, maleic acid, dihydromuconic acid, 1,4-phenylenediacetic acid, or *cis*-4-cyclohexene-1,2-dicarboxylic acid. Particularly preferable among these is a diester in which the alcohol is methanol, ethanol, *n*-propanol, or *n*-butanol, and the dibasic acid is malonic acid, succinic acid, glutaric acid, adipic acid, suberic acid, sebacic acid, phthalic acid, or maleic acid. In particular, diethyl malonate, dibutyl malonate, and dihexyl malonate are preferable.

[0031] Specific examples of triesters include tributyl trimellitate.

[0032] Specific examples of tetraesters include full esters of pentaerythritol with carboxylic acid. Preferable is a tetraester with pentaerythritol, mainly containing 2-ethylhexanoic acid, *n*-heptanoic acid, or *n*-octanoic acid as the carboxylic acid.

[0033] Examples of glycols which can be used in the present invention include alkylene glycols, polyalkylene glycols, and alkyl ethers thereof. Examples of the alkylene glycols include tetraethylene glycol and tripropylene glycol. Examples of the polyalkylene glycols include polyethylene glycol, polypropylene glycol, polybutylene glycol, poly(oxyethylene)glycol, poly(oxypropylene)glycol, poly(oxybutylene)glycol, and poly(oxypropylene, oxybutylene)glycol. Examples of the alkyl ethers of alkylene glycols include tetraethylene glycol dimethyl ether. Examples of the alkyl ethers of polyalkylene glycols include polyethylene glycol alkyl ethers, polypropylene glycol alkyl ethers (for example, polypropylene glycol monobutyl ether), polybutylene glycol alkyl ethers, and poly(oxypropylene, oxybutylene)glycol alkyl ethers. The alkyl ether has 1 to 18 carbon atoms in the alkyl, and may be monoether or diether.

[0034] The sulfur-containing compound which can be used in the present invention is a compound containing a sulfur atom in one molecule, which is usually used as a building block in a solvent or organic synthesis. Specific examples include dimethyl sulfoxide, 2,2'-thiodiethanol, diethyl sulfoxide, dibutyl sulfoxide, butyl sulfide, butyl disulfide, propyl sulfide, propyl disulfide, phenyl sulfide, and bis(2-hydroxyethoxy)disulfide. Among these, dimethyl sulfoxide and 2,2'-thiodiethanol are preferable.

[0035] The phosphorus-containing compound which can be used in the present invention is a compound containing a phosphorus atom in one molecule, which is usually used as an extreme pressure agent or antiwear agent for lubricating oil. Specific examples include trimethyl phosphate, triethyl phosphate, tributyl phosphate, trimethyl phosphine, triethyl phosphine, tributyl phosphine, and 2-ethylhexyl diphenyl phosphate. Among these, trimethyl phosphate is preferable.

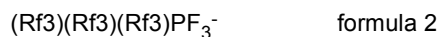
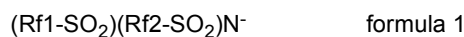
[0036] The nitrogen-containing compound which can be used in the present invention is a compound containing a nitrogen atom in one molecule, which is usually used as a building block in a solvent or organic synthesis. Specific examples include formamide, *N*-methylformamide, *N*-ethylformamide, *N*-*tert*-butylformamide, tetramethylurea, tetraethylurea, and tetrabutylurea. Among these, formamide, *N*-methylformamide, *N*-*tert*-butylformamide, tetramethylurea, and tetraethylurea are preferable.

[0037] The antistatic agent can be anionic, cationic, amphoteric, or nonionic, and examples thereof include poly(oxyethylene)alkylamines, poly(oxyethylene)alkylamides, poly(oxyethylene)alkyl ethers, poly(oxyethylene)alkyl phenyl ethers, glycerin aliphatic esters, sorbitan aliphatic esters, alkylsulfonates, alkylbenzene sulfonates, alkyl phosphates, quaternary ammonium chlorides, quaternary ammonium sulfates, quaternary ammonium nitrates, alkylbetaines, alkyl imidazolines, alkylalanines, polyvinyl benzyl, and polyacrylic, which are described in page 1238 of "16918 Chemical Products, Year 2018 Edition," published by The Chemical Daily Co., Ltd. Other examples include amine derivatives, succinic acid derivatives, partial esters of poly(oxyalkylene)glycol and polyhydric alcohol, ammonium compounds of alkyl naphthalene sulfonic acid, polyalkyl sulfones, and neutralized salts of alkyl aryl sulfonic acid and alkyl amine.

[0038] The ionic liquid is a molten salt which is liquid at room temperature, also called a room temperature molten salt. Examples of the ionic liquid which can be used in the present invention include ones in which the anion of the ionic

liquid is selected from the group consisting of hexafluorophosphate, trifluoromethanesulfonic acid, bis(perfluoroalkylsulfonyl)imide, (trifluoromethylsulfonyl)(heptafluoropropylsulfonyl)imide, bis[fluorosulfonyl]imide, bis(pentafluoroethanesulfonic acid)imide, nitrogen trioxide, *p*-toluenesulfonic acid, diethylene glycol monomethyl ether sulfonic acid, acetic acid, trifluoromethanecarboxylic acid, biscyanoimide, tris(trifluoromethanesulfonic acid)methide, tris(perfluoroalkyl)trifluorophosphate, and bis(perfluoroalkyl) (trifluoromethyl)trifluorophosphate.

[0039] For example, it is also possible to suitably use an ionic liquid in which the anion is represented by any one of the following formulas 1 and 2.



(In formula 1, Rf1 and Rf2 may be the same as or different from each other, and represent F, CF₃, C₂F₅, C₃F₇, or C₄F₉. In formula 2, Rf3 may be the same as or different from each other, and represents CF₃, C₂F₅, C₃F₇, or C₄F₉.)

