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

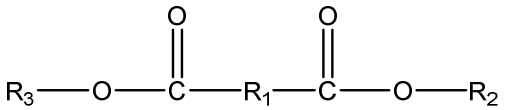
[0006] FIG. 1 is a graph of lubricant electrical conductivity per ASTM D2624-15 at 75ºC; and

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

SUMMARY

[0008] This present disclosure relates to a method for lubricating a transmission having an electric or a hybrid-electric motor. In one 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 example, one or more oils selected from Group I to Group V base oils, in another example, one or more oils selected from Group I to Group 1V base oils, and, in yet another 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 examples, the poly(meth)acrylate copolymer has a weight average molecular weight of about 50,000 g/mol.

[0009] In other 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 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 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 example herein to achieve a lubricating composition having the electrical conductivity and thermal conductive as discussed in any example herein.

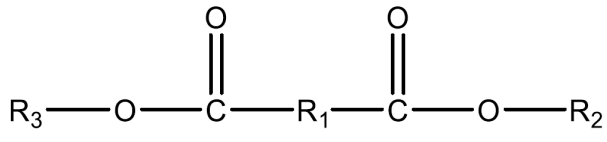
[0011] In other examples, the poly(meth)acrylate copolymer may be derived from at least C1 to C4 linear or branched alkyl (meth)acrylates monomer units and C12 to C20 linear or branched alkyl (meth)acrylate monomer units and has a weight average molecular weight of about 10,000 to about 50,000 g/mol.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

[0011a] In one aspect, the present disclosure refers to a method for lubricating a transmission having an electric or a hybrid-electric motor, the method comprising:

lubricating a transmission combined with 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 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 each includes a C8 to C10 branched alkyl chain;

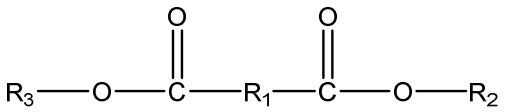
the base oil component including one or more oils selected from API Group I to Group V base oils;

the poly(meth)acrylate copolymer has a weight average molecular weight of 10,000 to 50,000 g/mol, wherein the poly(meth)acrylate copolymer has 5 to 40 mol percent monomer units derived from the C1 to C4 linear or branched alkyl (meth)acrylates, 50 to 90 mol percent monomer units derived from the C12 to C20 linear or branched alkyl (meth)acrylates, and more than 0 and up to 10 mol percent of the nitrogen-containing dispersant monomer units; and

wherein 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.

[0012] The present disclosure also relates to a transmission and lubricant for an electric or a hybrid-electric vehicle. In some 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 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 examples, one or more oils selected from Group I to Group 1V base oils, and, in yet another 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 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 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 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.

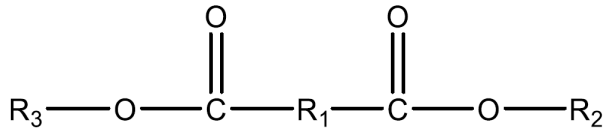
[0015a] In one aspect, the present disclosure refers to a transmission and lubricant for an electric or a hybrid-electric vehicle, the transmission and lubricant comprising:

a transmission coupled to an electric or a hybrid-electric motor;

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 API Group I to Group V oils and a branched diester, and (ii) a copolymer viscosity index improver having a weight average molecular weight of 10,000 to 50,000 g/mol, wherein the copolymer viscosity index improver has 5 to 40 mol percent monomer units derived from the C1 to C4 linear or branched alkyl (meth)acrylates, 50 to 90 mol percent monomer units derived from the C12 to C20 linear or branched alkyl (meth)acrylates, and more than 0 and up to 10 mol percent of the nitrogen-containing dispersant monomer units;

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;

R_2 and R_3 are the same or different and each includes a C8 to C10 branched alkyl chain; and

wherein the lubricating composition achieves 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.

