# DURABLE LUBRICATING FLUIDS FOR ELECTRIC VEHICLES

## FIELD

**[001]** The present disclosure relates to a durable lubricating fluid for an electric motor or hybrid-electric motor. The disclosed technology relates to a durable lubricating fluid comprising an oil of lubricating viscosity, a thiadiazole or derivative thereof, an amine salt of a phosphoric acid ester, and having a sulfur plus phosphorus to nitrogen ((S+P)/N)) weight ratio of at least 2.3. Such lubricants have an electrical conductivity durability of 50,000 pS/m.

## BACKGROUND

**[002]** A major challenge in developing electric motor or hybrid-electric motor lubricants is developing a lubricant that maintains a relatively low electrical conductivity even after aging. These types of lubricants should maintain relatively low electrical conductivity (or conversely relatively high electrical resistivity) over the lifetime of the lubricant to inhibit electrostatic buildup and discharge in electrified components found in the electric or hybrid-electric motor.

**[003]** Lubricating fluids for conventional internal combustion engines commonly employ additives to provide sufficient amounts of sulfur and phosphorus to deliver wear and extreme-pressure protection to mechanical components. However, such additives in lubricating fluids for electric motor or hybrid-electric motors may pose problems because active sulfur and phosphorus compounds are often chemically aggressive to copper wire and copper-based alloys used in electric and or hybrid-electric motors. In addition, sulfur and phosphorus compounds are often conductive, and the inclusion of active sulfur and phosphorus compounds in a lubricant can lead to undesirable increase in the lubricant's electrical conductivity. Thus, lubricating fluids for electric and hybrid-electric motors have the added challenge of maintaining a relatively low electrical conductivity while still protecting copper components and delivering sufficient protection for mechanical components.

## SUMMARY AND TERMS

**[003a]** In a first aspect of the present disclosure, there is provided a durable lubricating composition for electric or hybrid-electric vehicles, the lubricating composition comprising:

a base oil of lubricating viscosity;

at least 0.7 weight percent of a thiadiazole or derivative thereof,

an amine salt of a phosphoric acid ester providing at least 100 ppm of phosphorus to the durable lubricating composition;

a sulfur plus phosphorus to nitrogen ((S+P)/N) weight ratio of at least 2.3;

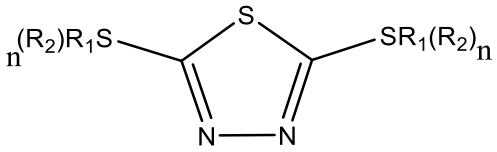
the lubricating composition having at least 150 ppm of phosphorus and at least 2000 ppm of sulfur; and

a conductivity durability of 50,000 pS/m or less.

**[004]** In one example, a durable lubricating composition for electric or hybrid-electric vehicles is described herein. In examples, the lubricating composition includes a

base oil of lubricating viscosity; at least about 0.7 weight percent of a thiadiazole or derivative thereof; an amine salt of a phosphoric acid ester providing at least about 100 ppm of phosphorus to the durable lubricating composition; a sulfur plus phosphorus to nitrogen ((S+P)/N) weight ratio of at least 2.3; the lubricating composition having at least about 150 ppm of phosphorus and at least about 2000 ppm of sulfur; and a conductivity durability of about 50,000 pS/m or less. The conductivity durability is defined as the difference between an initial conductivity and a final conductivity, wherein the initial and final conductivities are measured according to ATSM D2624-15 at 1.5 volts, 20 Hz, and at 160C, and wherein the final conductivity is measured after the lubricating composition has been aged according to CEC L-48-A-00 at 170°C for 192 hours.

**[005]** In other examples, the thiadiazole of the durable lubricating composition may be selected from a mono hydrocarbyl thiol-substituted thiadiazole, a bishydrocarbyl thiol-substituted thiadiazole, or combinations thereof; and/or wherein the thiadiazole is 1,3,4-thiadiazole or derivative thereof; and/or wherein the thiadiazole provides at least about 2000 ppm sulfur to the durable lubricating composition; and/or wherein the lubricating composition includes about greater than 0.5 wt% to about 1 wt% of the thiadiazole or derivative thereof; and/or wherein the thiadiazole or derivative thereof includes one or more compounds having a structure of Formula I:

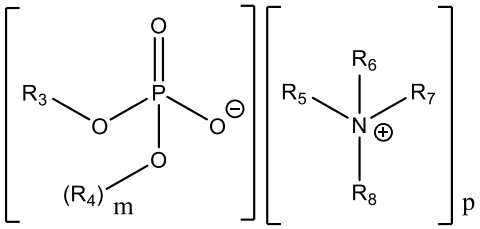



(Formula I) wherein each $R_1$ is independently hydrogen or sulfur; each $R_2$ is independently an alkyl group; n is an integer of 0 or 1 and if $R_1$ is hydrogen then the integer n of the adjacent $R_2$ moiety is 0 and if $R_1$ is sulfur then the n of the adjacent $R_2$ moiety is 1; and wherein at least one $R_1$ is sulfur; and/or wherein the thiadiazole or derivative thereof provides at least about 99 weight % of the sulfur to the durable lubricating composition.

**[006]** In other examples, the durable lubricating composition of any example herein may include up to about 3500 ppm total sulfur and up to about 300 ppm total phosphorus.

**[007]** In further examples, the amine salt of a phosphoric acid ester of any example herein includes one or more of a monoalkyl phosphoric acid ester and/or a dialkyl

phosphoric acid esters and wherein the alkyl groups thereof may be linear or branched; and/or wherein the amine salt of a phosphoric acid ester is represented by Formula II



(Formula II) wherein $R_3$ and $R_4$ may be independently hydrogen or a linear, branched, or cyclic hydrocarbyl group; m is an integer from 0 to 1, p is an integer from 1 to 2, and m + p equals 2; $R_5$, $R_6$, $R_7$ and $R_8$ may be independently hydrogen or a hydrocarbyl group and at least one of $R_5$ to $R_8$ is a hydrocarbyl group; and/or wherein $R_3$ and $R_4$ may independently be a C3 to C10 alkyl group; and/or wherein $R_3$ and $R_4$ are a C6 alkyl group; and/or wherein at least one of $R_5$, $R_6$, $R_7$ and $R_8$ is C10 to C20 alkyl group; and/or wherein two of $R_5$, $R_6$, $R_7$ and $R_8$ are independently a C10 to C20 alkyl group; and/or wherein two of $R_5$, $R_6$, $R_7$ and $R_8$ are independently a C12 to C14 alkyl group; and/or wherein the amine salt of a phosphoric acid ester provides about 40 to about 90 weight % of the total phosphorus in the durable lubricating composition; and/or wherein the lubricating composition includes about 0.25 to about 0.5 weight percent of the amine salt of a phosphoric acid ester.

**[008]** In other examples, the durable lubricating composition of any example may have an initial conductivity of about 150,000 pS/m or less when measured or less as measured according to ASTM D2624-15 at 160C.

**[009]** In yet other examples, the present disclosure provides for the use of a durable lubricating composition (or a method of lubricating) in an electric or hybrid electric motor wherein the durable lubricating composition includes a base oil of lubricating viscosity, at least about 0.7 weight percent of a thiadiazole or derivative thereof, an amine salt of a phosphoric acid ester providing at least about 100 ppm of phosphorus to the durable lubricating composition, a sulfur plus phosphorus to nitrogen ((S+P)/N) weight ratio of at least 2.3; the lubricating composition having at least about 150 ppm of phosphorus and at least about 2000 ppm of sulfur and a conductivity durability of about 50,000 pS/m or less. The conductivity durability is defined as the difference between an initial conductivity and a final conductivity, wherein the initial and final conductivities are measured according to ASTM D2624-15 at 1.5 volts, 20 Hz, and at 160C, and wherein the final conductivity is measured after the lubricating

composition has been aged according CEC L-48-A-00 at 170°C for 192 hours. The use or methods herein may also include any of the optional features of any example as described in this Summary.

**[010]** Other examples of the present disclosure will be apparent to those skilled in the art from consideration of the specification and practice of the present disclosure disclosed herein.

**[011]** The following definitions of terms are provided in order to clarify the meanings of certain terms as used herein.

**[012]** The terms “lubricating oil,” “lubricant composition,” “lubricating composition,” “lubricant” and “lubricating and cooling fluid” refer to a finished lubrication product comprising a major amount of a base oil plus a minor amount of an additive composition.

**[013]** As used herein, the terms “additive package,” “additive concentrate,” “additive composition,” and “transmission fluid additive package” refer the portion of the lubricating oil composition excluding the major amount of base oil.

