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

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AGENT ANTI-ÉCAILLAGE ET COMPOSITION DE LUBRIFIANT LE COMPRENANT

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(73) Proprietor: **Kyodo Yushi Co., Ltd.**
Fujisawa-shi, Kanagawa 251-8588 (JP)

(72) Inventors:
- **NOYAMA, Satoshi**
  Fujisawa-shi, Kanagawa 251-8588 (JP)
- **HAYAMA, Makoto**
  Fujisawa-shi, Kanagawa 251-8588 (JP)
- **DONG, Daming**
  Fujisawa-shi, Kanagawa 251-8588 (JP)
- **NAKAYAMA, Keiji**
  Kashiwa-shi, Chiba 277-0085 (JP)

(74) Representative: **Haseltine Lake Kempner LLP**
Bürkleinstrasse 10
80538 München (DE)

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Description

[Technical Field]

[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]

[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.

[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.

[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]

[0005]

[Patent Literature 1] International Publication No. WO2015/016376
[Patent Literature 2] Japanese Patent Application Publication No. Hei 3-210394
[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

[0006] The following patent literature also refers to grease and/or lubricant compositions. EP 3 029 132 A1; EP 2 003 187 A2; EP 2 239 313 A1; EP 3 336 161 A1; EP 2 431 449 A1; EP 1 609 844 A1; US 2009/069204 A1; CN 106 281 620 A; CN 107 312 589 A; US 2015/057203 A1; EP 1 516 911 A1; and US 5 462 683 A.

[Summary of Invention]

[Technical Problems]

[0007] 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).

[0008] The present inventors considered that the suppression of triboplasma generation could prevent white band flaking of e.g. a rolling bearing.

[0009] 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]

[0010] 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 $1.0 \times 10^{10}\ \Omega\cdot$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.
[0011] Specifically, the present invention provides the following use.
[0012]

[1] Use as an anti-flaking agent of at least one selected from the group consisting of (A) a compound having a specific volume resistivity of $1.0 \times 10^{10}\ \Omega\cdot$cm or less, wherein the compound (A) is a diester selected from the group consisting of dimethyl phthalate, dimethyl maleate, diethyl malonate, dibutyl malonate, and dihexyl malonate.

[0013] The present invention also provides the following lubricant composition.

[2] A lubricant composition comprising a diester selected from the group consisting of dimethyl maleate, dibutyl malonate, and dihexyl malonate and least one conventional base oil selected from the group consisting of mineral oils and synthetic oils.
[3] The lubricant composition according to 2 described above, wherein the base oil is at least one selected from the group consisting of mineral oils, synthetic hydrocarbon oils, and ether oils.
[4] The lubricant composition according to any one of 2 to 3 described above, wherein a content of the compound exceeds 0.1% by mass based on a total mass of the composition.
[5] The lubricant composition according to any one of 2 to 3 described above, wherein a content of the compound exceeds 1% by mass based on a total mass of the composition.
[6] The lubricant composition according to any one of 2 to 3 described above, wherein a content of the compound is 2% by mass or more based on a total mass of the composition.
[7] The lubricant composition according to any one of 2 to 3 described above, wherein a content of the compound is 3% by mass or more based on a total mass of the composition.
[8] The lubricant composition according to any one of 2 to 3 described above, wherein a content of the compound is 40% by mass or less based on a total mass of the composition.
[9] The lubricant composition according to any one of 2 to 8 described above, further comprising a thickener.

[0014] 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]

[0015] [Fig. 1] Fig. 1 is a schematic view of an apparatus, used in Examples, for generating hydrogen gas by triboplasma.

[Description of Embodiments]

[Definitions]

[0016] 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.
[0017] 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).
[0018] 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.

[0019] 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]

[0020] The compound used in the present invention is a compound having a specific volume resistivity of 1.0×10^{10} $\Omega\cdot$cm or less, and is a diester as defined above. 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 ($R^2OOC\text{-}R^1\text{-}COOR^2$) (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 $\Omega\cdot$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, $\Omega\cdot$cm
Dimethyl Malonate	1	0	6.6×10^7
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.			

[0021] 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, R^2) on the amount of hydrogen generated. Then, it was found that the specific volume resistivity increased as the number of carbon atoms of R^2 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, $\Omega\cdot$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.			

[0022] 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} $\Omega\cdot$cm.

