fluoropolyether oils generally suffer from low thermal-oxidative stability in the presence of metals to be advantageously used as lubricants in high vacuum and ultra-high vacuum pumps.

[0008] EP 1454938 B (SOLVAY SOLEXIS S.P.A.) 05.10.2005 discloses linear perfluoropolyether oils comprising $-CF_2CF_2O-$ and $-CF_2O-$ recurring units, statistically distributed along the perfluoropolyoxyalkylene chain, in a $-CF_2CF_2O-/-CF_2O-$ ratio comprised between 2 and 20, which exhibit improved thermal-oxidative stability in the presence of metals with respect to known linear perfluoropolyether oils having a lower $-CF_2CF_2O-/-CF_2O-$ ratio, typically comprised between 0.1 and 10, while maintaining a high viscosity index and a low pour point value as compared with known linear perfluoropolyether oils. The stability of the novel linear perfluoropolyether oils when used as lubricants may be further increased by the addition of perfluoropolyether-based thermal stabilizers comprising functional groups like, e.g., phosphines, phosphates, phosphazenes, benzothiazoles, triazines, amines, substituted amines, nitroderivative compounds.

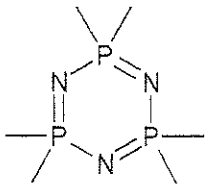
[0009] The need was thus felt to provide for (per)fluoropolyether lubricants having improved thermal-oxidative stability in the presence of metals while maintaining low evaporation weight loss and high lubrication performances in terms of suitable kinematic viscosity and anti-wear and anti-rust properties, so as to be successfully used in high vacuum and ultra-high vacuum pumps by ensuring lower maintenance costs of the pumps due to a longer life-time of the lubricants and lower consumptions due to their high lubrication performances.

Disclosure of Invention

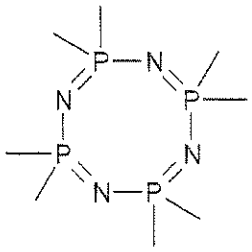
[0010] It is thus an object of the disclosure~~invention~~ a lubricant composition comprising:

(A) at least one non-functional (per)fluoropolyether oil (non-functional PFPE oil) comprising at least one (per)fluoropolyoxyalkylene chain (chain R_F);

(B) at least one cyclic phosphazene compound [compound (P)] comprising one or more cyclic moieties having formula (I) or (II) here below:



(I)



(II)

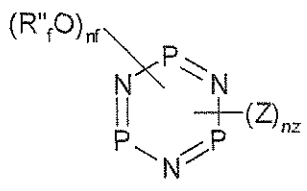
said cyclic moieties comprising, bound to one or more phosphorus atoms, at least one substituent comprising at least one (per)fluoropolyoxyalkylene chain (chain R'$_F$);

(C) *at least one functional (per)fluoropolyether derivative (functional* PFPE derivative) different from compound (P) comprising at least one (per)fluoropolyoxyalkylene chain (chain R'$_F$) *and at least one functional* group comprising at least one monocyclic or polycyclic aromatic ring, said aromatic ring optionally containing one or more heteroatoms selected from N, O *and S and one or more substituents different from hydrogen atoms.*

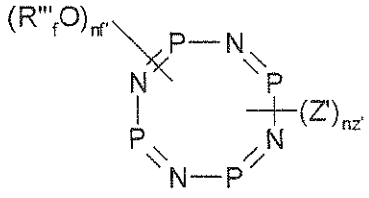
[0010a] In one aspect, there is provided a lubricant composition comprising:

(A) at least one non-functional (per)fluoropolyether oil (non-functional PFPE oil) comprising at least one (per)fluoropolyoxyalkylene chain (chain R_F);

(B) at least one cyclic phosphazene compound [compound (P)] comprising one or more cyclic moieties having formula (I-B) or (II-B) here below:



(I-B)



(II-B)

wherein:

- R"$_f$ and R"'$_f$, equal to or different from each other, independently represent a (per)fluoropolyoxyalkylene chain comprising one or more recurring units

selected from:

(i) -CFYO-, wherein Y is a fluorine atom or a $-CF_3$ group,

(ii) $-CF_2CFYO-$, wherein Y has the same meaning as defined above,

(iii) $-CF_2CF_2CF_2O-$,

(iv) $-CF_2CF_2CF_2CF_2O-$,

said recurring units being generally statistically distributed along the (per)fluoropolyoxyalkylene chain;

- Z and Z', equal to or different from each other, independently represent a polar group of formula $-O^-M^+$, wherein M is selected from hydrogen, a monovalent metal, preferably an alkaline metal, and an ammonium radical having formula $NR_1R_2R_3R_4^+$, wherein each of R_1, R_2, R_3, R_4 is, independently, a hydrogen atom or a C_1-C_{12} hydrocarbon group, optionally fluorinated, or a polar group of formula $-O^-)_2M'^{2+}$, wherein M' is a divalent metal, preferably an alkaline earth metal;

- n_Z is an integer comprised between 1 and 3, preferably equal to 1;

- $n_{Z'}$ is an integer comprised between 1 and 4, preferably equal to 1;

- n_f is an integer such that $n_Z + n_f$ is equal to 6;

- n_F is an integer such that $n_{Z'} + n_F$ is equal to 8

(C) at least one functional (per)fluoropolyether derivative (functional PFPE derivative) different from compound (P) comprising at least one (per)fluoropolyoxyalkylene chain (chain R'_F) and at least one functional group comprising at least one monocyclic or polycyclic aromatic ring, said aromatic ring optionally containing one or more heteroatoms selected from N, O and S and one or more substituents different from hydrogen atom.

[0010b] In another aspect, there is provided the use of the lubricant composition as defined above for lubricating vacuum pumps.

[0011] The Applicant has surprisingly found that the lubricant composition disclosed herein~~of the invention~~ advantageously exhibits improved thermal-oxidative stability in the presence of metals while maintaining low evaporation weight loss and high lubrication performances to be successfully used for high vacuum and ultra-high vacuum applications.

[0012] To the purpose of the present invention, "(per)fluoropolyether" is intended to denote either a fully fluorinated perfluoropolyether or a partially fluorinated fluoropolyether.

[0013] To the purpose of the present invention, "(per)fluoropolyoxyalkylene chain" is intended to denote either a fully fluorinated perfluoropolyoxyalkylene chain or a partially fluorinated fluoropolyoxyalkylene chain.

[0014] The (per)fluoropolyoxyalkylene chain (chain R_F) of the non-functional (per)fluoropolyether oil (non-functional PFPE oil) of the invention typically comprises one or more recurring units R° having general formula $-(CJJ')_j-CKK'-O-$, wherein J and J', equal to or different from each other, independently represent a fluorine atom or a C_1-C_6 (per)fluoro(oxy)alkyl group, K and K', equal to or different from each other, independently

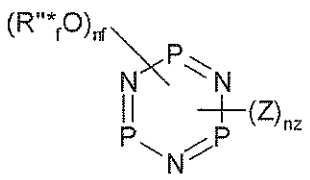
and a C_1-C_6 perfluoroalkyl group;

- j1' is equal to 1 or 2;

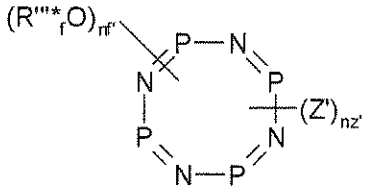
- j2' is an integer comprised between 5 and 250.

3. The lubricant composition according to claim 1 or 2, wherein a mixture of more than one non-functional PFPE oil is used in the composition.

