and twisted coils, can be obtained by controlling the nucleation of the crystals and the non-covalent interactions between the doped oligomers. These nanoscale crystals exhibit enhanced conductivity compared to their bulk counterparts as well as interesting structure–property relationships such as shape-dependent crystallinity. Furthermore, the morphology and dimension of these structures can be largely rationalized and predicted by monitoring molecule–solvent interactions via absorption studies. Using doped tetra-aniline as a model system, the results and strategies presented in this article provide insight into the general scheme of shape and size control for organic materials.

Capacitors as energy storage device have well-known advantages versus electrochemical energy storage, e.g. a battery. Compared to batteries, capacitors are able to store energy with very high power density, i.e. charge/recharge rates, have long shelf life with little degradation, and can be charged and discharged (cycled) hundreds of thousands or millions of times.

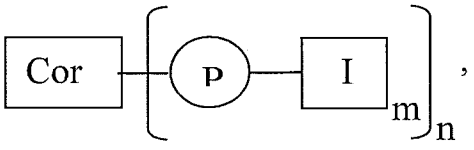
However, capacitors often do not store energy in such little volume or weight as in a battery, or at low cost per energy stored, making capacitors impractical for applications such as in electric vehicles. Accordingly, it would be an advance in energy storage technology to provide storing energy more densely per volume and/or mass.

Aspects of the present disclosure provide solutions to the problem of the further increase of volumetric and mass density of reserved energy of the energy storage device, and at the same time reduces cost of materials and manufacturing process.

SUMMARY

The present disclosure provides an energy storage molecular material, crystal dielectric layer and capacitor which may solve a problem of the further increase of volumetric and mass density of reserved energy associated with some energy storage devices, and at the same time reduce cost of materials. The energy storage molecular material is a relatively low molecular weight dielectric crystalline material having a molecular structure. Other dielectric materials, e.g. and polymers are also molecular but are characterized by a distribution of molecular weight.

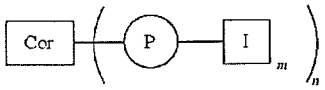
Disclosed is an energy storage molecular material having a general molecular structural formula:



,

where Cor is a predominantly planar polycyclic molecular system which forms column-like supramolecular stacks by means of π-π-interaction, P is a polarization unit providing polarization, I is a high-breakdown insulating substituent group, *n* is 1, 2, 3, 4, 5, 6, 7 or 8, m is 1, 2, 3, 4, 5, 6, 7 or 8.

In one aspect, there is provided an energy storage molecular material having a general molecular structural formula:



wherein Cor is a predominantly planar polycyclic molecular system which forms column-like supramolecular stacks by means of π-π-interaction, wherein the planar polycyclic molecular system comprises planar fused polycyclic hydrocarbons selected from the group of truxene, decacyclene, antanthrene, hexabenzotriphenylene, 1,2,3,4,5,6,7,8-tetra-(peri-naphthylene)-anthracene, dibenzoctacene, tetrabenzoheptacene, peropyrene, hexabenzocoronene and has a general structural formula from the group of structures 7-17:

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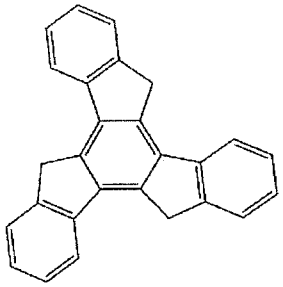

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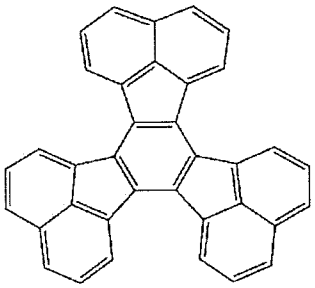

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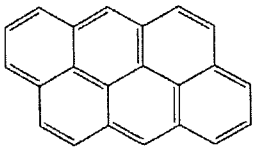

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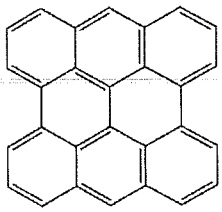

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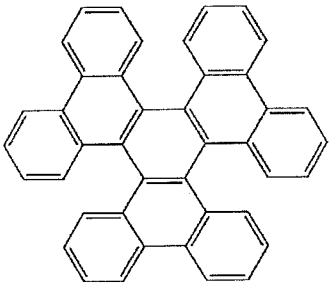