[0023] 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} $\Omega\cdot$cm or less, wherein the compound (A) is a diester selected from the group consisting of dimethyl phthalate, dimethyl maleate, diethyl malonate, dibutyl malonate, and dihexyl malonate.

(Compound (A))

[0024] The compound (A) preferably has a specific volume resistivity of 5.0 × 10^9 Ω·cm or less.
[0025] In addition, the compound (A) is preferably liquid at 25°C.
[0026] 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).
[0027] In addition, the compound (A) preferably has a Hansen solubility parameter polar term δp of 3.5 or more.
[0028] The term δp is expressed by the following formula, and δp 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 diel ectric 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.

$$\delta_p^{\,2} = \frac{12108}{V^2} \frac{\varepsilon - 1}{2\varepsilon + n_D^{\,2}} \left(n_D^{\,2} + 2\right) \mu^2$$

[0029] It has been found that a compound having a specific volume resistivity of 1.0 × 10^{10} Ω·cm has a δp of 3.5 or more. Therefore, it is considered that, when δp 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.
[0030] 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 triboplasma generation.
[0031] 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]

[0032] 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)

[0033] As the conventional base oil, one having a specific volume resistivity exceeding 1.0 × 10^{10} Ω·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.
[0034] 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.
[0035] 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 mm^2/s. When the kinematic

viscosity at 40°C of the base oil is less than 10 mm^2/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 mm^2/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 mm^2/s and further preferably 60 to 130 mm^2/s. Note that the kinematic viscosity of the base oil can be measured based on JIS K2283.

[0036] 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)

[0037] 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.

[0038] 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.

[0039] 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.

[0040] The antioxidant is known to suppress oxidative degradation of grease, and examples thereof include phenol-based antioxidants and amine-based antioxidants.

[0041] 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.

[0042] 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.

[0043] 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]

[0044] The lubricant composition of the present invention may further contain a thickener to form a grease composition.

[0045] 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.

[0046] 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.

[0047] 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.

(Penetration)

[0048] 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.

(Content of Thickener)

[0049] 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)

[0050] 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]

[0051] 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]

[0052] 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.

[0053] 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.

[0054] 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 φ0.43 mm × 30 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%.

[0055] 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 × 10^{10} Ω·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 × 10^{10} Ω·cm or less is contained.

[0056] Examples 1 to 3, 6 to 11, 15 to 39 and 41 to 71 are comparative.

Table 3

		Ex.	Ex.	Ex.	Ex.	Ex.	Ref. Ex.	Ref. Ex.	Ref. Ex.	Ref. Ex.	Ref. Ex.
		1	2	3	4	5	6	7	8	9	10
Aromatic Hydrocarbon Compound	Diphenylmethane	100									
	Diphenylpropane		100								
	Cis-1,2-Diphenylethylene			100							
Monoester	Methyl Myristate										
Diester	Dimethyl Phthalate				100						
	Dimethyl Maleate					100					
	Dimethyl Malonate						100				
	Dimethyl Succinate							100			
	Dimethyl Glutarate								100		
	Dimethyl Adipate									100	
	Dimethyl Suberate										100
	Dimethyl Sebacate										
	Diethyl Malonate										
	Dibutyl Malonate										
	Dihexyl Malonate										
	Dihexyl Sebacate										
	Di-2-Ethylhexyl Sebacate										
Triester	Tributyl Trimellitate										
Tetraester	Pentaerythritol										
Glycol	Tetraethylene Glycol										
	Tripropylene Glycol										
	Tetraethylene Glycol Dimethyl Ether										
	Poly (Oxyethylene) Glycol										
	Polypropylene Glycol Monobutyl Ether										
	Poly(Oxypropylene, Oxybutylene)Glycol										
S-cont. cmd.	Dibutyl Sulfoxide										
	2,2'-Thiodiethanol										