[0040] Examples of the anion represented by formula 1 include bis(perfluoroalkylsulfonyl)imide, (trifluoromethylsulfonyl) (heptafluoropropylsulfonyl)imide, and bis[fluorosulfonyl]imide. Examples of the anion represented by formula 2 include tris(perfluoroalkyl)trifluorophosphate and bis(perfluoroalkyl) (trifluoromethyl)trifluorophosphate.

[0041] Examples of the cation constituting the ionic liquid include imidazoliums, pyridiniums, pyrazoliums, piperidiniums, pyrrolidiniums, morpholines, piperazines, pyrroles, phosphoniums, quaternary ammonium salts, and isoxazoliums, and examples thereof include imidazoliums such as ethylmethylimidazolium, hexylmethylimidazolium, methyloctylimidazolium, and butyldimethylimidazolium; pyridiniums such as butyl-4-methylpyridinium; piperidiniums such as methoxyethyl-methyl piperidinium; pyrrolidiniums such as methoxyethyl-methyl pyrrolidinium; phosphoniums such as octyltriethylphosphonium and triethyloctylphosphonium; and isoxazoliums such as propyldimethylisoxazolium. In addition, some are classified as aliphatic amine-based, alicyclic amine-based, and pyridine-based (aromatic).

[0042] The ionic liquid which can be used in the present invention is preferably an ionic liquid in which the anion is bis(trifluoromethylsulfonyl)imide and the cation is 1-butyl-2,3-dimethylimidazolium, an ionic liquid in which the anion is bis(trifluoromethylsulfonyl)imide and the cation is 1-(2-methoxyethyl)-1-methylpyrrolidinium, an ionic liquid in which the anion is bis(trifluoromethylsulfonyl)imide and the cation is triethyloctylphosphonium, and an ionic liquid in which the anion is (trifluoromethylsulfonyl) (heptafluoropropylsulfonyl)imide and the cation is 1-ethyl-3-methylimidazolium.

[0043] The liquid crystal compound is a compound which, in a certain temperature range, is liquid in appearance and simultaneously exhibits birefringence characteristic of an optically anisotropic crystal. The liquid crystal compound is classified into a smectic liquid crystal, a nematic liquid crystal, a cholesteric liquid crystal, and a discotic liquid crystal depending on its molten state, and any of these liquid crystal compounds can be used in the present invention.

[0044] Specific examples of the liquid crystal compound used in the present invention include (1) Schiff base liquid crystals, (2) azo-based and azoxy-based liquid crystals, (3) benzoate-based liquid crystals, (4) biphenyl-based and terphenyl-based liquid crystals, (5) cyclohexyl carboxylic acid ester-based liquid crystals, (6) phenylcyclohexane-based and biphenylcyclohexane-based liquid crystals, (7) pyrimidine-based and dioxane-based liquid crystals, (8) cyclohexyl cyclohexane ester-based liquid crystals, (9) cyclohexyl ethane-based liquid crystals, (10) cyclohexane-based liquid crystals, (11) tolan-based liquid crystals, (12) cholesteric liquid crystals, (13) triazine-based liquid crystals, (14) COS-based liquid crystals, (15) CCN-based liquid crystals, and (16) discotic liquid crystals, which are as described later.

[0045] A cyanobiphenyl-based liquid crystal compound categorized as (4) is excellent in chemical stability but has a slightly narrow temperature range of liquid crystal phase, and is desirably mixed with other liquid crystal compounds. The compound is a nematic liquid crystal having a high dielectric anisotropy and is often used for a liquid crystal display. Examples of the cyanobiphenyl-based liquid crystal include 4-cyano-4'-pentylbiphenyl, 4-cyano-4'-butylbiphenyl, 4-cyano-4'-hexylbiphenyl, 4-cyano-4'-heptylbiphenyl, 4-cyano-4'-octylbiphenyl, 4-cyano-4'-nonylbiphenyl, 4-cyano-4'-undecylbiphenyl, 4-cyano-4'-dodecylbiphenyl, 4-butoxy-4'-cyanobiphenyl, 4-ethoxy-4'-cyanobiphenyl, 4-propoxy-4'-cyanobiphenyl, 4-pentoxy-4'-cyanobiphenyl, 4-hexoxy-4'-cyanobiphenyl, 4-heptoxy-4'-cyanobiphenyl, 4-octoxy-4'-cyanobiphenyl, 4-nonaloxy-4'-cyanobiphenyl, 4-decyloxy-4'-cyanobiphenyl, 4-dodecyloxy-4'-cyanobiphenyl, (S)-4-cyano-4'-(2-methylbutyl)biphenyl, 4-(*trans*-4-propylcyclohexyl)benzotrile, 4-(*trans*-4-butylcyclohexyl)benzotrile, 1-(*trans*-4-amyloxy-4'-cyanobenzene, 4-[*trans*-4-[(*E*)-1-propenyl]cyclohexyl]benzotrile, 4-cyano-4"-pentyl-*p*-terphenyl, 4-cyano-4"-propyl-*p*-terphenyl, and *trans*-4'-(4-amyloxy-4'-cyanobenzene)4-carbonitrile.

[0046] The SP compound which can be used in the present invention is a compound containing a sulfur atom and a phosphorus atom in one molecule, which is usually used as an extreme pressure agent or an antiwear agent for lubricating oil. Specific examples include alkylated triphenyl phosphorothioates and ZnDTP. Among these, alkylated triphenyl phosphorothioates are preferable.

[0047] The NS compound which can be used in the present invention is a compound containing a nitrogen atom and a sulfur atom in one molecule, which is usually used as a metal corrosion prevention agent for lubricating oil. Specific examples include dimercaptotriazole derivatives, molybdenum dithiocarbamate, and ZnDTC. Among these, dimer-

capthiadiazole derivatives and molybdenum dithiocarbamate are preferable.

[0048] The fatty acid amine salt which can be used in the present invention is a compound which is usually used as a corrosion inhibitor for lubricating oil. Specific examples include oleic acid dicycloamine salt, lauric acid amine salt, myristic acid amine salt, palmitic acid amine salt, stearic acid amine salt, linoleic acid amine salt, arachidonic acid amine salt, and linolenic acid amine salt. Among these, oleic acid dicycloamine salt is preferable.

