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DIELECTRIC MATERIAL AND ELECTRICAL APPARATUS CONTAINING IT

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FIG. 1

CORRELATION OF DIELECTRIC CONSTANT AND TEMPERATURE OF TETRACHLORO-ORTHO-XYLENE.

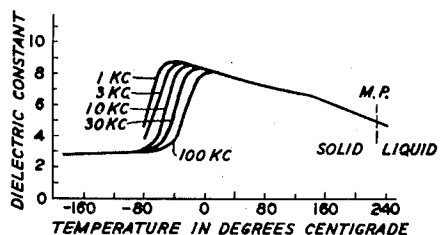


FIG. 2

CORRELATION OF DIELECTRIC CONSTANT AND TEMPERATURE OF 4,5,6 TRICHLORO-ORTHO-XYLENE.

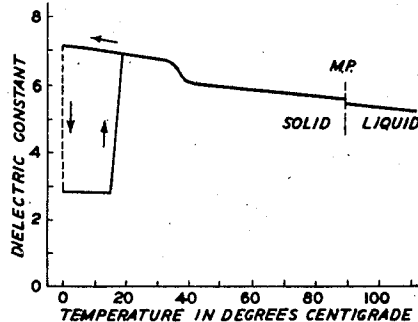


FIG. 3

CORRELATION OF DIELECTRIC CONSTANT & TEMPERATURE OF A MIXTURE OF 7 MOLS OF 4,5,6 TRICHLORO-ORTHO-XYLENE AND 1 MOL OF DICHLOROPREHNITENE.

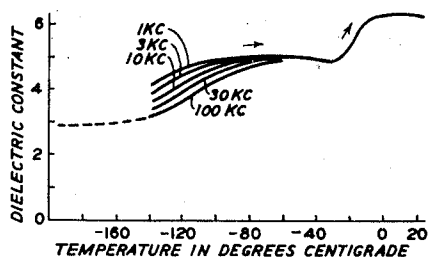


FIG. 4

CORRELATION OF DIELECTRIC CONSTANT & TEMPERATURE OF A MIXTURE OF 1 MOL OF TETRACHLORO-ORTHO-XYLENE & 7 MOLS OF 4,5,6 TRICHLORO-ORTHO-XYLENE.

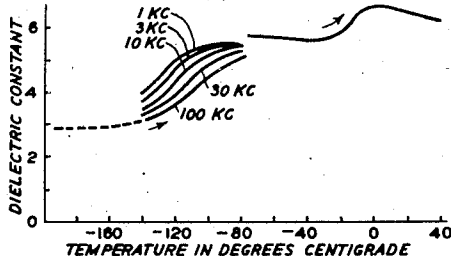
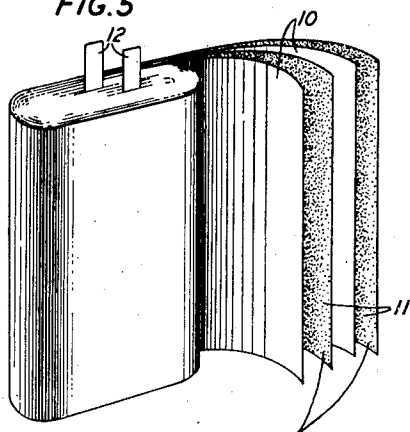
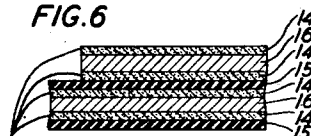


FIG. 5



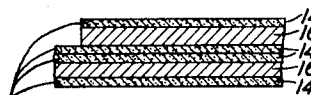
PAPER IMPREGNATED WITH A MATERIAL SUCH AS A HEXA SUBSTITUTED BENZENE, THE SUBSTITUENTS CONSISTING OF METHYL AND POLAR GROUPS, AT LEAST ONE OF THE SUBSTITUENTS BEING A METHYL GROUP AND AT LEAST ONE A POLAR GROUP.