P-cont. cmd.	Trimethyl Phosphate										
N-cont. cmd.	Formamide										
	N-Methylformamide										
	N-tert-Butylformamide										
	Tetramethylurea										
	Tetraethylurea										
General Antistatic Agent	Poly(Oxyethylene)Alkylamine										
	Glycerin Aliphatic Ester Monocaprylin										
Ionic Liquid	(*N*-(Methoxyethyl)-1-Methylpyrrolidinium Bis(Trifluoromethylsulfonyl)Imide)										
Liquid Crystal	4-Cyano-4'-Pentylbiphenyl										
Mineral Oil	P-Based Mineral Oil										
Synthetic Hydrocarbon	PAO										
Ether	ADE										
	Alkyl Tetraphenyl Ether										
	Pentaphenyl Ether										
	Tetraphenyl Ether										
SP-cont. cmd.	Alkylated Triphenyl Phosphorothioate										
NS-Based Compound	Dimercaptothiadiazole Derivative										
	MoDTC										
Fatty Acid Amine Salt	Oleic Acid Dicycloamine Salt										
Number of Aromatic Carbon Atoms %		92	80	86	60	0	0	0	0	0	0
Specific Volume Resistivity Ω·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

(continued)

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

Table 4

		Ref. Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.
		11	12	13	14	15	16	17	18	19	20
Aromatic Hydrocarbon Compound	Diphenylmethane										
	Diphenylpropane										
	Cis-1,2-Diphenylethylene										
Monoester	Methyl My ristate										
Diester	Dimethyl Phthalate										
	Dimethyl Maleate										
	Dimethyl Malonate										
	Dimethyl Succinate										
	Dimethyl Glutarate										
	Dimethyl Adipate										
	Dimethyl Suberate										
	Dimethyl Sebacate	100									
	Diethyl Malonate		100								
	Dibutyl Malonate			100							
	Dihexyl Malonate				100						
	Dihexyl Sebacate										
	Di-2-Ethylhexyl Sebacate										
Triester	Tributyl Trimellitate										
Tetraester	Pentaerythritol										
Glycol	Tetraethylene Glycol					100					
	Tripropylene Glycol						100				
	Tetraethylene Glycol Dimethyl Ether							100			
	Poly (Oxyethylene) Glycol								100		
	Polypropylene Glycol Monobutyl Ether									100	
	Poly(Oxypropylene, Oxybutylene)Glycol										
S-cont. cmd.	Dibutyl Sulfoxide										100
	2,2'-Thiodiethanol										

P-cont. cmd.	Trimethyl Phosphate										
N-cont. cmd.	Formamide										
	N-Methylformamide										
	N-tert-Butylformamide										
	Tetramethylurea										
	Tetraethylurea										
General Anti-static Agent	Poly (Oxyethylene)Alkylamine										
	Glycerin Aliphatic Ester Monocaprylin										
Ionic Liquid	(*N*-(Methoxyethyl)-1-Methylpyrrolidiniu m Bis(Trifluoromethylsulfonyl)Imide)										
Liquid Crystal	4-Cyano-4'-Pentylbiphenyl										
Mineral Oil	P-Based Mineral Oil										
Synthetic Hydrocarbon	PAO										
Ether	ADE										
	Alkyl Tetraphenyl Ether										
	Pentaphenyl Ether										
	Tetraphenyl Ether										
SP-cont. cmd.	Alkylated Triphenyl Phosphorothioate										
NS-Based Compound	Dimercaptothiadiazole 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
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

(continued)

Dielectric Constant 500 MHz	6.4	9.0	-	-	15.6	7.8	9.0	18.1	4.6	47.6
Dielectric Constant 1 GHz	6.4	9.0	-	-	12.3	6.3	9.0	13.9	4.3	47.3
Hansen Parameter Polar Force δP	4.5	6.0	4.4	3.8	9.4	7.8	6.0	9.4	7.8	16.4
Amount of Hydrogen Generated %	17	0	0	1	0	0	0	0	6	0

Table 5

		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										
Diester	Dimethyl Phthalate										
	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										
Glycol	Tetraethylene Glycol										
	Tripropylene Glycol										
	Tetraethylene Glycol Dimethyl Ether										
	Poly(Oxyethylene)Glycol										
	Polypropylene Glycol Monobutyl Ether										
	Poly(Oxypropylene, Oxybutylene)Glycol										

(continued)

		Ex. 21	Ex.22	Ex.23	Ex.24	Ex.25	Ex.26	Ex.27	Ex.28	Ex.29	Ex.30
S-cont. cmd.	Dibutyl Sulfoxide										
	2,2'-Thiodiethanol	100									
P-cont. cmd.	Trimethyl Phosphate		100								
N-cont. cmd.	Formamide			100							
	N-Methylformamide				100						
	N-tert-Butylformamide					100					
	Tetramethylurea						100				
	Tetraethylurea							100			

