vehicles. That is, some traditional lubricant packages may have low electrical conductivity but have poor thermal conductivity (providing poor cooling performance). Other traditional lubricant packages may have high thermal conductivity (providing good cooling capability) but have poor electrical conductivity. Thus, such prior fluids do not provide optimal performance for these unique applications.

BREIF DESCRIPTION OF THE FIGURES

[0006] FIG. 1 is a graph of lubricant electrical conductivity per ASTM D2624-15 at 75ºC; and

[0007] FIG. 2 is a graph of lubricant thermal conductivity per ASTM D7896-14 at 80 ºC.

SUMMARY

[0007a] In a first aspect of the present disclosure, there is provided a method for lubricating a transmission having an electric or a hybrid-electric motor, the method comprising:

lubricating a transmission having an electric or a hybrid-electric motor with a lubricant;

the lubricant including a poly(meth)acrylate copolymer and a solvent system including a base oil component blended with a branched diester component, the solvent system having 10 to 50 weight percent of the branched diester component;

the base oil component including one or more oils selected from Group I to Group V base oils;

the poly(meth)acrylate copolymer has a weight average molecular weight of 50,000 g/mol or less; and

wherein the branched diester component and the poly(meth)acrylate copolymer are effective so that the lubricant exhibits an electrical conductivity measured per ASTM D2624-15 at 75ºC of 80,000 pS/m or less and a thermal conductivity measured per ASTM D7896-14 at 80ºC of 134 mW/m*K or more.

[0007b] In another aspect of the present disclosure, there is provided a transmission and lubricant for an electric or a hybrid-electric vehicle, the transmission and lubricant comprising:

a transmission having an electric or a hybrid-electric motor thereof;

a lubricating composition of the transmission in contact with at least portions of the electric or the hybrid-electric motor; and

the lubricating composition including (i) an solvent system having a blend of one or more base oils selected from Group I to Group V oils and a branched diester, the solvent system having 10 to 50 weight percent of the branched diester and (ii) a copolymer viscosity index improver having a weight average molecular weight of 50,000 g/mol or less; and

wherein the lubricating composition includes amounts of the branched diester and amounts of the copolymer viscosity index improver effective to achieve an electrical conductivity measured per ASTM D2624-15 at 75ºC of 80,000 pS/m or less and a thermal conductivity measured per ASTM D7896-14 at 80ºC of 134 mW/m*K or more.

[0007c] In a further aspect of the present disclosure, there is provided a lubricating composition for electric or hybrid-electric motors, the lubricating composition comprising:

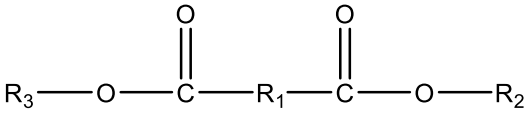
a solvent system including one or more Group I to Group V base oils blended with a branched diester, wherein the solvent system has 10 to 50 weight percent of the branched diester;

a copolymer viscosity index improver having a weight average molecular weight of 50,000 g/mol or less and a polydispersity index of 1 to 2; and

wherein the lubricating composition includes amounts of the branched diester in the solvent system and amounts of the copolymer viscosity index improver effective to achieve an electrical conductivity measured per ASTM D2624-15 at 75ºC of 80,000 pS/m or less and a thermal conductivity measured per ASTM D7896-14 at 80ºC of 134 mW/m*K or more at the same time.

[0008] This present disclosure relates to a method for lubricating a transmission having an electric or a hybrid-electric motor. In one ~~embodiment~~example, the method comprises lubricating a transmission having the electric or the hybrid-electric motor with a lubricant. The lubricant including a poly(meth)acrylate copolymer and a solvent system including a base oil component blended with a branched diester component. The base oil component including, in one ~~embodiment~~example, one or more oils selected from Group I to Group V base oils, in another ~~embodiment~~example, one or more oils selected from Group I to Group 1V base oils, and, in yet another ~~embodiment~~example, base oils selected from Group I, Group, II, Group III, Group IV, and/or Group V bases oils in any combination. In yet further ~~embodiment~~examples, the poly(meth)acrylate copolymer has a weight average molecular weight of about 50,000 g/mol.

[0009] In other ~~embodiment~~examples of the method, the branched diester component may be a reaction product of one or more dicarboxylic acids having an internal carbon chain length of 6 to 10 carbons and one or more alcohols having a branched carbon chain length of 6 to 12 carbons. The solvent system may include about 10 to about 50 weight percent of the branched diester component. The branched diester component may have the structure of Formula I:



(Formula I)

wherein R_1 is a carbon chain having n-2 carbons with n being an integer from 6 to 10; and R_2 and R_3 are the same or different and include C8 to C10 branched alkyl chains. The branched

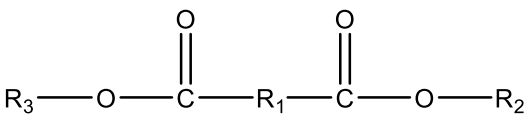
diester component may be selected from the group consisting of bis(6-methylheptyl) hexanedioate; bis(8-methylnonyl) hexanedioate; bis(2-ethylhexyl)decanedioate; bis(2-ethylhexyl) hexanedioate; or combinations thereof.