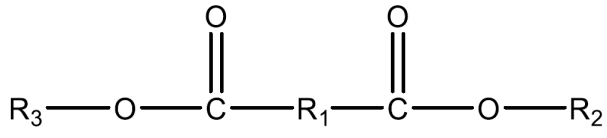
[0016] The present disclosure also relates to a lubricating composition for electric or hybrid-electric motors. In some examples, the lubricating composition comprises a solvent system including one or more Group I to Group V base oils blended with a branched diester; a copolymer viscosity index improver having a weight average molecular weight of about 50,000 g/mol or less and, in some examples, also having a polydispersity index of about 1 to about 2. The base oils may also include, in other examples, one or more oils selected from Group I to Group 1V base oils, and, in yet another 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 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 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 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 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.

[0018a] In one aspect, the present disclosure refers to a lubricating composition for electric or hybrid-electric motors, the lubricating composition comprising:

a solvent system including one or more API Group I to Group V base oils blended with a 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;

R_2 and R_3 are the same or different and each includes a C8 to C10 branched alkyl chain;

a copolymer viscosity index improver having a weight average molecular weight of 10,000 to 50,000 g/mol, wherein the copolymer viscosity index improver has 5 to 40 mol percent monomer units derived from the C1 to C4 linear or branched alkyl (meth)acrylates, 50 to 90 mol percent monomer units derived from the C12 to C20 linear or branched alkyl (meth)acrylates, and more than 0 and up to 10 mol percent of the nitrogen-containing dispersant monomer units; and

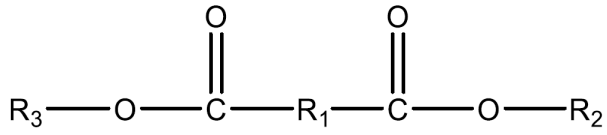
wherein the lubricating composition achieves an electrical conductivity measured per ASTM D2624-15 at 75ºC of 80,000 pS/m or less and a thermal conductivity measured per ASTM D7896-14 at 80ºC of 134 mW/m*K or more at the same time.

[0018b] In one aspect, the present disclosure refers to a method of blending a lubricant for a driveline, the method comprising:

blending amounts of a poly(meth)acrylate copolymer and amounts of a solvent system to form a lubricant;

the solvent system including a base oil component and a branched diester component;

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 each includes a C8 to C10 branched alkyl chain;

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

the poly(meth)acrylate copolymer has a weight average molecular weight of 10,000 to 50,000 g/mol, wherein the poly(meth)acrylate copolymer has 5 to 40 mol percent monomer units derived from the C1 to C4 linear or branched alkyl (meth)acrylates, 50 to 90 mol percent monomer units derived from the C12 to C20 linear or branched alkyl (meth)acrylates, and more than 0 and up to 10 mol percent of the nitrogen-containing dispersant monomer units; and

wherein the blended 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.

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

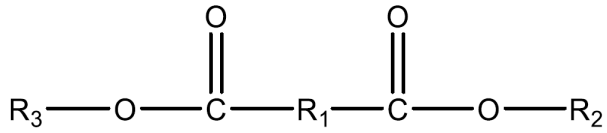
WHAT IS CLAIMED IS:

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

lubricating a transmission combined with 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 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 each includes a C8 to C10 branched alkyl chain;

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

the poly(meth)acrylate copolymer has a weight average molecular weight of 10,000 to 50,000 g/mol, wherein the poly(meth)acrylate copolymer has 5 to 40 mol percent monomer units derived from the C1 to C4 linear or branched alkyl (meth)acrylates, 50 to 90 mol percent monomer units derived from the C12 to C20 linear or branched alkyl (meth)acrylates, and more than 0 and up to 10 mol percent of the nitrogen-containing dispersant monomer units; and

wherein 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.

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 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.