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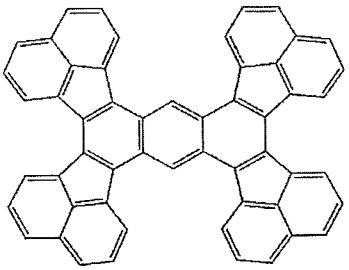

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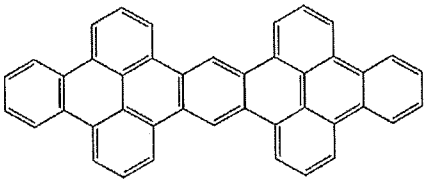

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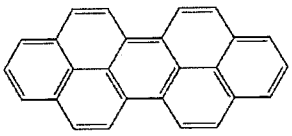

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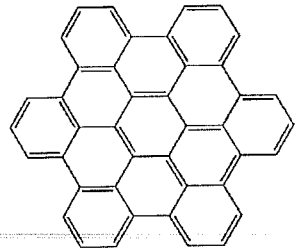

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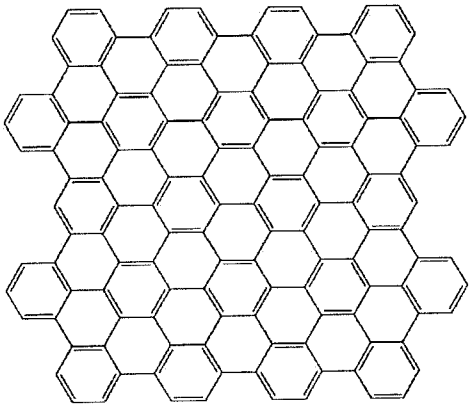

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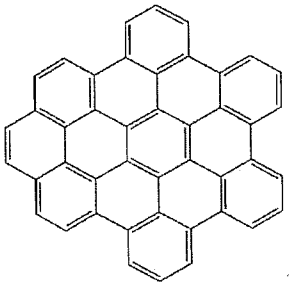

P is a polarization unit, wherein the polarization unit is selected from the group of doped oligoaniline and p-oligo-phenylene or comprises an electro-conductive oligomer having a general structural formula selected from the group of structures 26 to 32 wherein X=2, 3, 4, 5, 6, 7, 8, 9, 10, 11 or 12:

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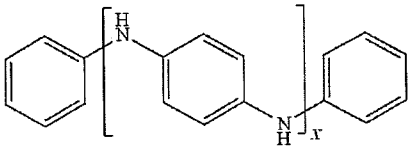

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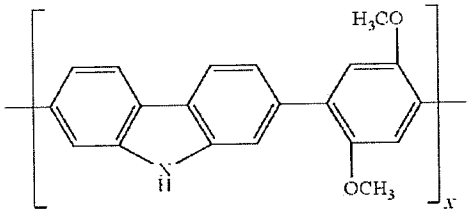

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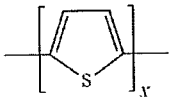

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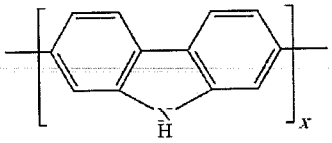

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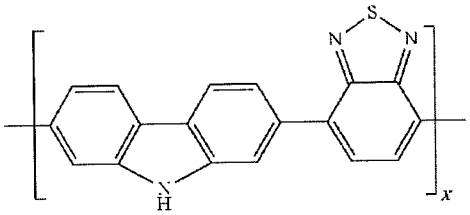

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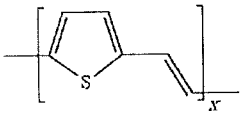

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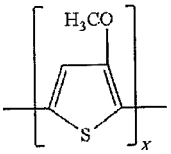
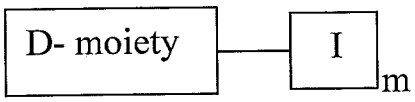


I is a high-breakdown insulating substituent group, n is 1, 2, 3, 4, 5, 6, 7 or 8, m is 1, 2, 3, 4, 5, 6, 7 or 8 and wherein at least one of the high-breakdown insulating substituent group is independently selected from the list comprising —$(CH_2)_n$—CH_3, —$CH((CH_2)_nCH_3)_2$) (where n=1 . . . 50), alkyl, aryl, substituted alkyl, substituted aryl, branched alkyl, branched aryl, and

any combination thereof and wherein the alkyl group is selected from the group of methyl, ethyl, propyl, butyl, I-butyl and t-butyl groups, and the aryl group is selected from the group of phenyl, benzyl and naphthyl groups.