General Antistatic Agent	Poly(Oxyethylene)Alkylamine								100		
	Glycerin Aliphatic Ester Monocaprylin									100	
Ionic Liquid	(*N*-(Methoxyethyl)-1-Methylpyrroli dinium Bis(Trifluoromethylsulfonyl)Imide)										100
Liquid Crystal	4-Cyano-4'-Pentylbiphenyl										
Mineral Oil	P-Based Mineral Oil										
Synthetic Hydrocarbon	PAO										
Ether	ADE										
	Alkyl Tetraphenyl Ether										
	Pentaphenyl Ether										
	Tetraphenyl Ether										
SP-cont. cmd.	Alkylated Triphenyl Phosphorothioate										
NS-Based Compound	Dimercaptothiadiazole 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
Specific Volume Resistivity Ω·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. 31	Ex. 32	Ex. 33	Ex. 34	Ex. 35	Ex. 36	Ex. 37	Ex. 38	Ex. 39	Ex. 40
Aromatic Hydrocarbon Compound	Diphenylmethane										
	Diphenylpropane										
	Cis-1,2-Diphenylethylene										
Monoester	Methyl Myristate										
Diester	Dimethyl Phthalate									3.0	
	Dimethyl Maleate										3.0
	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										
Glycol	Tetraethylene Glycol										
	Tripropylene Glycol										
	Tetraethylene Glycol Dimethyl Ether										
	Poly(Oxyethylene)Glycol										
	Polypropylene Glycol Monobutyl Ether										
	Poly(Oxypropylene, Oxybutylene)Glycol										
S-cont. cmd.	Dibutyl Sulfoxide										
	2,2'-Thiodiethanol										
P-cont. cmd.	Trimethyl Phosphate										

N-cont. cmd.	Formamide										
	N-Methylformamide										
	N-tert-Butylformamide										
	Tetramethylurea										
	Tetraethylurea										
General Anti-static Agent	Poly(Oxyethylene)Alkylamine										
	Glycerin Aliphatic Ester Monocaprylin										
Ionic Liquid	(*N*-(Methoxyethyl)-1-Methylpyrrolidiniu m Bis(Trifluoromethylsulfonyl)Imide)										
Liquid Crystal	4-Cyano-4'-Pentylbiphenyl	100									
Mineral Oil	P-Based Mineral Oil										
Synthetic Hydrocarbon	PAO									97.0	97.0
Ether	ADE										
	Alkyl Tetraphenyl Ether		100								
	Pentaphenyl Ether			100							
	Tetraphenyl Ether				100						
SP-cont. cmd.	Alkylated Triphenyl Phosphorothioate					100					
NS-Based Compound	Dimercaptothiadiazole Derivative						100				
	MoDTC							100			
Fatty Acid Amine Salt	Oleic Acid Dicycloamine Salt								100		
Number of Aromatic Carbon Atoms %		35	60	100	100	40	11	0	0	-	-
Specific Volume Resistivity Ω·cm		2.4E+08	2.4E+14	7.9E+12	3.1E+13	3.5E+12	<1.6E+06	2.8E+08	1.3E+07	-	-
Dielectric Constant 500 MHz		-	-	-	-	-	5.0	2.3	4.0	-	-
Dielectric Constant 1 GHz		-	-	-	-	-	4.5	2.4	4.0	-	-

(continued)

Hansen Parameter Polar Force δP	4.4	29.1	4.9	3.5	3.6	6.8	-	-	-	-
Amount of Hydrogen Generated %	12	16	1	1	1	0	0	0	0	0

Table 7

		Ex.41	Ex.42	Ex.43	Ex.44	Ex.45	Ex.46	Ex.47	Ex.48	Ex.49	Ex.50
Aromatic Hydrocarbon Compound	Diphenylmethane										
	Diphenylpropane										
	Cis-1,2-Diphenylethylene										
Monoester	Methyl Myristate										
Diester	Dimethyl Phthalate										
	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										
	Dihexyl Sebacate										
	Di-2-Ethylhexyl Sebacate			60.0							
Triester	Tributyl Trimellitate										
Tetraester	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										

(continued)