(Compound (B))

[0049] The compound (B) is a compound in which the percentage of the number of carbon atoms having an aromatic ring structure is 40% or more, preferably 50% or more, and more preferably 60% or more among all the carbon atoms constituting the compound.

[0050] Here, the percentage of the number of carbon atoms having an aromatic ring structure among all the carbon atoms constituting the molecule can be obtained by calculation. For example, in the case of diphenylamine, the total number of carbon atoms is 13, and the number of carbon atoms having an aromatic ring structure is 12. Therefore, the value obtained by dividing 12 by 13 is the percentage.

[0051] As the compound (B), an alkyl compound or an alkenyl compound having two or more aromatic rings is preferable. Specific examples include diphenylmethane, diphenylpropane, and diphenylethylene. Phenyl ethers having three or more aromatic rings are also preferable, and phenyl ethers such as pentaphenyl ether, tetraphenyl ether, and alkyl tetraphenyl ethers, alkyl benzenes, and alkyl naphthalenes are preferable.

[0052] The anti-flaking agent of the present invention may contain any substance as long as it does not negatively affect the anti-flaking effect of the compound (A) or (B) described above. However, the content of the compound is preferably 1% by mass or more, more preferably 2% by mass or more, and further preferably 3% by mass or more relative to the total mass of the anti-flaking agent of the present invention. When any one of the compound (A) and the compound (B) is used as the compound, the content thereof is more than 0.1% by mass, preferably more than 1% by mass, more preferably 2% by mass or more, and further preferably 4% by mass or more as in the case of the compound. When the compound (A) and the compound (B) are used in combination, the total amount thereof is preferably 2% or more and more preferably 4% or more. The upper limit of the percentage of the compound in the anti-flaking agent of the present invention is not particularly limited. In the case of polyvalent esters and glycols, from the viewpoints of heat resistance and resin resistance, the upper limit is preferably less than 40% by mass and more preferably 10% by mass or less based on the total mass of the anti-flaking agent. In the case of a compound other than polyvalent esters and glycols, the upper limit is preferably 10% by mass or less and more preferably 3% by mass or less from an economical viewpoint.

[0053] The flash point of the compound of the present invention is preferably 70°C or lower because there is a risk of ignition by plasma generated due to friction of the lubrication portion. The flash point can be measured based on JIS K2265.

[Lubricant Composition]

[0054] Since being liquid at room temperature, the compound can be used alone as a lubricant composition, can also be used as a lubricant or a base oil of a grease, or can be mixed with a conventional base oil as a lubricant or a base oil of a grease to form a lubricant composition.

(Conventional Base Oil)

[0055] As the conventional base oil, one having a specific volume resistivity exceeding $1.0 \times 10^{10} \Omega \cdot \text{cm}$ can be used. One containing a saturated or unsaturated hydrocarbon group having 12 or more carbon atoms in total is preferable, and specific examples thereof include mineral oils and synthetic oils. As the mineral oil, it is possible to use a paraffinic mineral oil, a naphthenic mineral oil, or a mixture thereof. It is preferable to contain a highly refined mineral oil (that is, a mineral oil which has been subjected to dewaxing treatment to reduce wax component precipitation at low temperature, thereby lowering its pour point as compared with the pour point of unrefined mineral oils (-5°C to -20°C, measured according to JIS K 2269)). Examples of synthetic oils include synthetic hydrocarbons, ester oils, ether oils, glycol oils, silicone oils, and fluorinated oils. Examples of synthetic hydrocarbon oils include poly alpha olefins ("PAOs") and polybutene. Among these, poly alpha olefins are preferable. Examples of ester oils include diesters, trimellitate esters, and polyol esters. Examples of ether oils include alkyl diphenyl ethers ("ADEs"), dialkyl diphenyl ethers, and polypropylene glycol. Examples of glycol oils include polypropylene glycol and polypropylene alkyl ethers.

[0056] In the case of use in combination with a mineral oil or synthetic hydrocarbon (especially poly alpha olefin), hydrogen generation can be effectively suppressed even when the compound is in a small amount, for example more than 0.1% by mass, preferably more than 1% by mass, more preferably 2% by mass or more, and further preferably 3% by mass or more based on the total mass of the lubricant composition. The content of the compound in the lubricant

composition of the present invention can be, for example, 40% by mass or less, 20% by mass or less, 10% by mass or less, 5% by mass or less, or 3% by mass or less. Considering the compatibility with the compounds described above, preferable conventional oils are ester oils such as diesters and polyol esters, ether oils such as alkyl phenyl ether oils, glycol oils such as water-insoluble polyalkylene glycols, silicone oils, fluorinated oils, and the like. From the viewpoints of resin resistance and heat resistance, mineral oils, synthetic oils, hydrocarbon oils, phenyl ether oils, and alkyl phenyl ether oils are preferable.

[0057] The kinematic viscosity at 40°C of the base oil in the lubricant composition of the present invention (that is, the compound (A) and/or (B) alone, or a mixture oil with the conventional oil) is preferably 10 to 500 mm²/s. When the kinematic viscosity at 40°C of the base oil is less than 10 mm²/s, it may be impossible to achieve a sufficient oil film at low speed or high temperature. Meanwhile, when the kinematic viscosity at 40°C of the base oil exceeds 500 mm²/s, there is a risk that the torque may rise at high speed or low temperature. For the same reasons, the range is more preferably 50 to 200 mm²/s and further preferably 60 to 130 mm²/s. Note that the kinematic viscosity of the base oil can be measured based on JIS K2283.

[0058] The content of the base oil in the lubricant composition of the present invention is preferably 60 to 99.9 parts by mass, more preferably 90 to 99.9 parts by mass, and further preferably 97 to 99.9 parts by mass relative to 100 parts by mass in total of the base oil and the anti-flaking agent. The content of the base oil is preferably in such ranges because of excellence in lubricity and low volatility.