FIG. 6



A MATERIAL SUCH AS A HEXA SUBSTITUTED BENZENE, THE SUBSTITUENTS CONSISTING OF METHYL AND POLAR GROUPS, AT LEAST ONE OF THE SUBSTITUENTS BEING A METHYL GROUP AND AT LEAST ONE A POLAR GROUP.

FIG. 7



A MATERIAL SUCH AS A HEXA SUBSTITUTED BENZENE, THE SUBSTITUENTS CONSISTING OF METHYL AND POLAR GROUPS, AT LEAST ONE OF THE SUBSTITUENTS BEING A METHYL GROUP AND AT LEAST ONE A POLAR GROUP.

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DIELECTRIC MATERIALS AND ELECTRICAL APPARATUS CONTAINING THEM

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23 Claims. (Cl. 175-41)

This invention relates to dielectric materials and more particularly to electrical apparatus embodying these materials.

In telephone exchanges, particularly in urban centers, space is at a premium and any substantial reduction in the size of apparatus is of paramount importance. Then too, in mobile bodies, such as airplanes, weight and space are factors which dictate the reduction of communication apparatus employed therein to the minimum in size necessary for successful operation. In both telephone and communication systems condensers are used in relatively great numbers and any reduction in their size without appreciable diminution in their functional characteristics results in material economies.

An object of this invention is to reduce substantially the size of apparatus employed in electrical systems which are subjected to wide variations in temperature.

Another object is to utilize in electrical apparatus materials having high dielectric constants and desirable physical and electrical properties.

In accordance with this invention dielectric materials are employed which under conditions of use are solids and which either alone or in conjunction with other dielectrics, such as paper, provide high capacity in electrical apparatus and which at the same time have physical properties such as melting point, compressibility, viscosity and penetrability, which render them admirably adapted for use in electrical apparatus. Further, these materials retain the high dielectric constant at high frequencies and over a wide range of temperatures, are non-hygroscopic, are chemically stable, do not undergo electrolytic changes and do not decompose or break down under conditions of use in electrical apparatus. The materials to which this invention relates include polar compounds selected from the group which consists of hexasubstituted benzenes, the substituents consisting of methyl and polar groups, at least one of the substituents being a methyl group and at least one a polar group; pentasubstituted benzenes, the substituents consisting of methyl and polar groups, at least two of the substituents being methyl groups and at least one a polar group; pentasubstituted benzenes, the substituents consisting of methyl and polar groups, at least one of the substituents being a methyl group and at least two other substituents being two different polar groups; pentasubstituted benzenes, the substituents consisting of methyl and polar groups, at least one of the substituents being a methyl group and at

least one of the polar substituents being a member of the class which consists of amino, bromo, fluoro, iodo, hydroxy, and nitro, all of the compounds having sufficient geometric symmetry in one plane about the molecular center of gravity to permit molecular rotation.

When polar molecules, that is, those containing an electric dipole moment greater than zero, engage in rotational motion, materials containing these molecules exhibit a dielectric constant higher than the square of the optical refractive index by an amount indicated by the magnitude of the dipole moment. All liquids composed of such polar molecules as a consequence manifest correspondingly high dielectric constants since rotational motion of molecules in liquids is relatively free. It would be expected that when such liquids were solidified, the dielectric constant would fall to the square of the refractive index—a value of between 2 and 3—because of the elimination of molecular rotation in the more rigid solid state.

Materials included in the class to which this invention relates have in the solid crystalline state dielectric constants much greater than the square of their refractive indices and equal to or greater than the dielectric constants of their respective liquids. These materials manifest great chemical stability, as compared with corresponding derivatives of hydrocarbon compounds containing two or more aromatic nuclei.

Examples of materials falling within the class of compounds to which the invention relates are pentamethyl chlorobenzene, dichloroprehnitene, dichloroisodurene, trichlorohemimellitene, trichloropseudocumene, tetrachlorometa-xylene, tetrachloro-ortho-xylene, pentachlorotoluene, pentamethyl fluorobenzene, tetrachloro-meta-fluorotoluene, dinitrophehntene, dinitroisodurene, 2,4,5-trichloro-meta-xylene, 4,5,6-trichloro-ortho-xylene, 2,4,6-trichloro-meta-fluorotoluene, and 5-nitro-3,4-dichloro-ortho-xylene.