		Ex.41	Ex.42	Ex.43	Ex.44	Ex.45	Ex.46	Ex.47	Ex.48	Ex.49	Ex.50
S-cont. cmd.	Dibutyl Sulfoxide										
	2,2'-Thiodiethanol										

P-cont. cmd.	Trimethyl Phosphate										
N-cont. cmd.	Formamide										
	N-Methylformamide										
	N-tert-Butylformamide										
	Tetramethylurea										
	Tetraethylurea										
General Anti-static Agent	Poly(Oxyethylene)Alkylamine										
	Glycerin Aliphatic Ester Monocaprylin										
Ionic Liquid	(*N*-(Methoxyethyl)-1-Methy lpyrrolidinium Bis(Trifluoromethyl-sulfonyl)Imide)										
Liquid Crystal	4-Cyano-4'-Pentylbiphenyl										
Mineral Oil	P-Based Mineral Oil	97.0									
Synthetic Hy-drocarbon	PAO		97.0		95.0		95.0	90.0	99.0	90.0	90.0
Ether	ADE					90.0					
	Alkyl Tetraphenyl Ether										
	Pentaphenyl Ether										
	Tetraphenyl Ether										
SP-cont. cmd.	Alkylated Triphenyl Phosphorothioate										
NS-Based Compound	Dimercaptothiadiazole Derivative										
	MoDTC										
Fatty Acid Amine Salt	Oleic Acid Dicycloamine Salt										
Number of Aromatic Carbon Atoms %		-	-	-	-	-	-	-	-	-	-
Specific Volume Resistivity Ω·cm		5.7E+14	2.3E+13	-	-	-	-	-	-	-	-
Dielectric Constant 500 MHz		-	-	-	-	-	-	-	-	-	-
Dielectric Constant 1 GHz		-	-	-	-	-	-	-	-	-	-
Hansen Parameter Polar Force δP		-	-	-	-	-	-	-	-	-	-

(continued)

Amount of Hydrogen Generated %	0	0	0	0	0	0	0	0	0	0

Table 8

		Ex. 51	Ex. 52	Ex. 53	Ex. 54	Ex. 55	Ex. 56	Ex. 57	Ex. 58	Ex. 59	Ex. 60
Aromatic Hydrocarbon Compound	Diphenylmethane										
	Diphenylpropane										
	Cis-1,2-Diphenylethylene										
Monoester	Methyl My ristate										
	Dimethyl Phthalate										
	Dimethyl Maleate										
	Dimethyl Malonate										
	Dimethyl Succinate										
	Dimethyl Glutarate										
	Dimethyl Adipate										
Diester	Dimethyl Suberate										
	Dimethyl Sebacate										
	Diethyl Malonate										
	Dibutyl Malonate										
	Dihexyl Malonate										
	Dihexyl Sebacate										
	Di-2-Ethylhexyl Sebacate	99.0			97.0				90.0		
Triester	Tributyl Trimellitate										
Tetraester	Pentaerythritol										
Glycol	Tetraethylene Glycol										
	Tripropylene Glycol										
	Tetraethylene Glycol Dimethyl Ether										
	Poly (Oxyethylene) Glycol	1.0	0.5	1.0							
	Polypropylene Glycol Monobutyl Ether										
	Poly(Oxypropylene, Oxybutylene)Glycol										
S-cont. cmd.	Dibutyl Sulfoxide				3.0	3.0	3.0				
	2,2'-Thiodiethanol							3.0			
P-cont. cmd.	Trimethyl Phosphate								10.0	10.0	10.0
N-cont. cmd.	Formamide										
	N-Methylformamide										
	N-tert-Butylformamide										
	Tetramethylurea										
	Tetraethylurea										

(continued)

General Anti-static Agent	Poly(Oxyethylene)Alkylamine										
	Glycerin Aliphatic Ester Monocapry lin										
Ionic Liquid	(*N*-(Methoxyethyl)-1-Methylpyrrolidinium Bis(Trifluoromethylsulfonyl)Imide)										
Liquid Crystal	4-Cyano-4'-Pentylbiphenyl										
Mineral Oil	P-Based Mineral Oil										
Synthetic Hydrocarbon	PAO		99.5			97.0		97.0		90.0	
Ether	ADE			99.0			97.0				90.0
	Alkyl Tetraphenyl Ether										
	Pentaphenyl Ether										
	Tetraphenyl Ether										
SP-cont. cmd.	Alkylated Triphenyl Phosphorothioate										
NS-Based Compound	Dimercaptothiadiazole Derivative										
	MoDTC										
Fatty Acid Amine Salt	Oleic Acid Dicycloamine Salt										
Number of Aromatic Carbon Atoms %		-	-	-	-	-	-	-	-	-	-
Specific Volume Resistivity Ω·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