(Optional Additive)

[0059] The lubricant composition of the present invention may further contain a general-purpose additive as necessary. For example, a rust inhibitor, a load-bearing additive, an antioxidant, and the like can be contained as necessary. The content of these optional additives is usually 0.5 to 5% by mass based on the total mass of the lubricant composition of the present invention.

[0060] Examples of the rust inhibitor include inorganic rust inhibitors and organic rust inhibitors. Examples of the inorganic rust inhibitors include inorganic metal salts such as sodium silicate, lithium carbonate, potassium carbonate, and zinc oxide. Examples of the organic rust inhibitors include benzoates such as sodium benzoate and lithium benzoate, sulfonates such as calcium sulfonate and zinc sulfonate, carboxylates such as zinc naphthenate and sodium sebacate, succinic acid derivatives such as succinic acid, succinic anhydride, and succinic acid half ester, sorbitan esters such as sorbitan monooleate and sorbitan trioleate, and fatty acid amine salts.

[0061] Examples of the load-bearing additive include phosphorus-containing ones such as phosphate esters, sulfur-based ones such as polysulfide and sulfurized oils and/or fats, phosphorus-sulfur-based ones such as phosphorothioates, thiocarbamates, thiophosphates, and organic phosphate esters.

[0062] The antioxidant is known to suppress oxidative degradation of grease, and examples thereof include phenol-based antioxidants and amine-based antioxidants.

[0063] Examples of the phenol-based antioxidants include 2,6-di-*tert*-butyl-*p*-cresol (BHT), 2,2'-methylenebis(4-methyl-6-*tert*-butylphenol), 4,4'-butylidenebis(3-methyl-6-*tert*-butylphenol), 2,6-di-*tert*-butyl-phenol, 2,4-dimethyl-6-*tert*-butylphenol, *tert*-butylhydroxyanisole (BHA), 4,4'-butylidenebis(3-methyl-6-*tert*-butylphenol), 4,4'-methylenebis(2,3-di-*tert*-butylphenol), 4,4'-thiobis(3-methyl-6-*tert*-butylphenol), and octadecyl-3-(3,5-di-*tert*-butyl-4-hydroxyphenyl)propionate. Among these, octadecyl-3-(3,5-di-*tert*-butyl-4-hydroxyphenyl)propionate is preferable.

[0064] Examples of the amine-based antioxidants include *N-n*-butyl-*p*-aminophenol, 4,4'-tetramethyl-di-aminodiphenylmethane, α -naphthylamine, *N*-phenyl- α -naphthylamine, phenothiazine, and alkyl diphenylamines. Among these, alkyl diphenylamines are preferable.

[0065] The lubricant composition of the present invention can be used as lubricating oil, conductive oil, dynamic pressure oil, and the like. The lubricant composition of the present invention is effective in preventing flaking wear.

[Grease Composition]

[0066] The lubricant composition of the present invention may further contain a thickener to form a grease composition.

[0067] For the same reasons as described for the lubricant composition, the content of the compound (A) and/or (B) is preferably more than 0.1% by mass, more preferably more than 1% by mass, further preferably 2% by mass or more, and particularly preferably 3% by mass or more based on the total mass of the grease composition of the present invention, and the upper limit can be, for example, 40% by mass or less, 20% by mass or less, 10% by mass or less, 5% by mass or less, or 3% by mass or less.

[0068] Examples of the thickener which can be used in the grease composition of the present invention include urea-based thickeners typified by diurea, lithium soap-based thickeners typified by lithium soap and lithium complex soap, and solid thickeners such as bentonite and silica gel. Urea-based thickeners and lithium soap-based thickeners are preferable.

[0069] The grease composition of the present invention may further contain a general-purpose additive as necessary. Examples of additives which can be used include ones described for the lubricant composition. The content of the optional additive is usually 0.1 to 5% by mass based on the total mass of the grease composition of the present invention.

5 (Penetration)

[0070] The worked penetration of the grease composition of the present invention is preferably 200 to 300 and more preferably 220 to 280. When the worked penetration exceeds 300, leakage due to high-speed rotation increases, which may result in failure to satisfy a sufficient lubrication life. Meanwhile, when the worked penetration is less than 200, the fluidity of the grease is deteriorated, which may result in failure to satisfy a sufficient lubrication life. Note that, in the present specification, the term "penetration" refers to a 60-stroke worked penetration. The penetration can be measured according to JIS K2220-7.

15 (Content of Thickener)

[0071] The content of the thickener is preferably 5 to 25% by mass and more preferably 10 to 20% by mass based on the total mass of the grease composition of the present invention. When the content is less than 5% by mass, the grease is soft and may leak, which could result in failure to satisfy a sufficient lubrication life. Meanwhile, when the content is more than 25% by mass, the fluidity is inferior and thus it becomes difficult for the grease to enter the lubrication portion, which could result in failure to satisfy a sufficient lubrication life.

(Content of Base Oil)

[0072] The content of the base oil is preferably 60 to 90% by mass and more preferably 70 to 90% by mass based on the total mass of the grease composition of the present invention. The content of the base oil is preferably in such ranges because of excellence in lubricity and low volatility.

[Bearing]

[0073] The grease composition of the present invention is used in various rolling bearings for industrial machines and automobiles. Examples for industrial machines include rolling bearings in various motors for industrial machines, reducers and hydraulic equipment of industrial robots, main shafts and reducers of wind power generators, and peripherals of elevator hoists. The use for automobiles is preferably a rolling bearing for automobile electrical equipment and auxiliaries. Examples of the automobile electrical equipment and auxiliaries include alternators, electromagnetic clutches for automobile air conditioners, intermediate pulleys, idler pulleys, and tension pulleys.

[Examples]

[Hydrogen Generation Test and Measurement of Amount of Hydrogen Generated]

[0074] The amount of hydrogen generated was measured according to the method described in Nouyama, Nakayama, et al., Manuscript Preparation for Tribology Conference, Tokyo (2017), 185.