It has been established heretofore that in an organic crystal, molecules cannot engage in translational motion to any great extent, their locations being fixed in a regular array in space according to the symmetry of the crystal. For a molecule thus fixed to engage in rotational motion to any great degree it is necessary that its energy of interaction with its neighbors should not change greatly as the orientation of the molecule changes. As a consequential requirement for molecular rotation, the smallest distance between any part of the molecule in question and the neighboring molecules must not

change greatly as the orientation of the molecule changes. Hence, the molecule must possess a high degree of geometrical symmetry about its center of gravity, which determines the axis of the rotational motion, for such motion to occur appreciably in the crystal. In theory, this symmetry may be either spherical or circular, molecular rotation occurring only about the axis perpendicular to the plane of the circle in the latter case. The effect on the dielectric constant of a specimen containing a large number of randomly oriented single crystals is the same in either case, provided the dipole lies in the plane of the circle when the symmetry is circular. The compounds of this invention have symmetry about one axis only and these compounds have sufficient geometric symmetry in one plane about their molecular center of gravity to permit molecular rotation. This symmetry may be ascertained by an examination of scale models and diagrams of the penta- and hexa-substituted benzene compounds to which this invention relates. The symmetry arises from the similar effective volume of the methyl and polar groups and atoms as compared with the extremely small hydrogen atoms which they replace.

The use of a methyl group or groups suitably located with respect to other polar groups is necessary to obtain a large dipole moment since if all the hydrogens of benzene were substituted with the same groups or with groups or atoms of similar polarity, then polarities would tend to cancel each other due to their opposing directions. For example, the geometrical symmetry of the dichloroprehnitenene molecule is high because of the similar volume of the chlorine atoms and methyl groups, while the molecule is polar because of the location of these substituents about the benzene nucleus; thus the molecule is able to rotate in the crystal because of its geometrical symmetry and the rotation in turn produces a high dielectric constant because of the dipole in the molecule. Geometrical symmetry about the molecular center of gravity is somewhat lower in dinitroprehnitenene because of the adjacent nitro groups weight one side of the molecule so heavily that its center of gravity is considerably displaced from the center of the benzene ring. In the pentasubstituted benzenes, symmetry is reduced because of the small size of the one hydrogen atom as compared with the substituents. The effect of the lower symmetry of these compounds appears in the abrupt drop of their dielectric constant at a transition, in place of the more gradual decline, depending on the frequency of measurement, which characterizes the dielectric constant of the hexasubstituted benzenes that are most symmetrical about their centers of gravity. Among solids whose molecules have two or more unsubstituted positions, such as 2,3,5-trichlorotoluene and ortho-dichlorobenzene, no evidence of a high dielectric constant in the solid state has been obtained. This demonstrates that with two or more unsubstituted positions benzene derivatives become so unsymmetrical as to reduce greatly the possibility of molecular rotation in the crystal.

It has been established heretofore that in pure homogeneous non-ionizing polar liquids, the difference observed between the dielectric constant at radio frequencies and at optical frequencies (the latter being the square of the optical refractive index according to Maxwell's law) is due almost entirely to the rotational motion of molecules containing dipoles. Furthermore, the mag-

