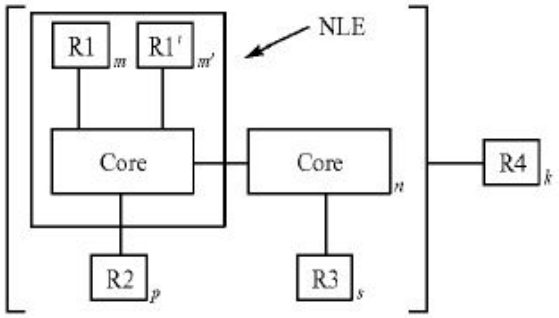


(I)

Where Corel is an aromatic polycyclic conjugated molecule having two-dimensional flat form and self-assembling by pi-pi stacking in a column-like supramolecule, Rl is a dopant group connected to the aromatic polycyclic conjugated molecule (Corel), m is the number of dopant groups Rl which is equal to 1, 2, 3 or 4, R2 is a substituent comprising one or more ionic groups from a class of ionic compounds that are used in ionic liquids connected to the aromatic polycyclic conjugated molecule (Corel) directly or via a connecting group, p is number of ionic groups R2 which is equal to 0, 1, 2, 3 or 4. The fragment marked NLE containing the aromatic polycyclic conjugated molecule with at least one dopant of group has nonlinear effect of polarization. The Core2 is an electro-conductive oligomer self-assembling by pi-pi stacking in a column-like supramolecule, n is number of the electro-conductive oligomers which is equal to 0, 2, or 4, R3 is a substituent comprising one or more ionic groups from a class of ionic compounds that are used in ionic liquids connected to the electro-conductive oligomer (Core2) directly or via a connecting group, s is number of the ionic groups R3 which is equal to 0, 1, 2, 3 or 4. The R4 is a resistive substituent providing solubility of the organic compound in a solvent and electrically insulating the column-like supramolecules from each other, k is the number of R4 substituents, on said electro-polarizable compound, which is equal to 0, 1, 2, 3, 4, 5, 6, 7 or 8.

In one aspect, the present disclosure refers to an electro-polarizable compound having the following general formula (I):



where Corel is an aromatic polycyclic conjugated molecule having two-dimensional flat form and self-assembling by pi-pi stacking in a column-like supramolecule comprising one or more rylene fragments, Rl are electron donor groups connected to the aromatic poly-cyclic conjugated molecule (Core1) and Rl' are electron acceptor groups connected to the aromatic polycyclic conjugated molecule (Corel), m is number of acceptor groups R1, m' is

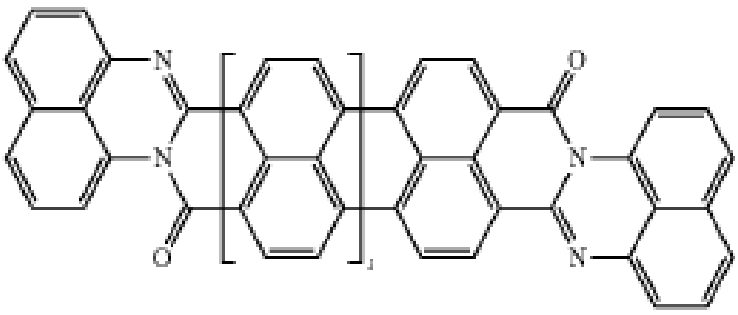
a number of donor groups R', m and m' are equal to 0, 1, 2, 3, 4, 5 or 6, wherein m and m' are not both equal to 0, R2 is a substituent comprising one or more ionic groups from a class of ionic compounds that form ionic liquids connected to the aromatic polycyclic conjugated molecule (Corel) directly or via a connecting group, p is a number of ionic groups R2 which is equal to 0, 1, 2, 3 or 4;

wherein the fragment marked NLE containing the Corel with at least one group R1 and/or R1' has a nonlinear effect of polarization,

wherein Core2 is an electro-conductive oligomer, n is a number of the electro-conductive oligomers which is equal to 0, 2, or 4, R3 is a substituent comprising one or more ionic groups from a class of ionic compounds that form ionic liquids connected to the electro-conductive oligomer (Core2) directly or via a connecting group, s is a number of the ionic groups R3 which is equal to 0, 1, 2, 3 or 4;

wherein R4 is a non-conjugate cyclic or polycyclic resistive substituent providing solubility of the organic compound in a solvent and electrically insulating the column-like supramolecules from each other and connected to the aromatic polycyclic conjugated molecule (Corel) and/or to the electro-conductive oligomer (Core2) directly or via a connecting group, k is a number of substituents R4 which is equal to 1, 2, 3, 4, 5, 6, 7 or 8;

wherein Corel has the structural formula:



where t is a repetition parameter that varies from 1 to 5.