[0075] Specifically, a triboplasma generator (Fig. 1) was used capable of generating triboplasma between the needle and the flat plate electrode. The needle was the cathode and the flat plate was the anode. The material of the needle was SCM435 steel and the apex angle of the needle was 120°. The needle was arranged perpendicular to the anode flat plate, and was fixed at a position where the distance between the tip of the needle and the upper surface of the anode was 50 μm. The distance between the needle and the flat plate electrode was controlled by a micrometer. The material of the anode flat plate was SPCC steel. The anode flat plate constituted the bottom portion inside the container. The container was charged with the anti-flaking agent and the like of Examples or Comparative Examples, and the needle was in contact with the anti-flaking agent and the like inside the container. The anode flat plate and the cathode needle were connected by a high voltage power source. The voltage and current when a voltage was applied was measurable by an oscilloscope. The container and the needle were surrounded by a larger casing (hereinafter referred to as the "atmosphere control chamber") so as to cover both. The top portion of the atmosphere control chamber had an opening provided therein, and the gas inside the atmosphere control chamber was collectable through a microsyringe. The upper side portion of the atmosphere control chamber also had an opening provided therein so as to introduce dry air therethrough. The gas inside the atmosphere control chamber was detectable by a semiconductor sensor.

[0076] Dry air was introduced for 30 seconds to replace the gas inside the atmosphere control chamber. After the gas inside the atmosphere control chamber was replaced with dry air, the atmosphere control chamber was subjected to

discharging for 30 seconds while monitoring the current value and the voltage value with an oscilloscope, and then left for 20 seconds to collect the generated gas through a microsyringe. The collected gas was introduced into gas chromatography to measure the amount of hydrogen gas. Note that the gas chromatography was measured using a gas chromatograph GC-2010 (manufactured by Shimadzu Corporation), a column RT-Msieve $\phi 0.43 \text{ mm} \times 30 \text{ m}$, and a detector TCD. The amount of hydrogen generated for each compound was calculated with the amount of hydrogen generated for *n*-hexadecane set to 100%.

[0077] Tables 3 to 10 present the results. Examples 1 to 38 are examples of the anti-flaking agent, and Examples 39 to 71 are examples of the lubricating oil composition containing the anti-flaking agent. Example 42 is a mixture of 3.0% by mass of dimethyl malonate of Example 3 and 97.0% by mass of poly alpha olefin of Comparative Example 8, and indicates that, even when the specific volume resistivity of the mixture exceeds $1.0 \times 10^{10} \Omega\text{-cm}$, the amount of hydrogen generated can be suppressed to 0% if a predetermined amount of the anti-flaking agent of the present application having a specific volume resistivity of $1.0 \times 10^{10} \Omega\text{-cm}$ or less is contained.

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(continued)

	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ref. Ex.	Ref. Ex.	Ref. Ex.
	1	2	3	4	5	6	7	8	9	10				
Synthetic Hydrocarbon														
Ether														
SP-cont. cmd.														
NS-Based Compound														
Fatty Acid Amine Salt														
Number of Aromatic Carbon Atoms %	92	80	86	60	0	0	0	0	0	0	0	0	0	0
Specific Volume Resistivity $\Omega \cdot \text{cm}$	3.6E+12	1.3E+13	7.5E+12	3.0E+08	9.4E+06	2.2E+07	2.7E+07	6.0E+07	1.1E+09	5.8E+08				
Dielectric Constant 500 MHz	3.2	-	-	8.8	10.2	11.2	8.5	9.1	7.9	-				
Dielectric Constant 1 GHz	3.3	-	-	8.0	10.1	11.3	8.5	9.1	8.0	-				
Hansen Parameter Polar Force δP	1.0	2.1	1.9	7.8	10.4	7.0	6.6	6.4	5.6	5.1				
Amount of Hydrogen Generated %	2	3	2	0	0	0	0	0	0	0	0	0	0	0

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	Ref. Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.
Mineral Oil	11	12	13	14	15	16	17	18	19	20		
P-Based Mineral Oil												
Synthetic Hydrocarbon												
PAO												
ADE												
Ether												
	Alkyl Tetraphenyl Ether											
	Pentaphenyl Ether											
Tetraphenyl Ether												
SP-cont. cmd.												
NS-Based Compound												
	Dimercapthothiadiazole Derivative											
MoDTC												
Fatty Acid Amine Salt												
Oleic Acid Dicycloamine Salt												
Number of Aromatic Carbon Atoms %	0	0	0	0	0	0	0	0	0	0	0	0
Specific Volume Resistivity Ω·cm	3.5E+09	4.1E+06	4.1E+08	4.4E+09	6.8E+06	2.0E+07	3.5E+07	3.1E+06	9.3E+09	3.1E+06	47.6	47.3
Dielectric Constant 500 MHz	6.4	9.0	-	-	15.6	7.8	9.0	18.1	4.6	4.3	16.4	0
Dielectric Constant 1 GHz	6.4	9.0	-	-	12.3	6.3	9.0	13.9	7.8	6.0	0	6
Hansen Parameter Polar Force δP	4.5	6.0	4.4	3.8	9.4	7.8	6.0	9.4	0	0	0	0
Amount of Hydrogen Generated %	17	0	0	1	0	0	0	0	6	0	0	0

Table 5

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	Ex. 21	Ex. 22	Ex. 23	Ex. 24	Ex. 25	Ex. 26	Ex. 27	Ex. 28	Ex. 29	Ex. 30	
Aromatic Hydrocarbon Compound	Diphenylmethane										
	Diphenylpropane										
	Cis-1,2-Diphenylethylene										
Monoester	Methyl Myristate										
	Dimethyl Phthalate										
	Dimethyl Maleate										
	Dimethyl Malonate										
	Dimethyl Succinate										
	Dimethyl Glutarate										
	Dimethyl Adipate										
	Dimethyl Suberate										
	Dimethyl Sebacate										
	Diethyl Malonate										
Diester	Dibutyl Malonate										
	Dihexyl Malonate										
	Dihexyl Sebacate										
	Di-2-Ethylhexyl Sebacate										
	Tributyl Trimellitate										
	Pentaerythritol										
	Triester										
	Tetraester										