nitude of this difference between the dielectric constant and the square of the refractive index is roughly determined by the magnitude of the molecular dipoles, the dielectric constant increasing with increasing dipole moment. Heretofore, it was believed that when a polar benzene derivative changed from the liquid to the solid state by freezing, rotational motion of the molecules ceased, the molecules being almost rigidly oriented in the crystal. This belief was supported by evidence including the invariable fall of dielectric constant upon freezing to a value about equal to the square of the refractive index, as well as X-ray studies which showed the orientation of the molecule in the crystal to be fixed. However, none of these studies involved the use of any of the materials falling within the class to which this invention relates. These materials have high dielectric constants through considerable ranges of temperature in the crystal as well as in the liquid state. It is believed that this high dielectric constant in the solid state is due to a continuation in the solid of the rotational motion of the molecule, which is known to exist in the liquid and to account for its dielectric constant. Support of this belief is found in the absence of any other known mechanism whereby a pure non-ionizing homogeneous organic solid can exhibit a dielectric constant appreciably greater than the square of the refractive index, and the relatively small change of dielectric constant which occurs at the melting points of the compounds within the class to which this invention relates. These facts indicate that the same mechanism is responsible for the observed values in the solid as in the liquid state. Finally a rough correlation exists between the values of dielectric constant of the solids and molecular dipole moment, which demonstrates clearly that the value of dielectric constant, although influenced by other factors such as density and molecular interaction, is primarily dependent on the dipole moment of the molecule. Since it has been established that the dipole moment cannot possible influence the dielectric constant except through molecular rotation, the high dielectric constant in the solid state of the materials to which this invention relates is due to a continuation of rotational motion in the molecule of the solid compound.

A molecule is said to possess a permanent electric dipole when it is electrically asymmetrical, that is, when the center of gravity of the positive charges is separated from the center of gravity of the negative charges by a finite distance. A molecule containing a permanent electric dipole tends to orient itself in an electric field analogously to the well-known behavior of a permanent magnet orienting itself in a magnetic field. The compounds to which this invention relates possess a permanent electric dipole which is electrically asymmetrical and the center of gravity of the positive charges is separated from the center of gravity of the negative charges by a finite distance. The existence of an electric dipole may be ascertained by any of the well-known standard methods.

A more comprehensive understanding of this invention is obtained by reference to the accompanying drawing, in which:

Figs. 1 to 4 show graphically the dielectric characteristics of compounds to which this invention relates;

Fig. 5 is a perspective view of an embodiment of this invention;

Fig. 6 is a cross-section of a capacitance constructed in accordance with this invention; and Fig. 7 is an alternate form of the invention shown in Fig. 6.

The polar compounds to which this invention relates may be divided into two classes. The distinguishing behavior of the first class is characterized by the manner in which, as the temperature of a polar compound is reduced the dielectric constant drops off from a high value at a different temperature for each frequency of the applied electric field used for measurement. In the second class of compounds when the temperature of the compound is reduced the dielectric constant drops sharply at all frequencies alike from a high to a low value. The dielectric behavior at various temperatures of a member of the first class is illustrated in Fig. 1 which shows the dielectric constant of tetrachloro-ortho-xylene plotted against temperature for a number of different frequencies of measurement. The dielectric constant for one, three, ten, thirty and one hundred kilocycles of various temperatures is shown by means of labeled black lines. The melting point of the tetrachloro-ortho-xylene is indicated by the M. P. symbol. It is observed that as the frequency is increased the temperature at which the dielectric constant drops off also increases. Such dependence of dielectric constant on frequency is commonly termed anomalous dispersion. The dielectric behavior of members of the second class is typified by 4,5,6 trichloro-ortho-xylene. The temperature variation of the dielectric constant for all frequencies between one and one hundred kilocycles is shown graphically in Fig. 2. When a compound of this latter class is heated from low temperatures, a temperature is reached where a sharp rise of dielectric constant to the original high value is observed. The black line shown in Fig. 2 shows the dielectric constant of the 4,5,6 trichloro-ortho-xylene at various temperatures, while the symbol M. P. indicates the melting point of that compound. The arrows represent the direction of the temperature change being effected. When the temperature is decreased from a high value to below approximately 20° C., a slight increase in dielectric constant is discernible and this increase continues to approximately 0° C. However, as indicated by the arrows, if the temperature of the 4,5,6 trichloro-ortho-xylene is increased from about 0° C. the dielectric constant remains at a substantially low level until approximately 15° C. is attained. At this point, the dielectric constant increases to that corresponding to the dielectric constant obtained with decreasing temperature. Frequently, this hysteresis occurs in compounds of the second class when subjected to rapid temperature change.

