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Haas et al. [45] June 11, 1974

[54] NEMATIC LIQUID CRYSTALLINE COMPOSITIONS HAVING EXTENDED MESOMORPHIC RANGE

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[52] **U.S. Cl.** .... **96/1,** 252/408, 350/160 LC, 353/84

[51] **Int. Cl.**...... **G03g 13/10,** G03g 9/04, G02f 1/28, G02f 1/36, G03b 21/24, 350 160 LC

[58] **Field of Search** 96/1; 252/408; 353/84

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[57] **ABSTRACT**

Compositions formed from nematic liquid crystalline compounds are disclosed. The novel compositions of the invention have extended nematic mesomorphic temperature ranges which are significantly larger than those of the individual components of the compositions and are stable at relatively low temperatures.

11 Claims, 11 Drawing Figures

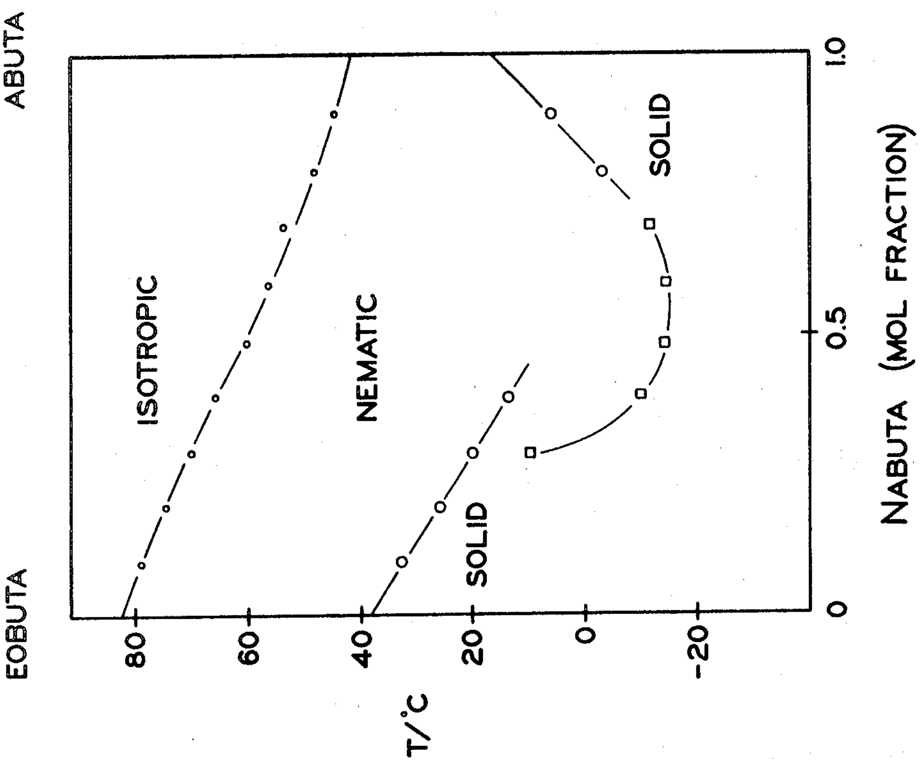

FIG. 2

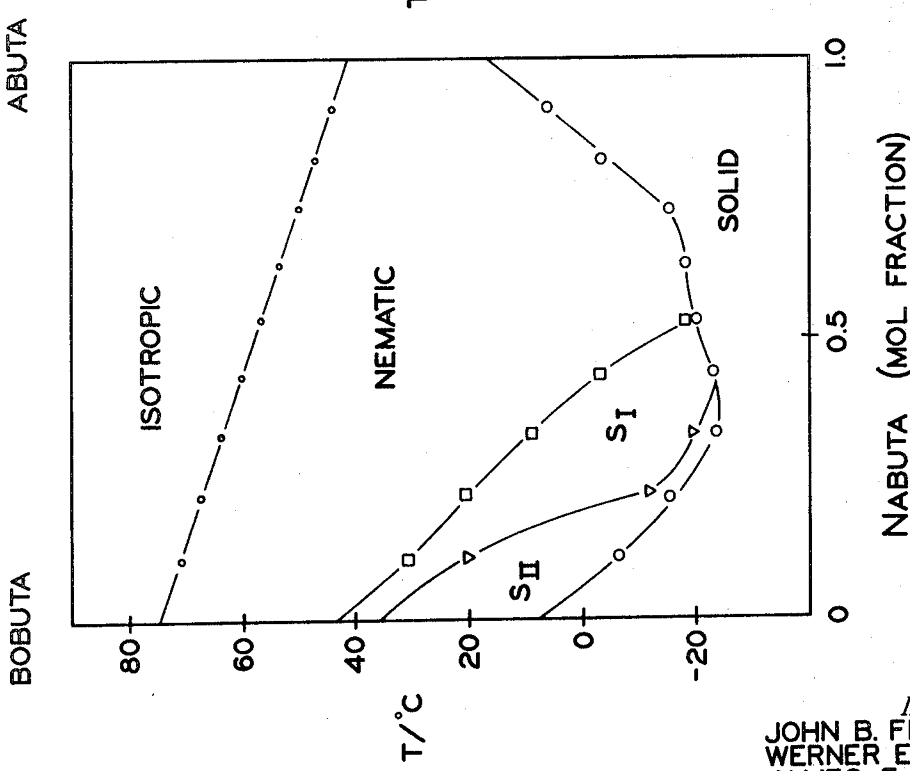

FIG. 1

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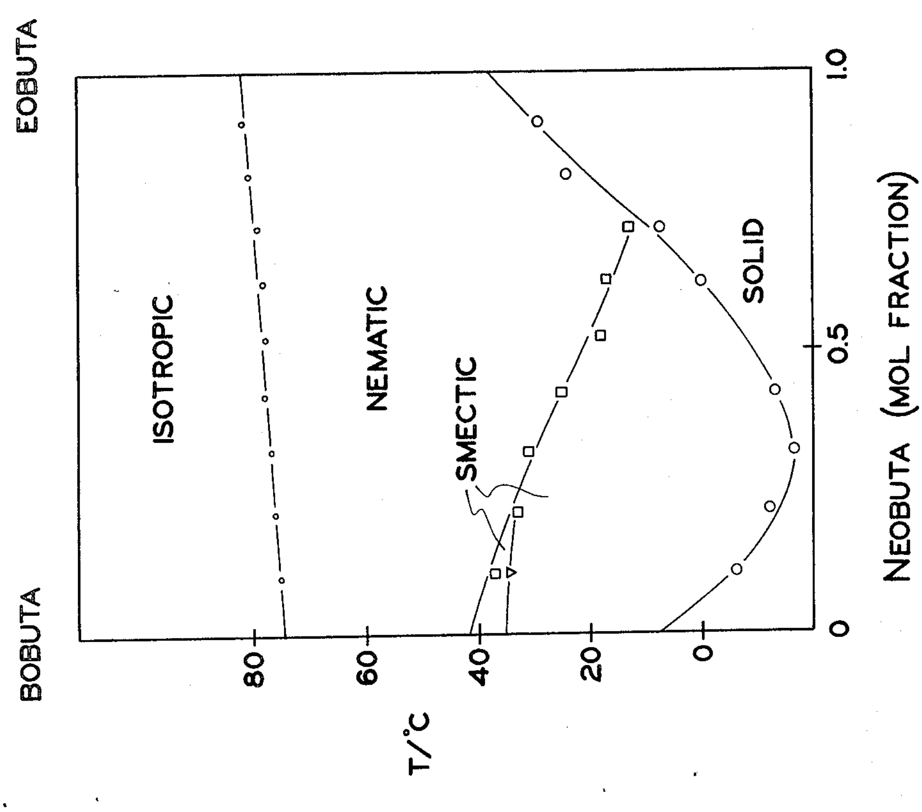
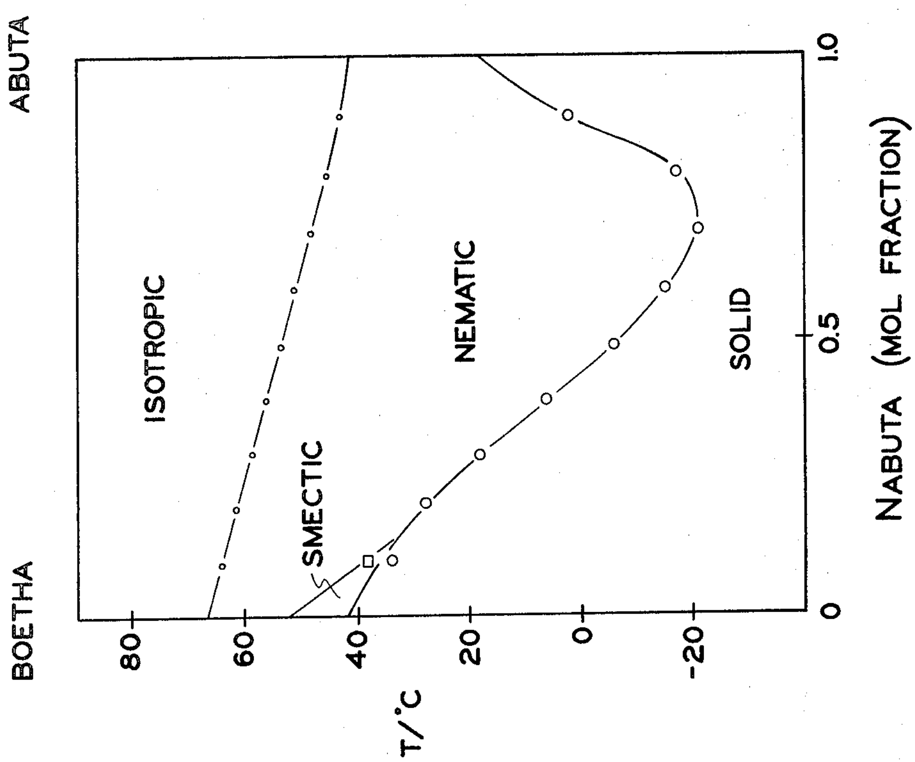