**[014]** As used herein, the term "hydrocarbyl substituent" or "hydrocarbyl group" is used in its ordinary sense, which is well-known to those skilled in the art. Specifically, it refers to a group having a carbon atom directly attached to the remainder of the molecule and having a predominantly hydrocarbon character. Each hydrocarbyl group is independently selected from hydrocarbon substituents, and substituted hydrocarbon substituents containing one or more of halo groups, hydroxyl groups, alkoxy groups, mercapto groups, nitro groups, nitroso groups, amino groups, pyridyl groups, furyl groups, imidazolyl groups, oxygen and nitrogen, and wherein no more than two non-hydrocarbon substituents are present for every ten carbon atoms in the hydrocarbyl group.

**[015]** As used herein, the term "percent by weight" or “wt%”, unless expressly stated otherwise, means the percentage the recited component represents to the weight of the entire composition.

**[016]** The terms "soluble," "oil-soluble," or "dispersible" used herein may, but does not necessarily, indicate that the compounds or additives are soluble, dissolvable, miscible, or capable of being suspended in the oil in all proportions. The foregoing terms do mean, however, that they are, for instance, soluble, suspendable, dissolvable, or stably dispersible in oil to an extent sufficient to exert their intended effect in the environment in which the oil is employed.

Moreover, the additional incorporation of other additives may also permit incorporation of higher levels of a particular additive, if desired.

**[017]** The term "alkyl" as employed herein refers to straight, branched, cyclic, and/or substituted saturated chain moieties of from about 1 to about 200 carbon atoms.

**[018]** The term "alkenyl" as employed herein refers to straight, branched, cyclic, and/or substituted unsaturated chain moieties of from about 3 to about 30 carbon atoms.

**[019]** The term “aryl” as employed herein refers to single and multi-ring aromatic compounds that may include alkyl, alkenyl, alkylaryl, amino, hydroxyl, alkoxy, halo substituents, and/or heteroatoms including, but not limited to, nitrogen, and oxygen.

**[020]** As used herein, the “number average molecular weight” or “Mn” is determined by gel permeation chromatography (GPC) using commercially available polystyrene standards (with a Mn of 180 to about 18,000 as the calibration reference). The GPC method additionally provides molecular weight distribution information; see, for example, W. W. Yau, J. J. Kirkland and D. D. Bly, “Modern Size Exclusion Liquid Chromatography”, John Wiley and Sons, New York, 1979, also incorporated herein by reference.

**[021]** It is to be understood that throughout the present disclosure, the terms "comprises," "includes," “contains,” etc. are considered open-ended and include any element, step, or ingredient not explicitly listed. The phrase "consists essentially of" is meant to include any expressly listed element, step, or ingredient and any additional elements, steps, or ingredients that do not materially affect the basic and novel examples of the present disclosure. The present disclosure also contemplates that any composition described using the terms, "comprises," "includes," “contains,” is also to be interpreted as including a disclosure of the same composition "consisting essentially of" or “consisting of” the specifically listed components thereof.

## DESCRIPTION OF DRAWINGS

**[022]** FIG. 1 is a chart of conductivity durability relative to sulfur, phosphorus, and nitrogen levels.

## DETAILED DESCRIPTION

**[023]** Disclosed herein are durable lubricating fluids suitable for use in electric or hybrid electric vehicles. The durable lubricating fluids contain sulfur and phosphorus for provide wear

WHAT IS CLAIMED IS:

1. A durable lubricating composition for electric or hybrid-electric vehicles, the lubricating composition comprising:

a base oil of lubricating viscosity;

at least 0.7 weight percent of a thiadiazole or derivative thereof,

an amine salt of a phosphoric acid ester providing at least 100 ppm of phosphorus to the durable lubricating composition;

a sulfur plus phosphorus to nitrogen ((S+P)/N) weight ratio of at least 2.3;

the lubricating composition having at least 150 ppm of phosphorus and at least 2000 ppm of sulfur; and

a conductivity durability of 50,000 pS/m or less.

2. The durable lubricating composition for electric or hybrid-electric vehicles of claim 1, wherein the thiadiazole is selected from a mono hydrocarbyl thiol-substituted thiadiazole, a bishydrocarbyl thiol-substituted thiadiazole, or combinations thereof.

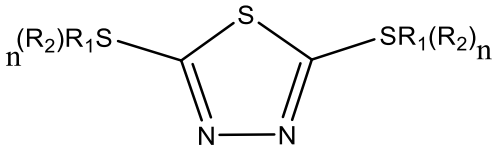
3. The durable lubricating composition for electric or hybrid-electric vehicles of claim 1, wherein the thiadiazole is 1,3,4-thiadiazole or derivative thereof.