Except at low temperatures, compounds of both classes have dielectric constants which are greater than the squares of their refractive indices, which in all cases are found to be no more than three by calculation according to well-known methods. At low temperatures the dielectric constants of both classes of material are approximately equal to the squares of their refractive indices. The dielectric behavior of both classes of compounds in the solid state resembles that of liquids and in all but a few cases, such as dinitrophenylene, the dielectric constant is higher in the crystalline than in the liquid state as shown in Figs. 1 and 2.

The dielectric constants at 20° C. and at -195° C. together with the molecular dipole moments

of some of the compounds of the first class are as follows:

	Dielectric constant at 20° C.	Dielectric constant at -195° C.	Molecular dipole moment
Pentamethylchlorobenzene	5.7	2.85	1.9
Dichloroprehniten	9.1	2.75	3.2
Dichloro-iso-durene	8.8	2.9	1.9
Trichlorohemimellitene	8.8	2.90	3.8
Trichloropseudocumene	6.3	2.9	1.9
Tetrachloro-meta-xylene	5.7	2.97	1.9
Tetrachloro-ortho-xylene	9.0	2.90	3.3
Pentachlorotoluene	8.2	3.0	1.9
Pentamethylfluorobenzene	3.5	2.8	1.7
Tetrachlorometafluorotoluene	8.8	2.93	1.9
Pentachloromethylbenzene	8.1	2.8	1.9

The dielectric constant was determined at 20° C. and at -195° C. since at the former temperature rotation of the molecule occurs, while at the latter temperature it does not.

The transition temperature, dielectric constants above the transition, the dielectric constants below the transition and the molecular dipole moments of some of the compounds of the second class are as follows:

	Transition temperature rising temperature	Dielectric constant above transition	Dielectric constant below transition	Molecular dipole moment
Dinitrophenylene	°C. +150	16.5	2.95	7.60
2,4,6-trichloro-meta-xylene	21	4.2	2.92	1.1
4,5,6-trichloro-ortho-xylene	17	7.0	2.82	2.2
2,4,6-trichloro-meta-fluorotoluene	-65	4.4	2.85	1.1
5-nitro-3,4-dichloro-ortho-xylene	0	9.4	2.9	-----

All of the compounds to which this invention relates are polar materials selected from the class which consists of hexa-substituted benzenes, the substituents consisting of methyl and polar groups, at least one of the substituents being a methyl group and at least one a polar group; penta-substituted benzenes, the substituents consisting of methyl and polar groups, at least two of the substituents being methyl groups and at least one a polar group; penta-substituted benzenes, the substituents consisting of methyl and polar groups, at least one of the substituents being a methyl group and at least two other substituents being two different polar groups; penta-substituted benzenes, the substituents consisting of methyl and polar groups at least one of the substituents being a methyl group and at least one of the polar substituents being a member of the class which consists of amino, bromo, fluoro, iodo, hydroxy, and nitro. The penta-substituted derivatives are those in which all but one of the hydrogen atoms are replaced with other atoms or atomic groups and the hexa-substituted derivatives are those in which all the hydrogen atoms are replaced with other atoms or atomic groups. The atoms and groups in each compound are so distributed among the substituted positions on the benzene ring that the molecule as a whole is polar, that is, that it possesses a known electrical dipole moment greater than zero. Accordingly, the compounds have a finite dipole moment. Although the most desirable compounds are those in which the polar substituent groups are methyl, chlorine, fluorine or nitro, other polar substituents such as, amino and hydroxyl may likewise be employed. Examples of compounds of this in-

vention are fluoro-nitro-prehnitene, difluoro-prehnitene, polar isomers of dichloro-fluoro-xylene, the polar isomers of trimethyl dichloro-fluoro benzene, chlorofluoro prehnitene, 4,5-dichloro, 6-fluoro-ortho-xylene, penta-methyl-phenol, penta-methyl-anilin and penta-bromotoluene.