Disclosed is an energy storage molecular material having a general molecular structural formula:



wherein D- moiety is a polarization unit forming column-like supramolecular stacks by means of π-π-interaction, I is a high-breakdown insulating substituent group, m is 1, 2, 3, 4, 5, 6, 7 or 8.

In yet another aspect, the present disclosure provides a crystal dielectric layer comprising the disclosed energy storage molecular material.

Disclosed is a capacitor comprising a first electrode, a second electrode, and a crystal dielectric layer disposed between said first and second electrodes. In another aspect, there is provided a capacitor comprising a first electrode, a second electrode, and a crystal dielectric layer disposed between said first and second electrodes, wherein said crystal dielectric layer comprises the energy storage molecular material disclosed herein. The electrodes are flat and planar and positioned parallel to each other. The crystal dielectric layer comprises the disclosed energy storage molecular material.

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 DRAWINGS

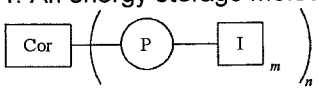
FIG. 1 is a schematic diagram of a capacitor according to an aspect of the present disclosure.

DETAILED DESCRIPTION

While various aspects of the present disclosure have been shown and described herein, it will be obvious to those skilled in the art that such aspects 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 aspects of the disclosure described herein may be employed.

What is claimed is:

1. An energy storage molecular material having a general molecular structural formula:



wherein Cor is a predominantly planar polycyclic molecular system which forms column-like supramolecular stacks by means of π-π-interaction, wherein the planar polycyclic molecular system comprises planar fused polycyclic hydrocarbons selected from the group of truxene, decacyclene, antanthrene, hexabenzotriphenylene, 1,2,3,4,5,6,7,8-tetra-(peri-naphthylene)-anthracene, dibenzoctacene, tetrabenzoheptacene, peropyrene, hexabenzocoronene and has a general structural formula from the group of structures 7-17:

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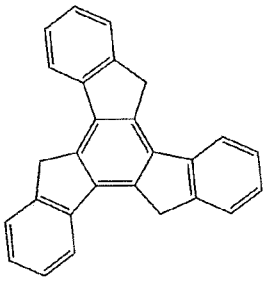

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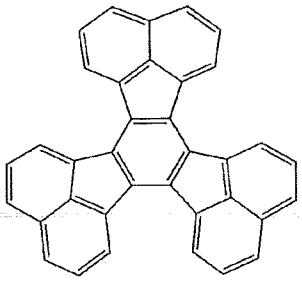

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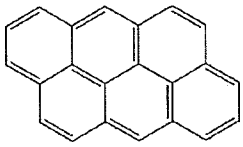

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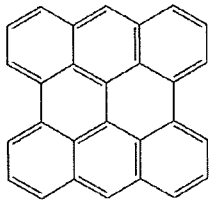

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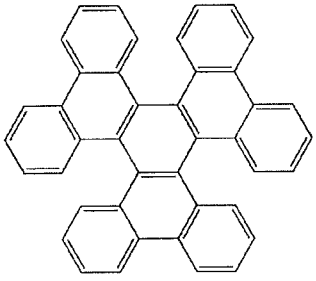

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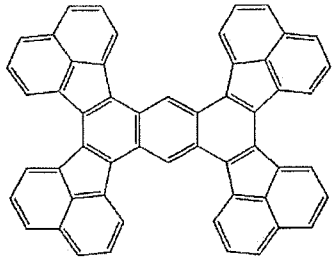

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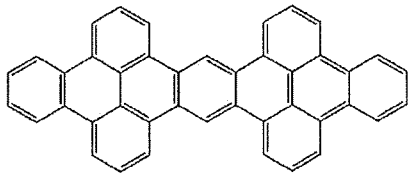

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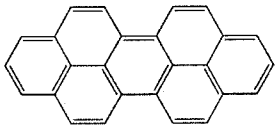

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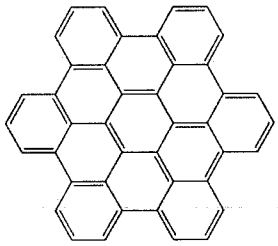