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	Ex. 21	Ex. 22	Ex. 23	Ex. 24	Ex. 25	Ex. 26	Ex. 27	Ex. 28	Ex. 29	Ex. 30
	Tetraethylene Glycol									
	Tripolyene Glycol									
	Tetraethylene Glycol Dimethyl Ether									
	Poly(Oxyethylene)Glycol									
	Polypropylene Glycol Monobutyl Ether									
	Poly(Oxypropylene, Oxybutylene)Glycol									
	Dibutyl Sulfoxide									
S-cont. cmd.	2,2'-Thiodiethanol	100								
P-cont. cmd.	Trimethyl Phosphate	100								
	Formamide		100							
	N-Methylformamide			100						
N-cont. cmd.	N-tert-Butylformamide				100					
	Tetramethy lurea					100				
	Tetraethy lurea						100			
	Poly(Oxyethylene) Alkylamine							100		
General Antistatic Agent	Glycerin Aliphatic Ester Monocaprylin								100	
Ionic Liquid	(N-(Methoxyethyl)-1-Methylpyrrolidinium Bis (Trifluoromethylsulfonyl) Imide)									100
Liquid Crystal	4-Cyano-4'-Pentylbiphenyl									
Mineral Oil	P-Based Mineral Oil									

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	Ex. 21	Ex. 22	Ex. 23	Ex. 24	Ex. 25	Ex. 26	Ex. 27	Ex. 28	Ex. 29	Ex. 30
Synthetic Hydrocarbon										
PAO										
ADE										
Ether	Alkyl Tetraphenyl Ether									
	Pentaphenyl Ether									
	Tetraphenyl Ether									
SP-cont. cmd.	Alkylated Triphenyl Phosphorothioate									
NS-Based Compound	Dimercaptothiadiazole Derivative									
	MoDTC									
	Oleic Acid Dicycloamine Salt									
Number of Aromatic Carbon Atoms %	0	0	0	0	0	0	0	0	0	0
Specific Volume Resistivity $\Omega \cdot \text{cm}$	<1.6E+06	4.4E+06	<1.6E+06	<1.6E+06	<1.6E+06	1.9E+06	1.7E+06	<1.6E+06	2.8E+08	<1.6E+06
Dielectric Constant 500 MHz	23.0	28.7	107.7	158.4	-	24.5	-	7.5	7.2	-
Dielectric Constant 1 GHz	15.5	27.5	104.2	117.3	-	24.1	-	6.5	6.0	-
Hansen Parameter Polar Force δP	8.8	10.5	26.2	18.8	11.8	8.2	7.9	7.2	6.8	18.0
Amount of Hydrogen Generated %	0	0	0	0	0	0	0	0	0	0

Table 6

	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.
	31	32	33	34	35	36	37	38	39	40		
Aromatic Hydrocarbon Compound	Diphenylmethane	Diphenylpropane	Cis-1,2-Diphenylethylene									
Monoester	Methyl Myristate											
	Dimethyl Phthalate								3.0			3.0
	Dimethyl Maleate											
	Dimethyl Malonate											
	Dimethyl Succinate											
	Dimethyl Glutarate											
	Dimethyl Adipate											
	Dimethyl Suberate											
	Dimethyl Sebacate											
	Diethyl Malonate											
	Dibutyl Malonate											
	Dihexyl Malonate											
	Dihexyl Sebacate											
	Di-2-Ethylhexyl Sebacate											
Triester	Tributyl Trimellitate											
Tetraester	Pentaerythritol											

Table 7

55	Aromatic Hydrocarbon Compound	Diphenylmethane	Ex. 41	Ex. 42	Ex. 43	Ex. 44	Ex. 45	Ex. 46	Ex. 47	Ex. 48	Ex. 49	Ex. 50	
		Diphenylpropane											
		Cis-1,2-Diphenylethylene											
	Monoester	Methyl Myristate											
		Dimethyl Phthalate											
	Diester	Dimethyl Maleate											
		Dimethyl Malonate	3.0	3.0	40.0								
		Dimethyl Succinate				5.0	10.0						
		Dimethyl Glutarate						5.0					
		Dimethyl Adipate											
		Dimethyl Suberate											
		Dimethyl Sebacate											
		Diethyl Malonate								10.0			
		Dibutyl Malonate											
		Dihexyl Malonate											
	Triester	Dihexyl Sebacate											
		Di-2-Ethylhexyl Sebacate			60.0								
	Tetraester	Tributyl Trimellitate											
		Pentaerythritol											
	Glycol	Tetraethylene Glycol								1.0			
		Tripropylene Glycol									10.0		
		Tetraethylene Glycol Dimethyl Ether										10.0	
		Poly(Oxyethylene)Glycol											
		Polypropylene Glycol Monobutyl Ether											
	Poly(Oxypropylene, Oxybutylene)Glycol												

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	Ex.41	Ex.42	Ex. 43	Ex. 44	Ex. 45	Ex. 46	Ex. 47	Ex. 48	Ex. 49	Ex. 50
Number of Aromatic Carbon Atoms %	-	-	-	-	-	-	-	-	-	-
Specific Volume Resistivity $\Omega \cdot \text{cm}$	5.7E+14	2.3E+13	-	-	-	-	-	-	-	-
Dielectric Constant 500 MHz	-	-	-	-	-	-	-	-	-	-
Dielectric Constant 1 GHz	-	-	-	-	-	-	-	-	-	-
Hansen Parameter Polar Force δP	-	-	-	-	-	-	-	-	-	-
Amount of Hydrogen Generated %	0	0	0	0	0	0	0	0	0	0