BOBUTA
EOBUTA
ISOTROPIC
NEMATIC
SMECTIC
SOLID
T/°C
80
60
40
20
0
0
0.5
1.0
NEOBUTA (MOL FRACTION)

FIG. 3


BOETHA
ABUTA
ISOTROPIC
NEMATIC
SMECTIC
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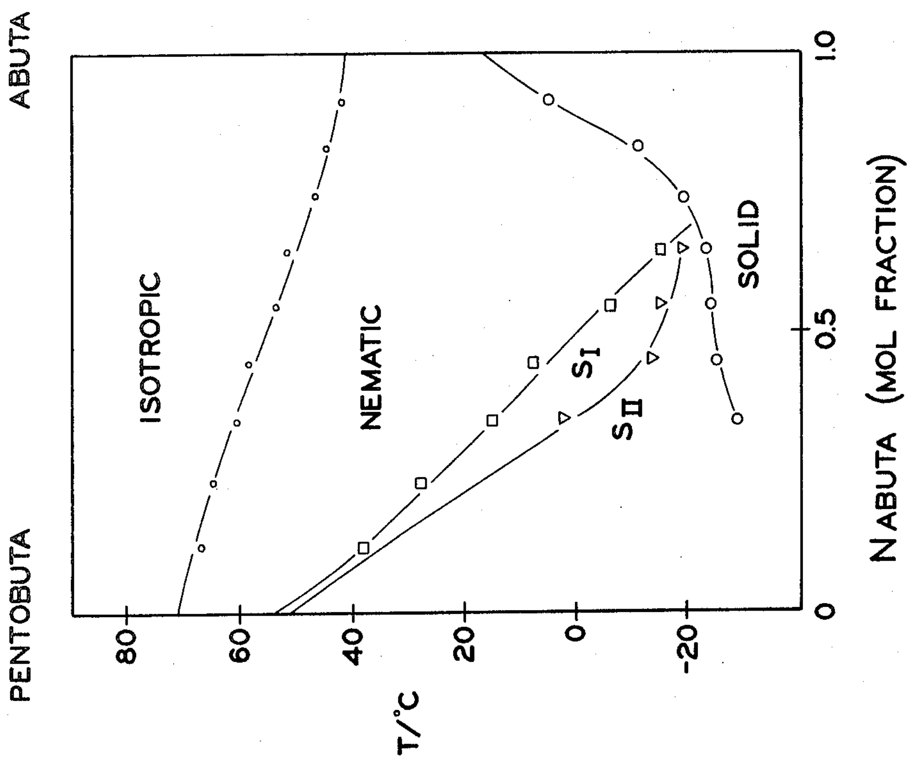
1.0
NABUTA (MOL FRACTION)