In one example, the present disclosure provides a solution comprising an organic solvent and at least one disclosed electro-polarizable compound.

In another aspect, the present disclosure refers to a solution comprising an organic solvent and at least one type of electro-polarizable compound as disclosed herein.

In another example, the present disclosure provides a crystal metadielectric layer comprising a mixture of the electro-polarizable compounds as disclosed above. The nonlinearly polarizable fragments comprising an aromatic polycyclic conjugated molecule

with at least one dopant group, optionally the electro-conductive oligomers, and the ionic groups which have electronic and/or ionic type of polarizability are placed into the resistive dielectric envelope formed by resistive substituents providing solubility of the organic compound in a solvent and electrically insulating the column-like supramolecules from each other.

In another aspect, the present disclosure refers to a metadielectric layer comprising a mixture of the electro-polarizable compounds as disclosed herein, wherein the nonlinearly polarizable fragments comprising an aromatic polycyclic conjugated molecule with one or more R1 groups, and wherein the one or more Rl and/or R1' groups form a resistive envelope and solubilize the organic compound in a solvent and electrically insulating the column-like supramolecules from each other.

In still another example, the present disclosure provides a meta-capacitor comprising two metal electrodes positioned parallel to each other and which can be rolled or flat and planar with said metadielectric layer between said electrodes, wherein the dielectric layer comprises one or more types of the disclosed electro-polarizable compounds. The nonlinearly polarizable fragments may include an aromatic polycyclic conjugated molecule with at least one dopant group. Optionally the electro-conductive oligomers, and the ionic groups which have electronic and/or ionic type of polarizability are placed into the resistive dielectric envelope formed by resistive substituents providing solubility of the organic compound in a solvent and electrically insulating the column-like supramolecules from each other.

In another aspect, the present disclosure refers to a meta-capacitor comprising two metal electrodes positioned parallel to each other and which can be rolled or flat and planar with said metadielectric layer between said electrodes, wherein the metadielectric layer comprises one or more types of the electro-polarizable compounds as disclosed herein wherein the nonlinearly polarizable fragments comprising an aromatic polycyclic conjugated molecule with at least one group Rl or R1', the electro-conductive oligomers and the ionic groups which have electronic and/or ionic type of polarizability are placed into a resistive dielectric envelope formed by resistive substituents Rl and/or R1' providing solubility of the organic compound in a solvent and electrically insulating the column-like supramolecules from each other.

INCORPORATION BY REFERENCE

All publications, patents, and patent applications mentioned in this specification are herein incorporated by reference to the same extent as if each individual publication, patent, or patent application was specifically and individually indicated to be incorporated by reference.

BRIEF DESCRIPTION OF THE DRAWING

Figure 1 A schematically shows a capacitor with flat and planar electrodes in accordance with an aspect of the present disclosure.

Figure IB schematically shows a capacitor with rolled (circular) electrodes in accordance with another aspect of the present disclosure.

DETAILED DESCRIPTION

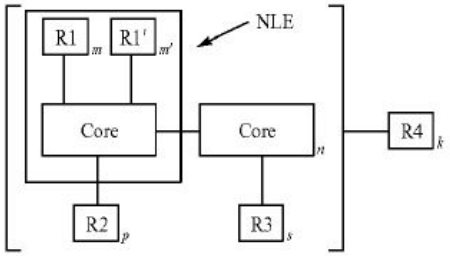
While various embodiments of the invention have been shown and described herein, it will be obvious to those skilled in the art that such embodiments are provided by way of example only. Numerous variations, changes, and substitutions may occur to those skilled in the art without departing from the invention. It should be understood that various alternatives to the embodiments of the invention described herein may be employed.

The present disclosure provides an electro-polarizable compound. Existence of the electrophilic groups (acceptors) and the nucleophilic groups (donors) in the aromatic polycyclic conjugated molecule (Corel) promotes increase of electronic polarizability of these molecules.