Penta-substituted and hexa-substituted polar compounds containing fluorine are particularly adapted for use as dielectrics. The presence of one or more atoms of fluorine which are substituted for a chlorine atoms in a penta- or hexa-substituted benzene lowers the transition temperature and thus increases the range of temperatures in which the material has a high dielectric constant. For example, the transition temperature of 2,4,6-trichloro-meta-fluoro-toluene is -65°C ., whereas that of 2,3,4,6-tetra-chloro-toluene is 22°C . In the hexa-substituted compounds the introduction of a fluorine atom or atoms has a similar effect in lowering the temperature at which the dielectric constant falls off for any given frequency although no transition is involved; for example, the fall of the dielectric constant of tetrachloro-meta-fluoro-toluene is for one hundred kilocycles most rapid at -78°C . while the corresponding temperature in pentachloro-toluene is $+10^{\circ}\text{C}$.

The dielectric materials in accordance with this invention may be employed in condensers as shown in Figs. 5, 6, and 7. In Fig. 5 sheets of a porous dielectric 11 such as paper are impregnated with a compound to which this invention relates. Interposed between the sheets of dielectric are metal foils 10. Both the dielectric and foils are wound in a well-known manner to form the condenser. Two metallic strips 12 are electrically connected to the electrodes 10 to form the terminals of the condenser. The compounds to which the invention relates are stable when aluminum foils are employed as electrodes 10. For example, the chlorine derivatives do not evolve any appreciable quantity of hydrochloric acid and accordingly condensers in which these derivatives are employed are not prone to break down. Alternately the polar penta- or hexa-substituted benzene may be a coating 14 on a metal foil 16 as shown in Figs. 6 and 7. The coated metal foils may be separated as shown in Fig. 6 by a strip of another dielectric 15 and the coated foils piled alternately in a well-known manner to form a condenser. The polar penta- or hexa-substituted benzenes may also be employed in other electrical apparatus such as wave guides in accordance with the disclosure in U. S. Patent 2,129,711 granted to G. C. Southworth on September 13, 1938, where a relatively high capacitance is required.

Mixtures or solid solutions of the compounds to which this invention relates may be used to obtain combinations of dielectric and physical properties which greatly enhance their usefulness for the impregnation of paper condensers. The proportions of the constituents of these mixtures are critical for this particular use. For example, a mixture of approximately 1 mol of dichloroprehnitene with 7 mols of 4,5,6-trichloro-ortho-xylene is found to have a transition reduced in magnitude and displaced to lower temperature than that found in pure 4,5,6-trichloro-ortho-xylene. The dielectric properties of this mixture are shown graphically in Fig. 3 in which the dielectric constant is correlated with the temperature of the mixture. The labeled black lines represent the dielectric constant for one, three, ten,

thirty and one hundred kilocycles when the temperature is increased from -140°C . The desirably high dielectric constant of 4,5,6-trichloro-ortho-xylene is thus made available at temperatures below -10°C . while it may be undesirably low at about $+15^{\circ}\text{C}$. in the pure material. At the same time the undesirable melting point of 191°C . found for dichloroprehnitene is reduced in the mixture to an initial crystallization temperature of 112°C . The characteristics of this mixture are desirable when paper condensers are impregnated since the dielectric must be liquefied. At temperatures above 130°C . paper tends to deteriorate and the vapor pressure of the compounds becomes so high as to render vacuum impregnation of paper units difficult. To secure the desired combination of melting point and transition temperature of this mixture, it is necessary that the proportions be extremely close to 1 mol of dichloroprehnitene and 7 mols of 4,5,6-trichloro-ortho-xylene. Any considerable increase of the 4,5,6-trichloro-ortho-xylene results in a transition temperature in the operating range of the condenser, while any considerable increase of the proportion of dichloroprehnitene raises the melting point of the mixture beyond the temperature of practicable impregnation of paper condensers.

Another mixture which has been found extremely satisfactory for paper condensers consists of approximately 1 mol of tetrachloro-ortho-xylene and 7 mols of 4,5,6-trichloro-ortho-xylene. The dielectric properties of this mixture at various temperatures are shown in Fig. 4. The labeled black lines represent the dielectric constant for one, three, ten, thirty and one hundred kilocycles when the temperature is increased from -140°C . The temperature of the initial crystallization of this mixture is 124°C ., an extremely great improvement over the melting point of tetrachloro-ortho-xylene which is 230°C . The proportions of the ingredients in this mixture are also very critical, depending on the proportions specified.