FIG. 4


ABUTA
PENTOBUTA
ISOTROPIC
NEMATIC
SOLID
S_I
S_{II}
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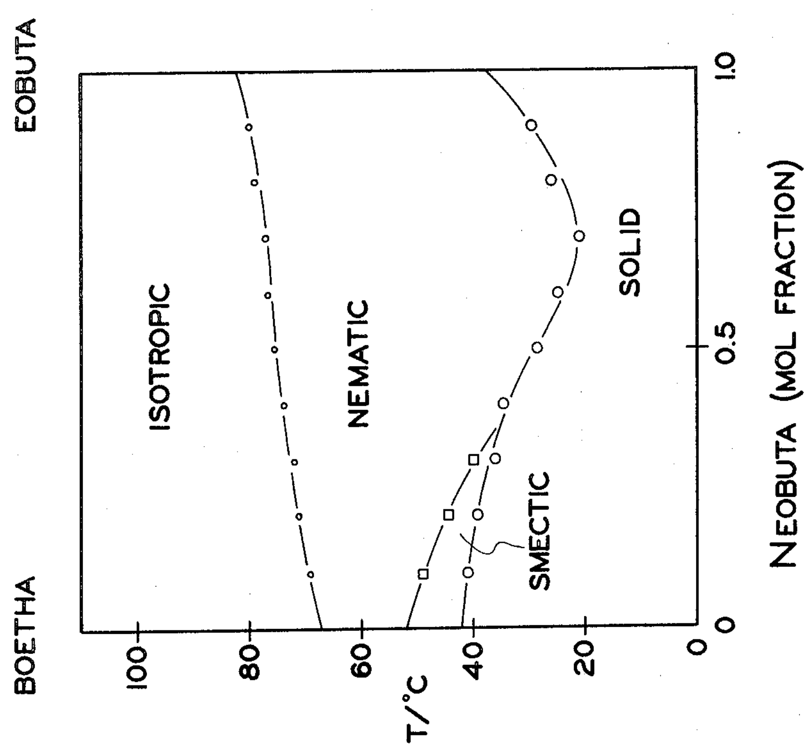
NABUTA (MOL FRACTION)

FIG. 6


EOBUTA
BOETHA
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NEMATIC
SOLID
SMECTIC
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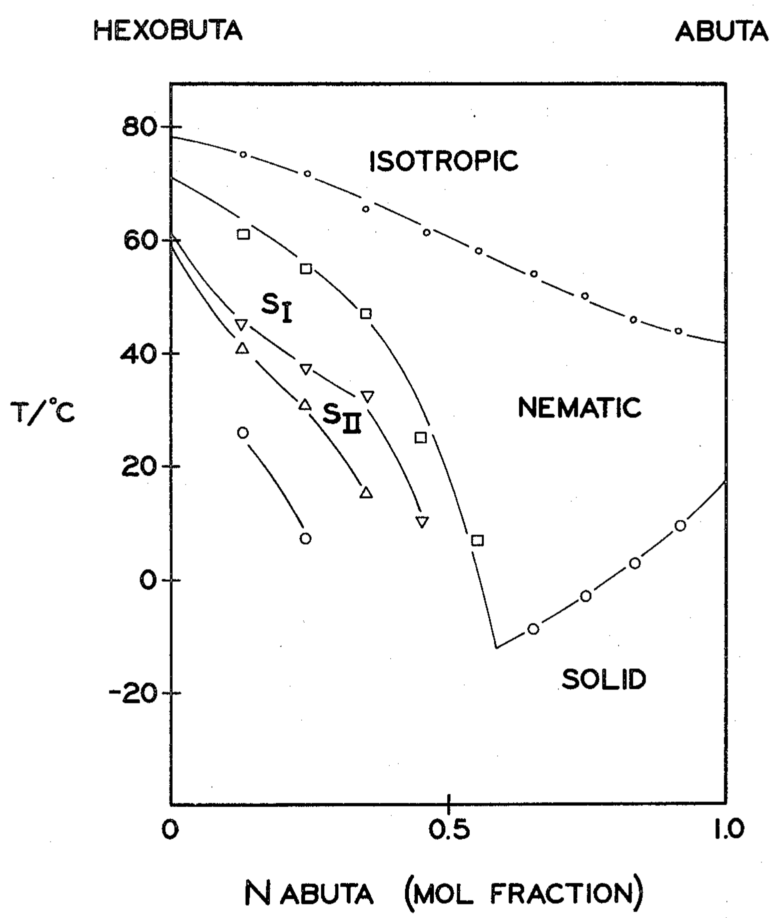
NEOBUTA (MOL FRACTION)