4. The lubricant composition of any one of claims 1 to 3, wherein the cyclic phosphazene compound [compound (P)] complies with formula (I-B*) or (II-B*) here below:



(I-B*)



(II-B*)

wherein:

- Z, Z', n_z, $n_{z'}$, n_f and $n_{f'}$ have the same meaning as defined in claim 4;

- R'''$_f$O- and R''''$_f$O-, equal to or different from each other, represent a (per)fluoropolyoxyalkylene chain having formula:

T^*-O-$(CF_2CF_2O)_{p^*}(CF_2O)_{q^*}$-$CF_2$-$CH_2O(CH_2CH_2O)_{s^*}$-

wherein:

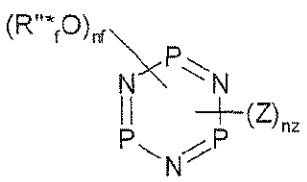
- T* is selected from $-CF_3$, $-CF_2CF_3$ and $-CF_2CF_2CF_3$ groups;

- p* and q* are numbers such that the (p*+q*) sum is comprised between 1 and 50 and the q*/p* ratio is comprised between 0.1 and 10;

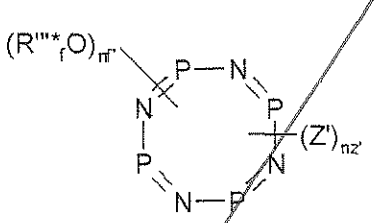
- s* is a number comprised between 0 and 5.

5. The lubricant composition of claims 3 and 4, wherein the cyclic phosphazene compound [compound (P)] complies with formula (III-B) or (III-B bis) here below:

4. The lubricant composition of any one of claims 1 to 3, wherein the cyclic phosphazene compound [compound (P)] complies with formula (I-B*) or (II-B*) here below:



(I-B*)



(II-B*)

wherein:

- Z, Z', n_z, $n_{z'}$, n_f and $n_{f'}$ have the same meaning as defined in claim 4;
- R'''*$_f$ O- and R''''*$_f$ O-, equal to or different from each other, represent a (per)fluoropolyoxyalkylene chain having formula:

$T^*\text{-}O\text{-}(CF_2CF_2O)_{p^*}(CF_2O)_{q^*}\text{-}CF_2\text{-}CH_2O(CH_2CH_2O)_{s^*}$-

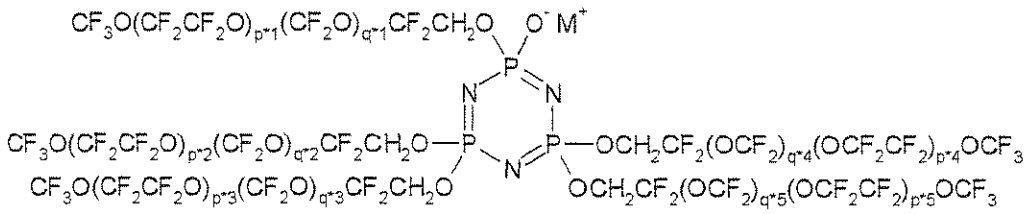
wherein:

- T* is selected from $-CF_3$, $-CF_2CF_3$ and $-CF_2CF_2CF_3$ groups;

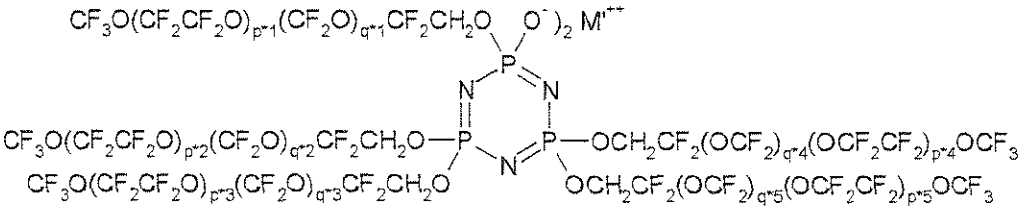
- p* and q* are numbers such that the (p*+q*) sum is comprised between 1 and 50 and the q*/p* ratio is comprised between 0.1 and 10;

- s* is a number comprised between 0 and 5.