CLAIMS

What is claimed is:

1. An electro-polarizable compound having the following formula (I):



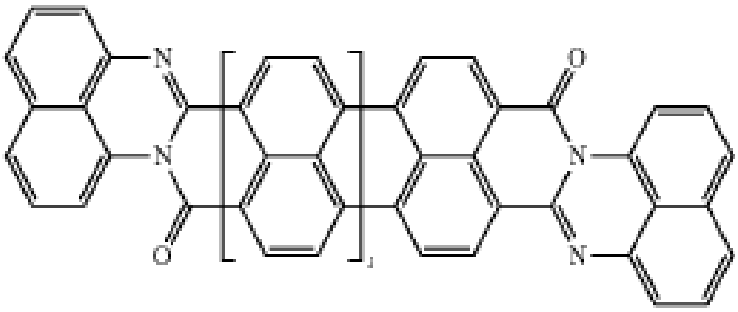
where Corel is an aromatic polycyclic conjugated molecule having two-dimensional flat form and self-assembling by pi-pi stacking in a column-like supramolecule comprising one or more rylene fragments, Rl are electron donor groups connected to the aromatic poly-cyclic conjugated molecule (Core1) and Rl' are electron acceptor groups connected to the aromatic polycyclic conjugated molecule (Corel), m is number of acceptor groups R1, m' is a number of donor groups R', m and m' are equal to 0, 1, 2, 3, 4, 5 or 6, wherein m and m' are not both equal to 0, R2 is a substituent comprising one or more ionic groups from a class of ionic compounds that form ionic liquids connected to the aromatic polycyclic conjugated molecule (Corel) directly or via a connecting group, p is a number of ionic groups R2 which is equal to 0, 1, 2, 3 or 4;

wherein the fragment marked NLE containing the Corel with at least one group R1 and/or R1' has a nonlinear effect of polarization,

wherein Core2 is an electro-conductive oligomer, n is a number of the electro-conductive oligomers which is equal to 0, 2, or 4, R3 is a substituent comprising one or more ionic groups from a class of ionic compounds that form ionic liquids connected to the electro-conductive oligomer (Core2) directly or via a connecting group, s is a number of the ionic groups R3 which is equal to 0, 1, 2, 3 or 4;

wherein R4 is a non-conjugate cyclic or polycyclic resistive substituent providing solubility of the organic compound in a solvent and electrically insulating the column-like supramolecules from each other and connected to the aromatic polycyclic conjugated molecule (Corel) and/or to the electro-conductive oligomer (Core2) directly or via a connecting group, k is a number of substituents R4 which is equal to 1, 2, 3, 4, 5, 6, 7 or 8;

wherein Corel has the structural formula:



where t is a repetition parameter that varies from 1 to 5.

2. The electro-polarizable compound according to claim **1**, wherein the acceptor groups (R1') are selected from -NO_2, -NH_3+and -NR_3+(quaternary nitrogen salts), counterion Cl- or Br-, -CHO (aldehyde), -CRO (keto group), -S03H (sulfonic acids), -SO_3R (sulfonates), -SO_2NH_2 (sulfonamides), -COOH (carboxylic acid), -COOR (esters,), -COCl (carboxylic acid chlorides), -$CONH_2$ (amides,), -CF_3, -$CC1_3$, -CN, -$C(CN)_2$ wherein R is radical selected from the list consisting of alkyl, allyl (-CH_2-CH=CH_2), benzyl (-$CH_2C_6H_5$,) groups, phenyl (+substituted phenyl) and other aryl (aromatic) groups.

3. The electro-polarizable compound according to claim **1**, wherein the donor groups (Rl) are selected from -0-(phenoxides,), -NH_2, -NHR, -NR_2, -OH, OR (ethers), -NHCOR (amides), -OCOR (esters), alkyls, -C_6H_5, vinyls, wherein R is radical selected from the list consisting of alkyl, allyl (-CH_2-CH=CH_2), benzyl (-$CH_2C_6H_5$) groups, phenyl (+substituted phenyl) and other aryl (aromatic) groups.

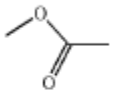
4. The electro-polarizable compound according to claim **1**, wherein the at least one connecting group is selected from the list comprising the following structures: 13-22, where X is hydrogen (H) or an alkyl group:



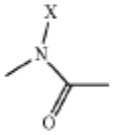
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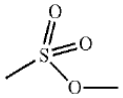


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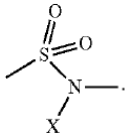
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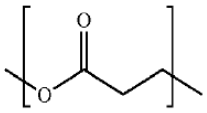
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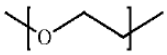
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5. The electro-polarizable compound according to claim **1,** wherein the at least one connecting group is selected from the group of CH_2, CF_2, SiR_2O, CH_2CH_2O, wherein R is selected from the list consisting of H, alky1 and fluorine.