[0010] In any of the ~~embodiment~~examples herein, the lubricant may also have an electrical conductivity measured per ASTM D2624-15 at 75ºC of about 80,000 pS/m or less and a thermal conductivity measured per ASTM D7896-14 at 80ºC of about 134 mW/m*K or more. In yet further ~~embodiment~~examples, the present disclosure also relates to the use of the poly(meth)acrylate copolymer and to the solvent system including a base oil component blended with a branched diester component as described in any ~~embodiment~~example herein to achieve a lubricating composition having the electrical conductivity and thermal conductive as discussed in any ~~embodiment~~example herein.

[0011] In other ~~embodiment~~examples, the poly(meth)acrylate copolymer may be derived from at least C1 to C4 linear or branched alkyl (meth)acrylates monomer units and C12 to C20 linear or branched alkyl (meth)acrylate monomer units and has a weight average molecular weight of about 10,000 to about 50,000 g/mol. The poly(meth)acrylate copolymer may have about 5 to about 50 mol percent monomer units derived from the C1 to C4 linear or branched alkyl (meth)acrylates and about 50 to about 95 mol percent monomer units derived from the C12 to C20 linear or branched alkyl (meth)acrylates.

[0012] The present disclosure also relates to a transmission and lubricant for an electric or a hybrid-electric vehicle. In some ~~embodiment~~examples, the transmission and lubricant comprise a transmission having an electric or a hybrid-electric motor or component thereof and a lubricating composition of the transmission in contact with at least portions of and/or a component of the electric or the hybrid-electric motor. The lubricating composition may include, in some ~~embodiment~~examples, (i) a solvent system having a blend of one or more base oils selected from Group I to Group V oils and a branched diester and (ii) a copolymer viscosity index improver having a weight average molecular weight of about 50,000 g/mol or less. The base oils may also include, in other ~~embodiment~~examples, one or more oils selected from Group I to Group 1V base oils, and, in yet another ~~embodiment~~example, base oils selected from Group I, Group, II, Group III, Group IV and/or Group V bases oils in any combination.

[0013] In other ~~embodiment~~examples, the transmission and lubricant may include the branched diester having the structure of Formula I:



(Formula I)

wherein R_1 is a carbon chain having n-2 carbons with n being an integer from 6 to 10; and R_2 and R_3 are the same or different and include C8 to C10 branched alkyl chains. The branched diester may have C6 to C12 branched alkyl groups in alcohol moieties thereof and 6 to 10 carbons in acid moieties thereof. The solvent system may include about 10 to about 50 weight percent of the branched diester. The branched diester may be selected from the group consisting of bis(6-methylheptyl) hexanedioate; bis(8-methylnonyl) hexanedioate; bis(2-ethylhexyl)decanedioate; bis(2-ethylhexyl) hexanedioate; or combinations thereof.

[0014] Any of the above ~~embodiment~~examples may include amounts of the branched diester and amounts of the copolymer viscosity index improver effective to achieve an electrical conductivity measured per ASTM D2624-15 at 75ºC of about 80,000 pS/m or less and a thermal conductivity measured per ASTM D7896-14 at 80ºC of about 134 mW/m*K or more at the same time.

[0015] In yet other ~~embodiment~~examples of the transmission and lubricant, the copolymer viscosity index improver includes monomer units derived from C1 to C4 linear or branched short chain alkyl (meth)acrylates and C12 to C20 linear or branched long chain alkyl (meth)acrylates and has a weight average molecular weight of about 10,000 to about 50,000 g/mol. The copolymer viscosity index improver has about 5 to about 50 mol percent monomer units derived from the short chain (meth)acrylates and about 50 to about 95 mol percent monomer units derived from the long chain (meth)acrylates.

[0016] The present disclosure also relates to a lubricating composition for electric or hybrid-electric motors. In some ~~embodiment~~examples, the lubricating composition comprises a solvent system including one or more Group I to Group V base oils blended with a branched diester; a copolymer viscosity index improver having a weight average molecular weight of about 50,000 g/mol or less and, in some ~~embodiment~~examples, also having a polydispersity index of about 1 to about 2. The base oils may also include, in other ~~embodiment~~examples, one or more oils selected from Group I to Group 1V base oils, and, in yet another ~~embodiment~~example, base oils selected from Group I, Group, II, Group III, Group IV and/or Group V bases oils in any combination. The lubricating composition may also include amounts of the branched diester in the solvent system and amounts of the copolymer viscosity index improver effective to achieve an electrical conductivity measured per ASTM D2624-15 at 75ºC of about 80,000 pS/m or less and a thermal conductivity measured per ASTM D7896-14 at 80ºC of about 134 mW/m*K or more at the same time.