Table 9

		Ex. 61	Ex. 62	Ex. 63	Ex. 64	Ex. 65	Ex. 66	Ex. 67	Ex. 68	Ex. 69	Ex. 70	Ex. 71
Aromatic Hydrocarbon Compound	Diphenylmethane											
	Diphenylpropane											
	Cis-1,2-Diphenylethylene											
Monoester	Methyl My ristate											
	Dimethyl Phthalate											
	Dimethyl Maleate											
	Dimethyl Malonate											
	Dimethyl Succinate											
	Dimethyl Glutarate											
	Dimethyl Adipate											

(continued)

		Ex. 61	Ex. 62	Ex. 63	Ex. 64	Ex. 65	Ex. 66	Ex. 67	Ex. 68	Ex. 69	Ex. 70	Ex. 71
Diester	Dimethyl Suberate											
	Dimethyl Sebacate											
	Diethyl Malonate											
	Dibutyl Malonate											
	Dihexyl Malonate											
	Dihexyl Sebacate											
	Di-2-Ethylhexyl Sebacate	99.0								99.0		
Triester	Tributyl Trimellitate											
Tetraester	Pentaerythritol											
Glycol	Tetraethylene Glycol											
	Tripropylene Glycol											
	Tetraethylene Glycol Dimethyl Ether											
	Poly(Oxyethylene) Glycol											
	Polypropylene Glycol Monobutyl Ether											
	Poly (Oxypropylene, Oxybutylene) Glycol											
S-cont. cmd.	Dibutyl Sulfoxide											
	2,2'-Thiodiethanol											

P-cont. cmd.	Trimethyl Phosphate											
N-cont. cmd.	Formamide	1.0	0.1	1.0								
	N-Methylformamide				0.1							
	N-tert-Butylformamide					3.0						
	Tetramethylurea						3.0					
	Tetraethylurea											
General Anti-static Agent	Poly (Oxyethylene)Alkylamine							3.0	3.0			
	Glycerin Aliphatic Ester Monocaprylin											
Ionic Liquid	(*N*-(Methoxyethyl)-1-Methylpyrrolidiniu m Bis(Trifluoro-methylsulfonyl)Imide)									1.0	0.5	1.0
Liquid Crystal	4-Cyano-4'-Pentylbiphenyl											
Mineral Oil	P-Based Mineral Oil											
Synthetic Hy-drocarbon	PAO		99.9		99.9	97.0	97.0	97.0			99.5	
Ether	ADE			99.0					97.0			99.0
	Alkyl Tetraphenyl Ether											
	Pentaphenyl Ether											
	Tetraphenyl Ether											
SP-cont. cmd.	Alkylated Triphenyl Phosphorothioate											
NS-Based Compound	Dimercaptothiadiazole Derivative											
	MoDTC											
Fatty Acid Amine Salt	Oleic Acid Dicycloamine Salt											
Number of Aromatic Carbon Atoms %		-	-	-	-	-	-	-	-	-	-	-
Specific Volume Resistivity Ω·cm		-	-	-	-	-	-	-	-	-	-	-
Dielectric Constant 500 MHz		-	-	-	-	-	-	-	-	-	-	-
Dielectric Constant 1 GHz		-	-	-	-	-	-	-	-	-	-	-
Hansen Parameter Polar Force δP		-	-	-	-	-	-	-	-	-	-	-

(continued)

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 Hydro-carbon Com-pound	Diphenylmethane										
	Diphenylpropane										
	Cis-1,2-Diphenylethy-lene										
Monoester	Methyl Myristate	100									
Diester	Dimethyl Phthalate										
	Dimethyl Maleate										
	Dimethyl Malonate										
	Dimethyl Succinate										
	Dimethyl Glutarate										
	Dimethyl Adipate										
	Dimethyl Suberate										
	Dimethyl Sebacate										
	Diethyl Malonate										
	Dibutyl Malonate										
	Dihexyl Malonate										
	Dihexyl Sebacate		100								
	Di-2-Ethylhexyl Seba-cate			100							
Triester	Tributyl Trimellitate				100						
Tetraester	Pentaerythritol					100					