Table 8

	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.
Aromatic Hydrocarbon Compound	51	52	53	54	55	56	57	58	59	60		
Monoester												
Diester												
	Triester											
Tetraester												

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	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.
	51	52	53	54	55	56	57	58	59	60	
			99.0			97.0				90.0	
Ether											
SP-cont. cmd.											
NS-Based Compound											
Fatty Acid Amine Salt											
Number of Aromatic Carbon Atoms %	-	-	-	-	-	-	-	-	-	-	-
Specific Volume Resistivity $\Omega \cdot \text{cm}$	-	-	-	-	-	-	-	-	-	-	-
Dielectric Constant 500 MHz	-	-	-	-	-	-	-	-	-	-	-
Dielectric Constant 1 GHz	-	-	-	-	-	-	-	-	-	-	-
Hansen Parameter Polar Force δP	-	-	-	-	-	-	-	-	-	-	-
Amount of Hydrogen Generated %	0	0	0	0	0	0	0	0	0	0	0

Table 10

	Comp. Ex. 1	Comp. Ex. 2	Comp. Ex. 3	Comp. Ex. 4	Comp. Ex. 5	Comp. Ex. 6	Comp. Ex. 7	Comp. Ex. 8	Comp. Ex. 9	Comp. Ex. 10	
Aromatic Hydrocarbon Compound	Diphenylmethane										
	Diphenylpropane										
	Cis-1,2-Diphenylethylene										
Monoester	Methyl Myristate	100									
	Dimethyl Phthalate										
	Dimethyl Maleate										
	Dimethyl Malonate										
	Dimethyl Succinate										
	Dimethyl Glutarate										
	Dimethyl Adipate										
	Dimethyl Suberate										
	Dimethyl Sebacate										
	Diethyl Malonate										
Diester	Dibutyl Malonate										
	Dihexyl Malonate										
	Dihexyl Sebacate	100									
	Di-2-Ethylhexyl Sebacate		100								
	Tributyl Trimellitate			100							
	Pentaerythritol					100					
	Triester										
	Tetraester										

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	Comp. Ex. 1	Comp. Ex. 2	Comp. Ex. 3	Comp. Ex. 4	Comp. Ex. 5	Comp. Ex. 6	Comp. Ex. 7	Comp. Ex. 8	Comp. Ex. 9	Comp. Ex. 10
Synthetic Hydrocarbon								100		99.95
									100	
Ether										
SP-cont. cmd.										
NS-Based Compound										
Fatty Acid Amine Salt										
Number of Aromatic Carbon Atoms %	0	0	0	0	0	0	0	0	35	-
Specific Volume Resistivity $\Omega \cdot \text{cm}$	7.9E+10	2.2E+11	2.4E+12	2.7E+10	2.8E+13	2.1E+11	5.7E+14	4.3E+13	7.7E+14	-
Dielectric Constant 500 MHz	4.0	-	4.2	-	3.5	3.5	2.7	2.7	2.8	-
Dielectric Constant 1 GHz	4.1	-	3.9	-	3.5	3.5	2.8	2.8	2.9	-
Hansen Parameter Polar Force δP	2.7	3.0	2.1	6.8	2.1	8.1	-	1.0	25.0	-
Amount of Hydrogen Generated %	105	95	100	77	88	101	106	100	93	100

[0078] The suppliers and trade names of the compounds used in Examples and Comparative Examples are presented below.

5	Tetraester	: Ester of pentaerythritol with carboxylic acid (manufactured by Kao Corporation under the trade name of "KAOLUBE 279")
	Glycol	: Poly(oxyethylene)glycol (manufactured by NOF Corporation under the trade name of "PEG #200")
10		Polypropylene glycol monobutyl ether (manufactured by NOF Corporation under the trade name of "UNILUBE MB-19")
		: Poly(oxypropylene, oxybutylene)glycol monodecyl ether (manufactured by Dow Chemical Company under the trade name of "OSP-68")
	Antistatic Agent	: Poly(oxyethylene)laurylamine (manufactured by Nippon Nyukazai Co., Ltd. under the trade name of "Newcol LA-407")
15		: Glycerin aliphatic ester monocaprylin (manufactured by Riken Vitamin Co., Ltd. under the trade name of "Poem M-100")
	Ionic Liquid	: <i>N</i> -(Methoxyethyl)-1-methylpyrrolidinium bis(trifluoromethylsulfonyl)imide (manufactured by Merck)
20	Liquid Crystal	: 4-Cyano-4'-pentylbiphenyl (manufactured by Tokyo Chemical Industry Co., Ltd. under the trade name of "5CB")
	Mineral Oil	: P-based mineral oil (manufactured by JX Energy under the trade name of "Super Oil K-100")
	Synthetic Hydrocarbon Ether Oil	: PAO8 (kinematic viscosity at 40°C is 45 mm ² /s)
25		: ADE (manufactured by MORESCO under the trade name of "LB-100")
		: Alkyl tetraphenyl ether (manufactured by MORESCO under the trade name of "s-3101")
		: Pentaphenyl ether (manufactured by MORESCO under the trade name of "s-3105")
		: Tetraphenyl ether (manufactured by MORESCO under the trade name of "s-3103")
30	SP-Based Compound	: Alkylated triphenyl phosphorothionate (manufactured by BASF Japan under the trade name of "IRGALUBE 211")
	NS-Based Compound	: Dimercaptothiadiazole derivative (manufactured by The Elco Corporation under the trade name of "Elco 461")
		: MoDTC (manufactured by ADEKA Corporation under the trade name of "SAKURALUBE 525")
35	Fatty Acid Amine Salt	: Oleic acid dicycloamine salt (manufactured by Albess Co., Ltd. under the trade name of "NONRUST Z-1000")

40 **Claims**

1. An anti-flaking agent comprising at least one selected from the group consisting of

- (A) a compound having a specific volume resistivity of $1.0 \times 10^{10} \Omega \cdot \text{cm}$ or less, and
 45 (B) a compound in which a percentage of the number of carbon atoms having an aromatic ring structure is 40% or more among all carbon atoms constituting the compound,

each in an amount exceeding 0.1% by mass based on a total mass of the anti-flaking agent, wherein the compounds are none of dimethyl malonate, dimethyl succinate, dimethyl glutarate, dimethyl adipate, dimethyl suberate, and dimethyl sebacate.