5. The lubricant composition of claims 3 and 4, wherein the cyclic phosphazene compound [compound (P)] complies with formula (III-B) or (III-B bis) here below:



(III-B)



(III-B bis)

wherein:

- M and M' have the same meaning as defined in claim 1, M being preferably an alkaline metal selected from Li, Na and K or an ammonium radical having formula $NR_1R_2R_3R_4^+$, wherein each of R_1, R_2, R_3, R_4 is, independently, a hydrogen atom or a C_1-C_{12} hydrocarbon group, preferably $R_1 = R_2 = R_3 = R_4$ = n-butyl, and M' being preferably an alkaline earth metal selected from Ca and Mg, more preferably M' being Ca;
- each of p*i (i = 1 to 5) and q*i (i = 1 to 5) is independently an integer ≥ 0 such that the (p*i+q*i) sum is comprised between 2 and 25 and the q*i/p*i ratio is comprised between 0.1 and 10.

6. The lubricant composition of anyone of claims 1 to 5, wherein the functional PFPE derivative complies with formula (V) here below:

$T\text{-}(CFW_1)_{p1}\text{-}O\text{-}R_F\text{-}(CFW_2)_{p1'}\text{-}T'$ (V)

wherein:

- R_F is a (per)fluoropolyoxyalkylene chain (chain R'_F);
- T and T', equal to or different from each other, are selected from:

i) functional end-groups comprising at least one ether, thioether, ester or amine group comprising at least one monocyclic or polycyclic aromatic ring, said

aromatic ring optionally containing one or more heteroatoms selected from N, O and S and one or more substituents different from hydrogen atoms,

ii) non-functional end-groups selected from a fluorine atom, a chlorine atom and a C_1-C_3 (per)fluoroalkyl group optionally containing one or more chlorine atoms,

with the proviso that at least one of T and T' is a functional end-group as defined hereinabove;

- W_1 and W_2, equal to or different from each other, independently represent a fluorine atom or a $-CF_3$ group;

- p1 and p1', equal to or different from each other, are independently integers comprised between 1 and 3, preferably being equal to 1 when W_1 and/or W_2 are $-CF_3$ groups.

7. The lubricant composition of claim 6, wherein the functional PFPE derivative complies with formula (VI) here below:

$T''-CF_2O(CF_2CF_2O)_{m^*}(CF_2O)_{n^*}CF_2-T'''$ (VI)

wherein:

- T'' and T''', equal to or different from each other, are selected from:

i) functional end-groups selected from those having formulae $-CH_2$-A-Y, $-CH(CF_3)$-A-Y, $-CHW'$-B-$(CH_2CH_2O)_{m'}$-Y and -COOY, wherein:

(a') A is selected from oxygen and sulphur atoms,

(b') B is selected from an oxygen atom, a sulphur atom and a -NH group,

(c') W' is selected from a hydrogen atom and a $-CF_3$ group,

(d') m' is an integer comprised between 0 and 6,

(e') Y is selected from phenyl, pyridine, triazine, benzoxazole, benzothiazole and benzopyrazine groups optionally substituted with one or more substituents different from hydrogen atoms,

ii) non-functional end-groups selected from a fluorine atom, a chlorine atom, a $-CF_3$ group, a $-C_2F_5$ group and a $-(CF_2)_nCl$ group, wherein n is an integer comprised between 1 and 3,

with the proviso that at least one of T'' and T''' is a functional end-group as defined hereinabove;

- m* and n* are integers such that the number average molecular weight of the functional PFPE derivative is comprised between 400 and 10000, the m*/n*

ratio being comprised between 0.1 and 10.

8. The lubricant composition of anyone of claims 1 to 7, wherein at least one cyclic phosphazene compound [compound (P)] is comprised in an amount ranging from 0.3% to 5% by weight with respect to the weight of the non-functional PFPE oil and at least one functional PFPE derivative different from compound (P) is comprised in an amount ranging from 2% to 6% by weight with respect to the weight of the non-functional PFPE oil.

9. Use of the lubricant composition of any one of claims 1 to 8 for lubricating vacuum pumps.