(continued)

		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
Glycol	Tetraethylene Glycol										
	Tripropylene Glycol										
	Tetraethylene Glycol Dimethyl Ether										
	Poly(Oxyethylene)Glycol										
	Polypropylene Glycol Monobutyl Ether										
	Poly(Oxypropylene, Oxybutylene)Glycol						100				
S-cont. cmd.	Dibutyl Sulfoxide										
	2,2'-Thiodiethanol										
P-cont. cmd.	Trimethyl Phosphate										

N-cont. cmd.	Formamide										0.05
	N-Methylformamide										
	N-tert-Butylformamide										
	Tetramethylurea										
	Tetraethylurea										
General Anti-static Agent	Poly(Oxyethylene)Alkylamine										
	Glycerin Aliphatic Ester Monocaprylin										
Ionic Liquid	(*N*-(Methoxyethyl)-1-Methylpyrrolidinium Bis(Trifluoromethylsulfonyl)Imide)										
Liquid Crystal	4-Cyano-4'-Pentylbiphenyl										
Mineral Oil	P-Based Mineral Oil							100			
Synthetic Hydrocarbon	PAO								100		99.95
Ether	ADE									100	
	Alkyl Tetraphenyl Ether										
	Pentaphenyl Ether										
	Tetraphenyl Ether										
SP-cont. cmd.	Alkylated Triphenyl Phosphorothioate										
NS-Based Compound	Dimercaptothiadiazole Derivative										
	MoDTC										
Fatty Acid Amine Salt	Oleic Acid Dicycloamine Salt										
Number of Aromatic Carbon Atoms %		0	0	0	0	0	0	0	0	35	-
Specific Volume Resistivity Ω·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	-

(continued)

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

[0057] The suppliers and trade names of the compounds used in Examples and Comparative Examples are presented below.

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")
	: 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")
	: Glycerin aliphatic ester monocaprylin (manufactured by Riken Vitamin Co., Ltd. under the trade name of "Poem M-100")
Ionic Liquid	: *N*-(Methoxyethyl)-1-methylpyrrolidinium bis(trifluoromethylsulfonyl)imide (manufactured by Merck)
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	: PAO8 (kinematic viscosity at 40°C is 45 mm^2/s)
Ether Oil	: 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")
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 "SAKURA-LUBE 525")
Fatty Acid Amine Salt	: Oleic acid dicycloamine salt (manufactured by Albess Co., Ltd. under the trade name of "NONRUST Z-1000")

Claims

1. Use as an anti-flaking agent of 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, wherein the compound (A) is a diester selected from the group consisting of dimethyl phthalate, dimethyl maleate, diethyl malonate, dibutyl malonate, and dihexyl malonate.

2. Lubricant composition comprising a diester selected from the group consisting of dimethyl maleate, dibutyl malonate, and dihexyl malonate and at least one conventional base oil selected from the group consisting of mineral oils and synthetic oils.

3. The lubricant composition according to claim 2, wherein the base oil is at least one selected from the group consisting of mineral oils, synthetic hydrocarbon oils, and ether oils.

4. The lubricant composition according to any one of claims 2 to 3, wherein a content of the compound exceeds 0.1% by mass based on a total mass of the composition.

5. The lubricant composition according to any one of claims 2 to 4, further comprising a thickener.

Patentansprüche

1. Verwendung als Antischuppenmittel von mindestens einem aus der Gruppe bestehend aus
(A) eine Verbindung mit einem spezifischen Volumenwiderstand von 1,0 × 10^{10} Ω·cm oder weniger, wobei die Verbindung (A) ein Diester ist, ausgewählt aus der Gruppe, bestehend aus Dimethylphthalat, Maleinsäuredimethylester, Malonsäurediethylester, Malonsäuredibutylester und Malonsäuredihexylester.

2. Schmiermittelzusammensetzung, umfassend einen Diester, ausgewählt aus der Gruppe, bestehend aus Maleinsäuredimethylester, Malonsäuredibutylester und Malonsäuredihexylester, und mindestens ein konventionelles Grundöl, ausgewählt aus der Gruppe, bestehend aus Mineralölen und synthetischen Ölen.