In addition to the example cited above, other mixtures of two or more polar compounds of the type to which this invention relates may be employed: For example, mixtures of 4,5,6-trichloro-ortho-xylene with tetrachloro-meta-fluoro-toluene, of 4,5,6-trichloro-ortho-xylene with pentachloro-toluene, of 4,5,6-trichloro-ortho-xylene with tetrachloro-meta-xylene, of 4,5,6-trichloro-ortho-xylene with trichloro-pseudocumene, of 4,5,6-trichloro-ortho-xylene with trichloro-hemimellitene, of 4,5,6-trichloro-ortho-xylene with penta-methyl chlorobenzene, of 4,5,6-trichloro-ortho-xylene with penta-methyl fluoro-benzene, of 2,4,6-trichloro-meta-fluoro-toluene with tetrachloro-meta-fluorotoluene, of 2,4,6-trichloro-meta-fluorotoluene with tetrachloro-ortho-xylene, of 2,4,6-trichloro-meta-fluorotoluene with dichloroprehnitene, of difluoroprehnitene with dichloroprehnitene, of 2,4,6-trichloro-meta-fluorotoluene with dinitroprehnitene, of 3-nitro-4,5-dichloro-ortho-xylene with dinitroprehnitene, of 4,5,6-trichloro-ortho-xylene with penta-chloroethylbenzene, of 3-nitro-4,5-dichloro-ortho-xylene with dichloroprehnitene, and of 3-nitro-4,5-dichloro-ortho-xylene with tetrachloro-ortho-xylene may be used. These compounds may be mixed in various proportions depending upon the particular use and characteristic of the resulting solid solution desired.

The advantages of the use of the pure compounds and mixtures, to which this invention re-

lates, as dielectric materials in electrical devices are illustrated by various examples:

Example 1.—A paper insulated capacitor such as that shown in Fig. 5 designed for operation at low voltage (500 volts or less) and having a volume of 13.3 cubic centimeters has, when impregnated according to standard practice with halowax, a commercial dielectric comprising chlorinated naphthalenes, a capacity of 1.0 microfarad. When such a paper insulated capacitor unit is similarly impregnated with a mixture of one mol of tetrachloro-ortho-xylene and 7 mols of 4,5,6-trichloro-ortho-xylene, its capacity is found to be 1.0 microfarad and it withstands severe treatment such as subjection to a temperature of 100° C. over a long period of time before showing evidence of decomposition.

Example 2.—A similar condenser impregnated with a mixture of one mol of dichloroprehnitene and 7 mols of 4,5,6-trichloro-ortho-xylene exhibited a capacity of 1.0 microfarad and is capable of withstanding severe heat treatment.

Example 3.—A paper insulated condenser impregnated with tetrachloro-meta-fluorotoluene by a continuous process whereby the temperature of about 150° C. necessary to maintain the liquid state does not affect the paper long enough to cause appreciable decomposition, may have a capacity equal to that obtainable with halowax.

Example 4.—A paper insulated condenser impregnated with difluoroprehnitene may have a capacity equal to that obtained with halowax combined with excellent chemical stability, long life and dielectric breakdown strength because of the intrinsic stability of the aromatic fluorine bond and the absence of any catalysis of decomposition by aluminum fluoride, which may be formed in small quantities due to the contact of the aluminum foil of the condenser with the difluoroprehnitene.

While preferred embodiments of this invention have been illustrated and described various modifications may be made therein without departing from the scope of the appended claims.

What is claimed is:

1. An electrical condenser comprising armatures separated by a solid dielectric comprising a solid polar substituted benzene having at least five substituents, the substituents consisting of methyl and polar groups, at least two of the substituents being methyl groups and at least one a polar group, said compound having a finite dipole moment and having sufficient geometric symmetry in one plane about the molecular center of gravity to permit molecular rotation in the solid state, whereby the compound in the solid state, throughout at least a limited temperature range, possesses a dielectric constant which is substantially greater than the square of the optical refractive index of the substance.