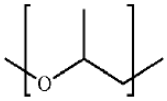
6. The electro-polarizable compound according to claim **1**, wherein the at least one connecting group is selected from structures 24 to 29:



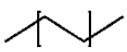
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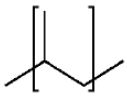
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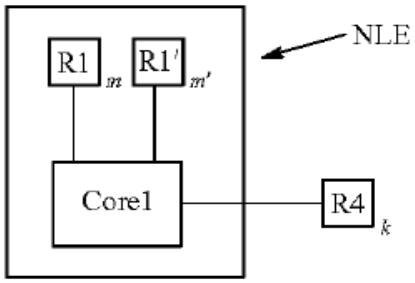
7. The electro-polarizable compound according to claim **1**, wherein the resistive substituent R4 is selected from the group of alkyl, aryl, substituted alkyl, substituted aryl, fluorinated alkyl, chlorinated alkyl, branched and complex alkyl, branched and complex fluorinated alkyl, branched and complex chlorinated alkyl groups, and any combination thereof.

8. The electro-polarizable compound of claim 1, wherein the aromatic polycyclic conjugated molecule (Corel) and the groups Rl and Rl' form a non-centrosymmetric molecular structure.

9. The electro-polarizable compound of claim **1**, wherein the aromatic polycyclic conjugated molecule (Corel), the groups Rl and Rl' and the resistive substituents (R4) form a non-centrosymmetric molecular structure.

10. The electro-polarizable compound of claim **1** having the following formula (II):

(II)



wherein the Corel is the aromatic polycyclic conjugated molecule, resistive substituents R4 are a non-conjugated part of compound II, and are either monocycles or fused polycycles, wherein the monocycles or polycycles are either saturated hydrocarbons or saturated halocarbons forming rigid spatial structures with dense packing of SP3 carbon saturated with H, F, Cl, and/or Br, and wherein k is a number of substituents R4 which is equal to 0, 1, 2, 3, 4, 5, 6, 7 or 8 and parameters n=p=s=0.

11. The electro-polarizable compound of claim **10**, wherein a length of the non-conjugated part of the electro-polarizable compound is selected such that the resistivity of the electro-polarizable compound is greater than 10^{18} ohm/cm.

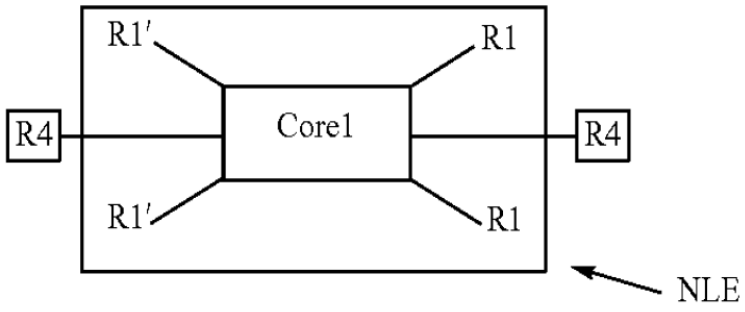
12. The electro-polarizable compound of claim **10**, wherein a length of the non-conjugated part of the electro-polarizable compound is selected such that the resistivity of the electro-polarizable compound is between 10^{18} ohm/cm and 10^{24} ohm/cm.

13. The electro-polarizable compound of claim **10,** wherein the resistive substituent R4 is a polycyclic alkyl group and a polycyclic halo-alkyl group, wherein in the polycyclic halo-alkyl group is connected to the apex of Corel on which the electrophilic group (acceptor) Rl is connected, or the apex of Corel on which the nucleophilic group (donor) Rl' is connected, but not both.

14. The electro-polarizable compound of claim **10,** wherein the resistive substituent R4 is a resistive polycyclic substituent selected from the list consisting of $C_{25}H_{34}$ and $C_{25}H_{35}$ or $C_{25}F_{34}$ and $C_{25}F_{35}$ and located on the apex phenyl, naphthyl, or anthryl rings of Corel.