[0017] In some ~~embodiment~~examples of the lubricating composition, the branched diester of the lubricating composition may be the reaction product of one or more dicarboxylic acids having an internal carbon chain length of 6 to 10 carbons and one or more alcohols having a branched carbon chain length of 6 to 12 carbons. The solvent system may also include about 10 to about 50 weight percent of the branched diester.

[0018] In any of the above ~~embodiment~~examples, the lubricating composition may include about 5 to about 40 weight percent of the branched diester and about 2.5 to about 17.5 weight percent of the copolymer viscosity index improver. In any of the above ~~embodiment~~examples, the lubricating composition may also include an ester-to-copolymer weight ratio in the lubricating composition of about 1.4 to about 5.0 (solids content of copolymer). In any of the ~~embodiment~~examples, the copolymer viscosity index improver of the lubricating composition may be derived from C1 to C4 short chain linear or branched alkyl (meth)acrylates and C12 to C20 long chain linear or branched alkyl (meth)acrylates.

DETAILED DESCRIPTION

[0019] This present disclosure describes lubricant compositions suitable for electric and hybrid-electric applications, and in particular, suitable for transmissions where the lubricating compositions come into contact with electric and/or hybrid-electric motors and components thereof and have good lubricating properties, good electrical properties, and good thermal properties. In some aspects, the lubricating compositions herein include a solvent system having a mineral and/or synthetic base oil component blended with a branched diester component; the solvent system is further combined with low weight average molecular weight poly(meth) acrylate copolymers. The lubricating compositions described herein surprisingly achieve the desired lubricating, electrical, and thermal properties required for electric and hybrid-electric applications.

[0020] In one aspect or embodiment, the solvent system herein includes one or more Group I to Group V base oils blended with select branched esters of dicarboxylic acids. In some embodiments, the solvent system herein includes a Group III base oil component. In another approach, the solvent system includes a Group IV base oil component. In any of the above embodiments, the branched diester component is a reaction product of one or more dicarboxylic acids having a specific internal carbon chain length and one or more alcohols having a specific branched carbon chain length. When blended with the low weight average molecular weight poly(meth) acrylate copolymers described herein, monoesters and diesters

WHAT IS CLAIMED IS:

1. A method for lubricating a transmission having an electric or a hybrid-electric motor, the method comprising:

lubricating a transmission having an electric or a hybrid-electric motor with a lubricant;

the lubricant including a poly(meth)acrylate copolymer and a solvent system including a base oil component blended with a branched diester component, the solvent system having ~~about~~ 10 to ~~about~~ 50 weight percent of the branched diester component;

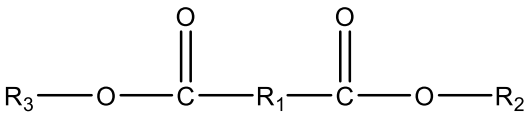
the base oil component including one or more oils selected from Group I to Group V base oils;

the poly(meth)acrylate copolymer has a weight average molecular weight of ~~about~~ 50,000 g/mol or less; and

wherein the branched diester component and the poly(meth)acrylate copolymer are effective so that the lubricant exhibits an electrical conductivity measured per ASTM D2624-15 at 75ºC of ~~about~~ 80,000 pS/m or less and a thermal conductivity measured per ASTM D7896-14 at 80ºC of ~~about~~ 134 mW/m*K or more.

2. The method of claim 1, wherein the branched diester component is a reaction product of one or more dicarboxylic acids having an internal carbon chain length of 6 to 10 carbons and one or more alcohols having a branched carbon chain length of 6 to 12 carbons.

3. The method of claim 1, wherein the branched diester component has the structure of Formula I:



(Formula I)

wherein

R_1 is a carbon chain having n-2 carbons with n being an integer from 6 to 10; and

R_2 and R_3 are the same or different and include C8 to C10 branched alkyl chains.

4. The method of claim 1, wherein the branched diester component is selected from the group consisting of bis(6-methylheptyl) hexanedioate; bis(8-methylnonyl) hexanedioate; bis(2-ethylhexyl) decanedioate; bis(2-ethylhexyl) hexanedioate; and combinations thereof.

5. The method of claim 1, wherein the poly(meth)acrylate copolymer is derived from at least C1 to C4 linear or branched alkyl (meth)acrylates monomer units and C12 to C20 linear or branched alkyl (meth)acrylate monomer units and has a weight average molecular weight of ~~about~~ 10,000 to ~~about~~ 50,000 g/mol.