2. An electrical condenser comprising armatures separated by a dielectric comprising a solid polar substituted benzene having at least five substituents, the substituents consisting of methyl and polar groups, at least one of the substituents being a methyl group and at least two other substituents being two different polar groups, said compound having a finite dipole moment and having sufficient geometric symmetry in the one plane about the molecular center of gravity to permit molecular rotation in the solid state, whereby the compound in the solid state, throughout at least a limited temperature range, possesses a dielectric constant which is substan-

tially greater than the square of the optical refractive index of the substance.

3. Electrical apparatus comprising two conducting elements separated by a dielectric element comprising a substance having a dielectric constant in the solid state substantially in excess of the square of its optical refractive index said substance comprising a solid polar substituted benzene having at least five substituents, the substituents consisting of at least one methyl group, at least one nitro group and the remainder, if any, halogens.

4. The device described in claim 3 wherein the electrical apparatus is an electrical condenser and the conducting elements are condenser armatures.

5. An electrical condenser comprising armatures separated by a solid dielectric comprising a substance having a dielectric constant in the solid state substantially in excess of the square of its optical refractive index said substance consisting of a nitrodichloroxylylene substance.

6. An electrical condenser comprising armatures separated by a solid dielectric comprising 5-nitro, 3,4-dichloro-ortho-xylene.

7. Electrical apparatus comprising two conducting elements separated by a solid dielectric element comprising a polar substituted benzene having at least five substituents, the substituents consisting of methyl and halogen groups, at least two of said substituents being methyl groups and at least one of said substituents being a halogen.

8. The device described in claim 7 wherein the electrical apparatus is an electrical condenser and the conducting elements are condenser armatures.

9. The device described in claim 7 wherein at least one of the halogen substituents is fluorine.

10. Electrical apparatus comprising two conducting elements separated by a solid dielectric element comprising a polar substituted benzene containing at least five substituents, said substituents consisting of methyl and polar groups, at least one of said substituents being a methyl group and at least one of said substituents being fluorine, said substituted benzene having a dielectric constant in the solid state substantially in excess of the square of its optical refractive index.

11. The device described in claim 10 wherein all of the polar groups are halogens.

12. An electrical condenser comprising armatures separated by a solid dielectric comprising a penta-substituted benzene, the substituents consisting of methyl and halogen groups, at least two of said substituents being methyl groups and at least one of said substituents being a halogen.

13. An electrical condenser comprising armatures separated by a solid dielectric comprising a penta-substituted benzene, the substituents consisting of methyl and chlorine groups, at least two of said substituents being methyl groups and at least one of said substituents being chlorine.

14. An electrical condenser comprising armatures separated by a solid dielectric comprising dichloroprehnitene.

15. An electrical condenser comprising armatures separated by a solid dielectric comprising 4,5,6-trichloro-ortho-xylene.

16. An electrical condenser comprising armatures separated by a solid dielectric comprising tetrachloro-ortho-xylene.

17. An electrical condenser comprising armatures separated by a solid dielectric element comprising 2,4,6-trichloro-meta-fluoro-toluene.

18. An electrical condenser comprising armatures separated by a dielectric element comprising a plurality of polar compounds forming a solid solution, the dielectric constant of each of said compounds being substantially higher than the square of its respective optical refractive index, at least one of said polar compounds being a substituted benzene having at least five substituents, said substituents consisting of methyl and halogen groups, at least two of said substituents being methyl groups and at least one of said substituents being a halogen.

19. A device as described in claim 18 wherein each of said polar compounds is a substituted benzene having at least five substituents, said substituents consisting of methyl and polar groups.

20. A dielectric material comprising a solid solution of approximately one mol of dichloroprehnitene and seven mols of 4,5,6-trichloro-ortho-xylene.

5 21. An electrical condenser comprising armatures separated by a dielectric comprising a solid solution of dichloro-prehnitene and 4,5,6-trichloro-ortho-xylene.

10 22. A dielectric element comprising a solid solution of dichloroprehnitene and a nitro-dichloroxylene.

23. A dielectric element comprising a solid solution of tetrachloro-ortho-xylene and 2,4,6-trichloro-meta-fluoro-toluene.

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