3. Schmierstoffzusammensetzung nach Anspruch 2, wobei das Grundöl mindestens eines ist, ausgewählt aus der Gruppe, bestehend aus Mineralölen, synthetischen Kohlenwasserstoffölen und Etherölen.

4. Schmiermittelzusammensetzung nach einem der Ansprüche 2 bis 3, wobei ein Gehalt der Verbindung 0,1 Masse-%, bezogen auf eine Gesamtmasse der Zusammensetzung, übersteigt.

5. Schmiermittelzusammensetzung nach einem der Ansprüche 2 bis 4, ferner umfassend ein Verdickungsmittel.

Revendications

1. Utilisation comme agent anti-écaillage d'au moins un élément choisi dans le groupe constitué
(A) d'un composé ayant une résistivité volumique spécifique de 1,0 × 10^{10} Ω cm ou moins, dans laquelle le composé (A) est un diester choisi dans le groupe constitué du phtalate de diméthyle, du maléate de diméthyle, du malonate de diéthyle, du malonate de dibutyle, et du malonate de dihexyle.

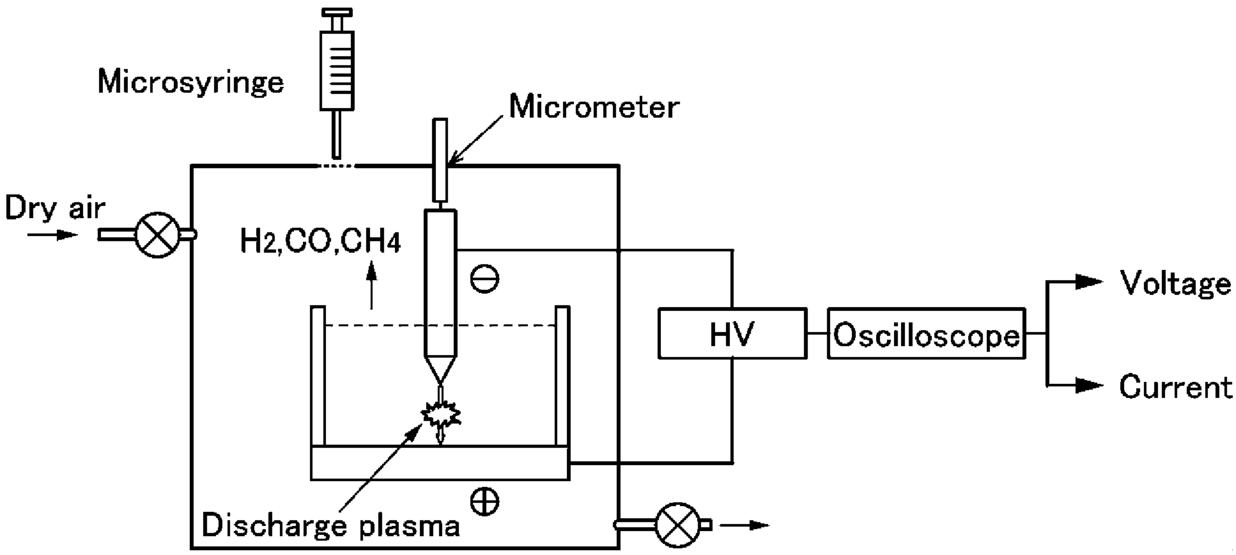
2. Composition de lubrifiant comprenant un diester choisi dans le groupe composé du maléate de diméthyle, du malonate de dibutyle et du malonate de dihexyle et au moins une huile de base classique choisie dans un groupe composé d'huiles minérales et d'huiles synthétiques.

3. Composition de lubrifiant selon la revendication 2, dans laquelle l'huile de base est au moins une huile choisie dans le groupe constitué d'huiles minérales, d'huiles hydrocarbonées synthétiques et d'huiles éther.

4. Composition de lubrifiant selon l'une quelconque des revendications 2 et 3, dans laquelle la teneur en composé dépasse 0,1 % en masse sur la base d'une masse totale de la composition.

5. Composition de lubrifiant selon l'une quelconque des revendications 2 à 4, comprenant également un épaississant.

FIG.1



Microsyringe
Micrometer
Dry air
H2,CO,CH4
HV
Oscilloscope
Voltage
Current
Discharge plasma

REFERENCES CITED IN THE DESCRIPTION

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