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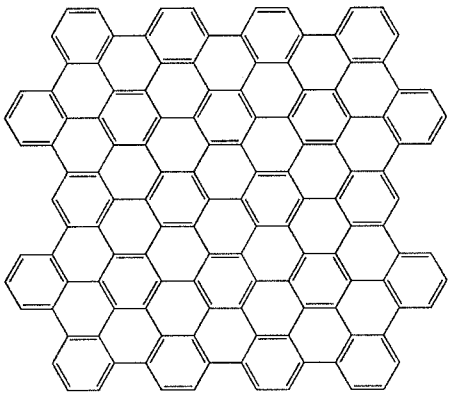

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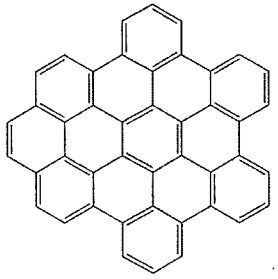

P is a polarization unit, wherein the polarization unit is selected from the group of doped oligoaniline and p-oligo-phenylene or comprises an electro-conductive oligomer having a general structural formula selected from the group of structures 26 to 32 wherein X=2, 3, 4, 5, 6, 7, 8, 9, 10, 11 or 12:

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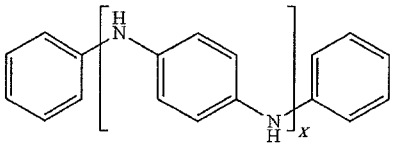

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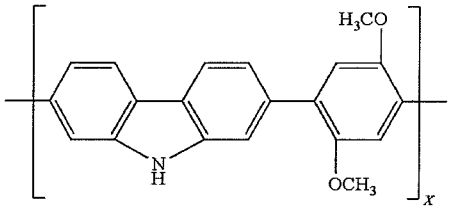

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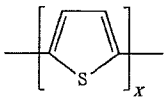

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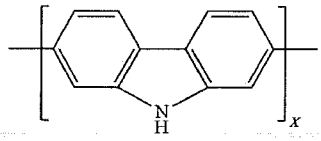

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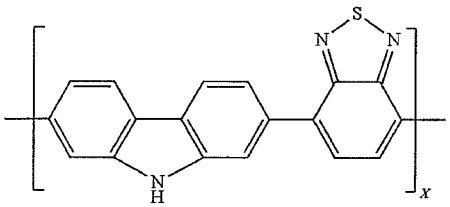

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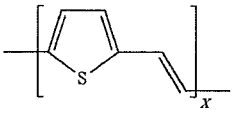

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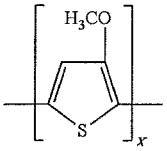

I is a high-breakdown insulating substituent group, n is 1, 2, 3, 4, 5, 6, 7 or 8, m is 1, 2, 3, 4, 5, 6, 7 or 8 and wherein at least one of the high-breakdown insulating substituent group is independently selected from the list comprising —$(CH_2)_n$—CH_3, —$CH((CH_2)_nCH_3)_2$) (where n=1 . . . 50), alkyl, aryl, substituted alkyl, substituted aryl, branched alkyl, branched aryl, and any combination thereof and wherein the alkyl group is selected from the group of methyl, ethyl,

propyl, butyl, I-butyl and t-butyl groups, and the aryl group is selected from the group of phenyl, benzyl and naphthyl groups.

2. An energy storage molecular material according to claim 1, wherein the doped oligoaniline is self-doped oligoaniline with SO_3-groups or COO-groups on the phenyl rings of aniline.

3. An energy storage molecular material according to claim 1, wherein the doped oligoaniline is mix-doped by acid compounds selected from the group of alkyl-SO_3H acid or alkyl-COOH mixed to oligoaniline in oxidized state.

4. An energy storage molecular material according to claim 1, further comprising at least one linker unit selected from the group of the following structures: 33-42, which connect the predominantly planar polycyclic molecular system (Cor) with the polarization units (P):

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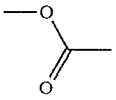

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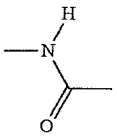

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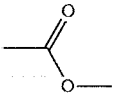

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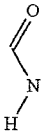

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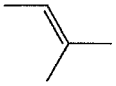

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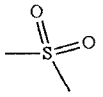

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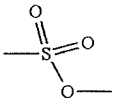

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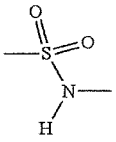

5. A crystal dielectric layer comprising the energy storage molecular material according to any of claims 1, 2, 3, 4.
6. A capacitor comprising
a first electrode,
a second electrode, and
a crystal dielectric layer disposed between said first and second electrodes,
wherein said crystal dielectric layer comprises the energy storage molecular material according to any of claims 1, 2, 3, 4.