6. The method of claim 5, wherein the poly(meth)acrylate copolymer has ~~about~~ 5 to ~~about~~ 50 mol percent monomer units derived from the C1 to C4 linear or branched alkyl (meth)acrylates and ~~about~~ 50 to ~~about~~ 95 mol percent monomer units derived from the C12 to C20 linear or branched alkyl (meth)acrylates.

7. A transmission and lubricant for an electric or a hybrid-electric vehicle, the transmission and lubricant comprising:

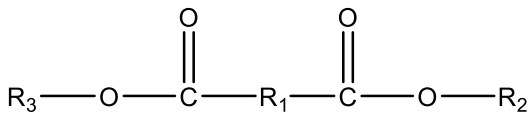
a transmission having an electric or a hybrid-electric motor thereof;

a lubricating composition of the transmission in contact with at least portions of the electric or the hybrid-electric motor; and

the lubricating composition including (i) an solvent system having a blend of one or more base oils selected from Group I to Group V oils and a branched diester, the solvent system having ~~about~~ 10 to ~~about~~ 50 weight percent of the branched diester and (ii) a copolymer viscosity index improver having a weight average molecular weight of ~~about~~ 50,000 g/mol or less; and

wherein the lubricating composition includes amounts of the branched diester and amounts of the copolymer viscosity index improver effective to achieve an electrical conductivity measured per ASTM D2624-15 at 75ºC of ~~about~~ 80,000 pS/m or less and a thermal conductivity measured per ASTM D7896-14 at 80ºC of ~~about~~ 134 mW/m*K or more.

8. The transmission and lubricant of claim 7, wherein the branched diester has the structure of Formula I:



(Formula I)

wherein

R_1 is a carbon chain having n-2 carbons with n being an integer from 6 to 10; and

R_2 and R_3 are the same or different and include C8 to C10 branched alkyl chains.

9. The transmission and lubricant of claim 7, wherein branched diester has C6 to C12 branched alkyl groups in alcohol moieties thereof and 6 to 10 carbons in acid moieties thereof.

10. The transmission and lubricant of claim 7, wherein the branched diester is selected from the group consisting of bis(6-methylheptyl) hexanedioate; bis(8-methylnonyl) hexanedioate; bis(2-ethylhexyl) decanedioate; bis(2-ethylhexyl) hexanedioate; and combinations thereof.

11. The transmission and lubricant of claim 7, wherein the copolymer viscosity index improver includes monomer units derived from C1 to C4 linear or branched short chain alkyl (meth)acrylates and C12 to C20 linear or branched long chain alkyl (meth)acrylates and has a weight average molecular weight of ~~about~~ 10,000 to ~~about~~ 50,000 g/mol.

12. The transmission and lubricant of claim 11, wherein the copolymer viscosity index improver has ~~about~~ 5 to ~~about~~ 50 mol percent monomer units derived from the short chain (meth)acrylates and ~~about~~ 50 to ~~about~~ 95 mol percent monomer units derived from the long chain (meth)acrylates.

13. A lubricating composition for electric or hybrid-electric motors, the lubricating composition comprising:

a solvent system including one or more Group I to Group V base oils blended with a branched diester, wherein the solvent system has ~~about~~ 10 to ~~about~~ 50 weight percent of the branched diester;

a copolymer viscosity index improver having a weight average molecular weight of ~~about~~ 50,000 g/mol or less and a polydispersity index of ~~about~~ 1 to ~~about~~ 2; and

wherein the lubricating composition includes amounts of the branched diester in the solvent system and amounts of the copolymer viscosity index improver effective to achieve an electrical conductivity measured per ASTM D2624-15 at 75ºC of ~~about~~ 80,000 pS/m or less and a thermal conductivity measured per ASTM D7896-14 at 80ºC of ~~about~~ 134 mW/m*K or more at the same time.

14. The lubricating composition of claim 13, wherein the branched diester is the reaction product of one or more dicarboxylic acids having an internal carbon chain length of 6 to 10 carbons and one or more alcohols having a branched carbon chain length of 6 to 12 carbons.

15. The lubricating composition of claim 13, wherein the lubricating composition includes ~~about~~ 5 to ~~about~~ 40 weight percent of the branched diester and ~~about~~ 8 to ~~about~~ 15 weight percent of the copolymer viscosity index improver on an oil-free basis.

16. The lubricating composition of claim 13, wherein an ester-to-copolymer weight ratio in the lubricating composition of ~~about~~ 1.4 to ~~about~~ 5.0, wherein the copolymer is measured on an oil-free basis.

17. The lubricating composition of claim 13, wherein the copolymer viscosity index improver derived from C1 to C4 short chain linear or branched alkyl (meth)acrylates and C12 to C20 long chain linear or branched alkyl (meth)acrylates.