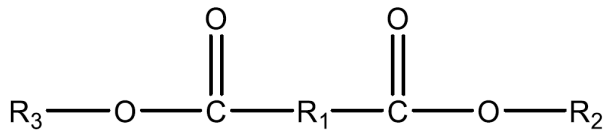
4. A transmission and lubricant for an electric or a hybrid-electric vehicle, the transmission and lubricant comprising:

a transmission coupled to an electric or a hybrid-electric motor;

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 API Group I to Group V oils and a branched diester, and (ii) a copolymer viscosity index improver having a weight average molecular weight of 10,000 to 50,000 g/mol, wherein the copolymer viscosity index improver has 5 to 40 mol percent monomer units derived from the C1 to C4 linear or branched alkyl (meth)acrylates, 50 to 90 mol percent monomer units derived from the C12 to C20 linear or branched alkyl (meth)acrylates, and more than 0 and up to 10 mol percent of the nitrogen-containing dispersant monomer units;

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;

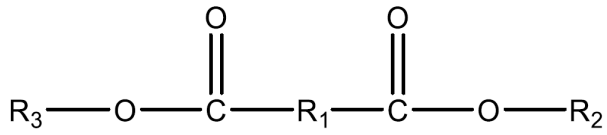
R_2 and R_3 are the same or different and each includes a C8 to C10 branched alkyl chain; and

wherein the lubricating composition achieves 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.

5. The transmission and lubricant of claim 4, 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.

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

a solvent system including one or more API Group I to Group V base oils blended with a 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;

R_2 and R_3 are the same or different and each includes a C8 to C10 branched alkyl chain;

a copolymer viscosity index improver having a weight average molecular weight of 10,000 to 50,000 g/mol, wherein the copolymer viscosity index improver has 5 to 40 mol percent monomer units derived from the C1 to C4 linear or branched alkyl (meth)acrylates, 50 to 90 mol percent monomer units derived from the C12 to C20 linear or branched alkyl (meth)acrylates, and more than 0 and up to 10 mol percent of the nitrogen-containing dispersant monomer units; and

wherein the lubricating composition achieves 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.

7. The lubricating composition of claim 6, wherein the lubricating composition includes 5 to 40 weight percent of the branched diester and 8 to 15 weight percent of the copolymer viscosity index improver on an oil-free basis.

8. The lubricating composition of claim 6, wherein an ester-to-copolymer weight ratio in the lubricating composition is 1.4 to 5.0, wherein the copolymer is measured on an oil-free basis.

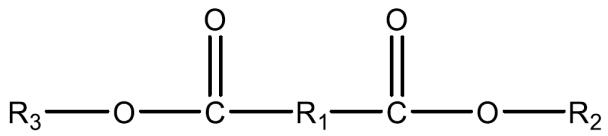
9. The lubricating composition of claim 6, wherein the copolymer viscosity index improver has a polydispersity index of 1 to 3.

10. A method of blending a lubricant for a driveline, the method comprising:

blending amounts of a poly(meth)acrylate copolymer and amounts of a solvent system to form a lubricant;

the solvent system including a base oil component and a branched diester component;

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 each includes a C8 to C10 branched alkyl chain;

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

the poly(meth)acrylate copolymer has a weight average molecular weight of 10,000 to 50,000 g/mol, wherein the poly(meth)acrylate copolymer has 5 to 40 mol percent monomer units derived from the C1 to C4 linear or branched alkyl (meth)acrylates, 50 to 90 mol percent monomer units derived from the C12 to C20 linear or branched alkyl (meth)acrylates, and more than 0 and up to 10 mol percent of the nitrogen-containing dispersant monomer units; and

wherein the blended 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.

11. The method of blending a lubricant of claim 10, 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.

12. The method of blending a lubricant of claim 10, 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.

13. The method of blending a lubricant of claim 10, wherein an ester-to-copolymer weight ratio in the lubricating composition is 1.4 to 5.0, wherein the copolymer is measured on an oil-free basis.

14. The method of blending a lubricant of claim 10, wherein an ester-to-copolymer weight ratio in the lubricating composition is 2.5 to 5.0, wherein the copolymer is measured on an oil-free basis.