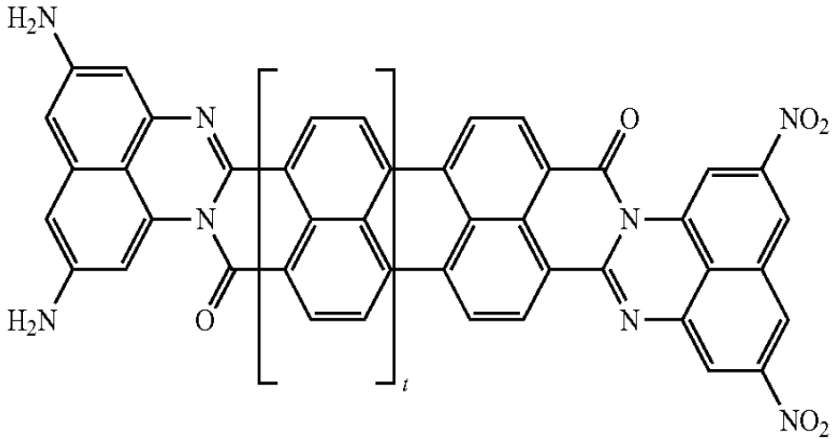
15. The electro-polarizable compound of claim **10** having the following formula (III):

(III)

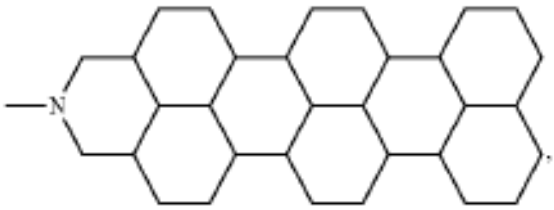


wherein Rl' is an acceptor group, and R1 is a donor group.

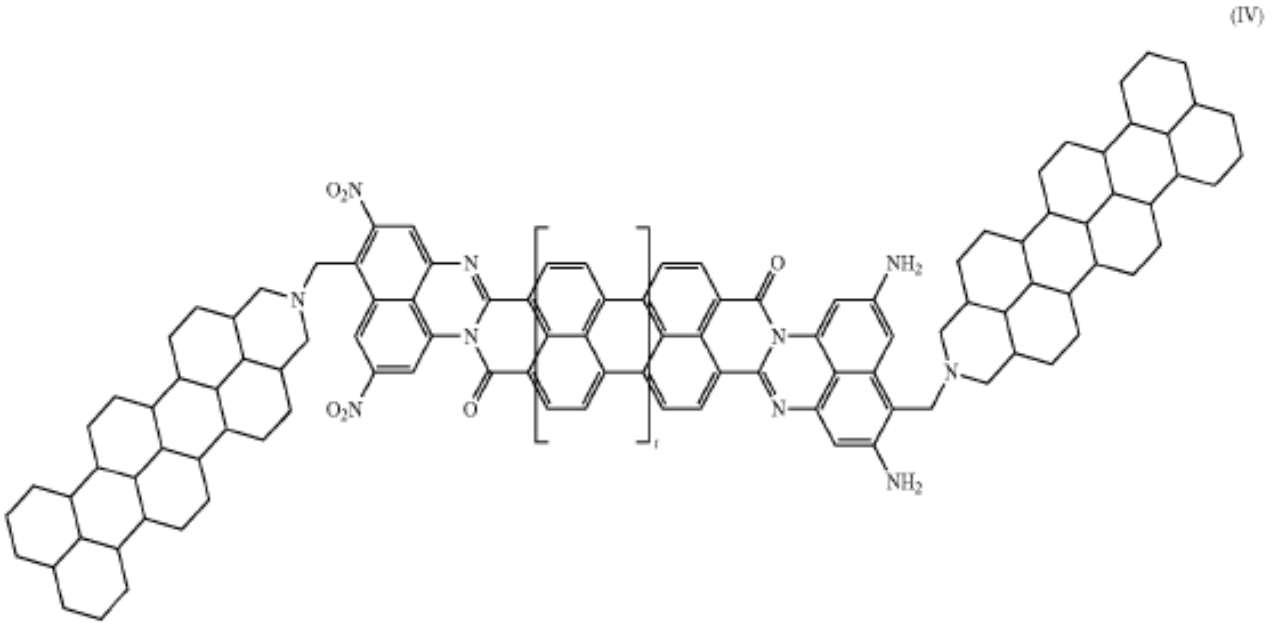
16. The electro-polarizable compound according to claim **15**, wherein the set of the electron donor and acceptor groups consists of two donor groups —NH_2 and two acceptor groups —NO_2 (m is equal to 4) located on rylene rings, or on apex phenyl, naphthyl, and/or anthryl ring positions of the Corel, or on both rylene rings positions and apex phenyl, naphthyl, and/or anthryl ring positions and the fragment having a nonlinear effect of polarization (NLE) is represented by following chemical structure:



wherein the resistive substituent (R4) is an amine structure having a formula of the type:



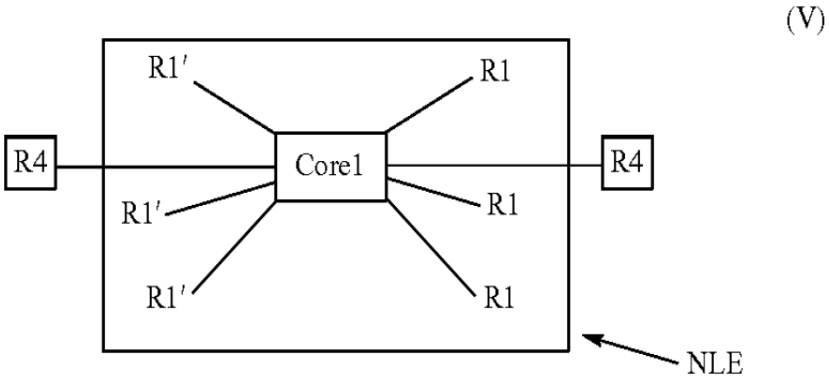
whereby the electro-polarizable compound has the following structural formula (IV)



(IV)

wherein the resistive substituents R4 are connected the Corel via a connecting group.

17. The electro-polarizable compound of claim **10** having a formula (V):



(V)

wherein the Corel is the aromatic polycyclic conjugated molecule, R1 is a donor group, and R1' is acceptor group.

18. A solution comprising an organic solvent and at least one type of electro-polarizable compound according to claim 1.

19. The solution according to claim **18**, comprising a mixture of different electro-polarizable compounds.

20. The solution according to claim **18**, wherein the mixture of the electro-polarizable compounds comprises rylene fragments of different length.

21. The solution according to claim **18**, wherein the organic solvent is selected from the list comprising ketones, carboxylic acids, hydrocarbons, cyclic hydrocarbons, chlorohydrocarbons, alcohols, ethers, esters, and any combination thereof.

22. The solution according to claim **18**, wherein the organic solvent is selected from the list comprising acetone, xylene, toluene, ethanol, methylcyclohexane, ethyl acetate, diethyl ether, octane, chloroform, methylene chloride, dichloroethane, trichloroethene, tetrachloroethene, carbon tetrachloride, 1,4-dioxane, tetrahydrofuran, pyridine, triethylamine, nitromethane, acetonitrile, dimethylformamide, dimethyl sulfoxide, and any combination thereof.

23. A solution according to claim **18**, wherein the solution is a lyotropic liquid crystal solution.

24. A metadielectric layer comprising a mixture of the electro-polarizable compounds according to claim **1**, wherein the nonlinearly polarizable fragments comprising an aromatic polycyclic conjugated molecule with one or more R1 groups, and wherein the one or more Rl and/or R1' groups form a resistive envelope and solubilize the organic compound in a solvent and electrically insulating the column-like supramolecules from each other.

25. The metadielectric layer according to claim **24**, wherein the column-like supramolecules are formed by the electro-polarizable compounds comprising rylene fragments of different length.

26. The metadielectric layer according to claim **24**, wherein the metadielectric layer's relative permittivity is greater than or equal to 1000.

27. The metadielectric layer according to claim **24**, wherein the layer's resistivity is greater than or equal to 10^{13} ohm/cm.

28. A meta-capacitor comprising two metal electrodes positioned parallel to each other and which can be rolled or flat and planar with said metadielectric layer between said electrodes, wherein the metadielectric layer comprises one or more types of the electro-polarizable compounds according to claim **1** wherein the nonlinearly polarizable fragments comprising an aromatic polycyclic conjugated molecule with at least one group Rl or R1', the electro-conductive oligomers and the ionic groups which have electronic and/or ionic type of polarizability are placed into a resistive dielectric envelope formed by resistive substituents Rl and/or R1' providing solubility of the organic compound in a solvent and electrically insulating the column-like supramolecules from each other.