2. The anti-flaking agent according to claim 1, wherein the compound (A) is at least one selected from the group consisting of compounds having a dielectric constant ϵ of 3.0 or more at 500 MHz and 1 GHz.

55 3. The anti-flaking agent according to claim 1 or 2, wherein the compound (A) is at least one selected from the group consisting of compounds having a Hansen solubility parameter polar term δ_p of 3.5 or more.

4. The anti-flaking agent according to any one of claims 1 to 3, wherein the compound (A) is at least one selected from

the group consisting of polyvalent esters, glycols, sulfur-containing compounds, phosphorus-containing compounds, nitrogen-containing compounds, antistatic agents, ionic liquids, liquid crystals, SP compounds, NS compounds, and fatty acid amine salts.

- 5 **5.** The anti-flaking agent according to any one of claims 1 to 4, wherein the compound (A) is a diester of an aliphatic monoalcohol having 6 or less carbon atoms with an alicyclic fatty acid having 3 to 10 carbon atoms or aromatic dibasic acid having 3 to 10 carbon atoms.
- 10 **6.** The anti-flaking agent according to any one of claims 1 to 5, wherein the compound (A) is a diester selected from the group consisting of dimethyl phthalate, dimethyl maleate, diethyl malonate, dibutyl malonate, and dihexyl malonate.
- 15 **7.** The anti-flaking agent according to any one of claims 1 to 4, wherein the compound (A) is an antistatic agent selected from the group consisting of poly(oxyethylene)alkylamines, poly(oxyethylene)alkylamides, poly(oxyethylene)alkyl ethers, poly(oxyethylene)alkyl phenyl ethers, glycerin aliphatic esters, sorbitan aliphatic esters, alkylsulfonates, alkylbenzene sulfonates, alkyl phosphates, quaternary ammonium chlorides, quaternary ammonium sulfates, quaternary ammonium nitrates, alkylbetaines, alkyl imidazolines, alkylalanines, polyvinyl benzyl, polyacrylic, amine derivatives, succinic acid derivatives, partial esters of poly(oxyalkylene)glycol and polyhydric alcohol, ammonium compounds of alkyl naphthalene sulfonic acid, polyalkyl sulfones, and neutralized salts of alkyl aryl sulfonic acid and alkyl amine.
- 20 **8.** The anti-flaking agent according to any one of claims 1 to 7, wherein the compound (B) is at least one selected from the group consisting of phenyl ethers, alkylbenzenes, and alkylnaphthalenes.
- 25 **9.** A lubricant composition comprising the compound according to any one of claims 1 to 8.
- 10.** The lubricant composition according to claim 9, further comprising at least one conventional base oil selected from the group consisting of mineral oils and synthetic oils.
- 30 **11.** The lubricant composition according to claim 9 or 10, wherein the base oil is at least one selected from the group consisting of mineral oils, synthetic hydrocarbon oils, and ether oils.
- 12.** The lubricant composition according to any one of claims 9 to 11, wherein a content of the compound exceeds 0.1% by mass based on a total mass of the composition.
- 35 **13.** The lubricant composition according to any one of claims 9 to 12, further comprising a thickener.

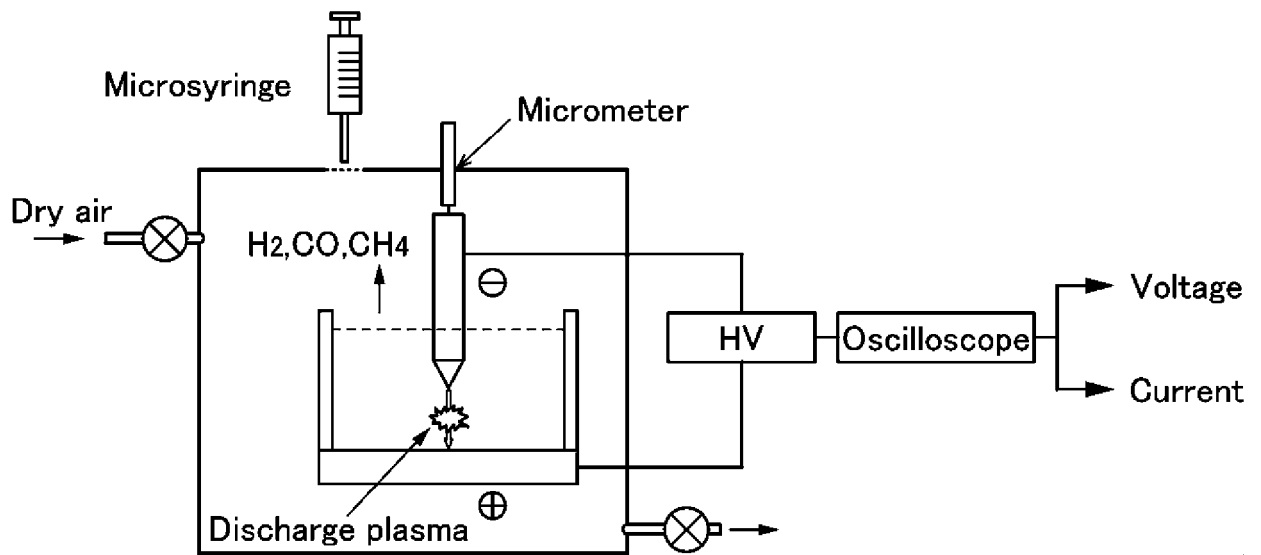
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FIG. 1





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Application Number
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Place of search Munich		Date of completion of the search 27 April 2020	Examiner Péntek, Eric	
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