4. The durable lubricating composition for electric or hybrid-electric vehicles of claim 1, wherein the thiadiazole provides at least 2000 ppm sulfur to the durable lubricating composition.

5. The durable lubricating composition for electric or hybrid-electric vehicles of claim 4, wherein the durable lubricating composition includes up to 3500 ppm total sulfur and up to 300 ppm total phosphorus.

6. The durable lubricating composition for electric or hybrid-electric vehicles of claim 1, wherein the lubricating composition includes 1 weight percent or less of the thiadiazole or derivative thereof.

7. The durable lubricating composition for electric or hybrid-electric vehicles of claim 1, wherein the thiadiazole or derivative thereof includes one or more compounds having a structure of Formula I:




(Formula I)

wherein

Each $R_1$ is independently hydrogen or sulfur;

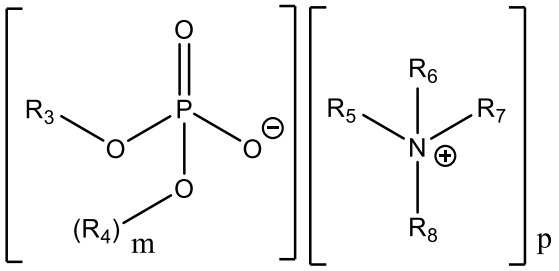
Each $R_2$ is independently an alkyl group;

n is an integer of 0 or 1 and if $R_1$ is hydrogen then the integer n of the adjacent $R_2$ moiety is 0 and if $R_1$ is sulfur then the n of the adjacent $R_2$ moiety is 1; and

wherein at least one $R_1$ is sulfur.

8. The durable lubricating composition for electric or hybrid-electric vehicles of claim 1, wherein the amine salt of a phosphoric acid ester includes one or more of a monoalkyl phosphoric acid ester and/or a dialkyl phosphoric acid esters and wherein the alkyl groups thereof may be linear or branched.

9. The durable lubricating composition for electric or hybrid-electric vehicles of claim 7, wherein the amine salt of a phosphoric acid ester is represented by Formula II




(Formula II)

wherein

$R_3$ and $R_4$ may be independently hydrogen or a linear, branched, or cyclic hydrocarbyl group;

m is an integer from 0 to 1, p is an integer from 1 to 2, and m + p equals 2;

$R_5$, $R_6$, $R_7$ and $R_8$ may be independently hydrogen or a hydrocarbyl group and at least one of $R_5$ to $R_8$ is a hydrocarbyl group.

10. The durable lubricating composition for electric or hybrid-electric vehicles of claim 9, wherein $R_3$ and $R_4$ may independently be a C3 to C10 alkyl group.

11. The durable lubricating composition for electric or hybrid-electric vehicles of claim 10, wherein at least one of $R_5$, $R_6$, $R_7$ and $R_8$ is C10 to C20 alkyl group.

12. The durable lubricating composition for electric or hybrid-electric vehicles of claim 10, wherein two of $R_5$, $R_6$, $R_7$ and $R_8$ are independently a C10 to C20 alkyl group.

13. The durable lubricating composition for electric or hybrid-electric vehicles of claim 1, wherein the amine salt of a phosphoric acid ester provides 40 to 90 weight % of the total phosphorus in the durable lubricating composition.

14. The durable lubricating composition for electric or hybrid-electric vehicles of claim 13, wherein the thiadiazole or derivative thereof provides at least 99 weight % of the total sulfur in the durable lubricating composition.

15. The durable lubricating composition for electric or hybrid-electric vehicles of claim 1, wherein the lubricating composition includes 0.25 to 0.5 weight percent of the amine salt of a phosphoric acid ester.

16. The durable lubricating composition for electric or hybrid-electric vehicles of claim 1, wherein the lubricating composition has an initial conductivity before aging of 150,000 or less when measured according to ASTM D2624-15 at 1.5 volts, 20 Hz, and at 160 °C.

17. The durable lubricating composition for electric or hybrid-electric vehicles of claim 1, wherein the conductivity durability is the difference between an initial conductivity and a final conductivity, and the initial and final conductivities are measured according to ATSM D2624-15 at 1.5 volts, 20 Hz, and at 160 °C, and wherein the final conductivity is measured after the lubricating composition has been aged according to CEC L-48-A-00 at 170° C for 192 hours.