FIG. 5


HEXOBUTA
ABUTA
ISOTROPIC
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SOLID
S_I
S_{II}
T/°C
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N ABUTA (MOL FRACTION)

FIG. 7

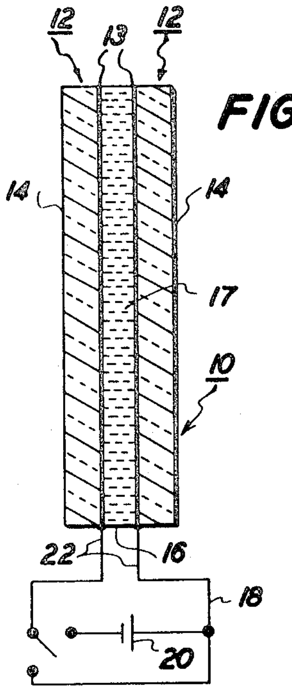


FIG. 8

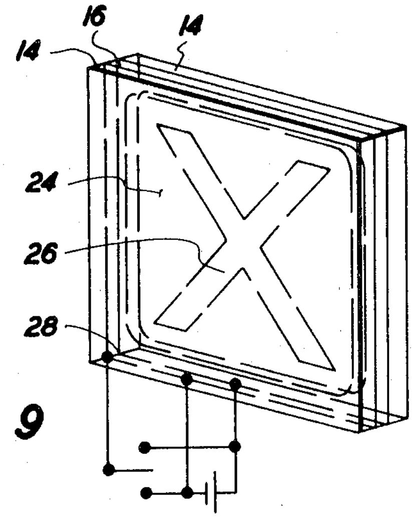
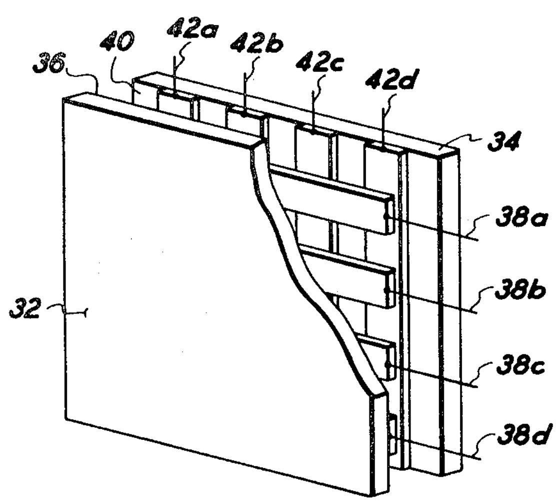


FIG. 9

FIG. 10



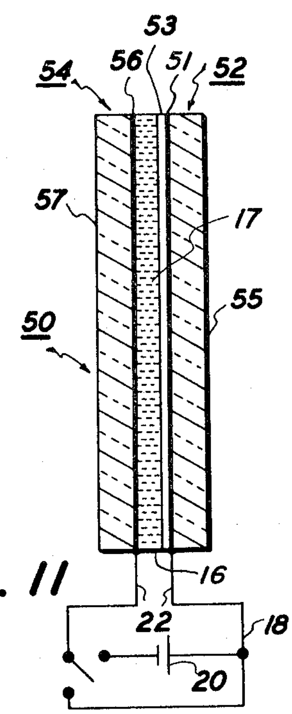


FIG. 11

NEMATIC LIQUID CRYSTALLINE COMPOSITIONS HAVING EXTENDED MESOMORPHIC RANGE

BACKGROUND OF THE INVENTION

This application relates generally to liquid crystalline compositions. More particularly the invention relates to such compositions having extended nematic mesomorphic temperature ranges which are stable at relatively low temperatures and their use in electro-optic applications.

Liquid crystalline substances exhibit physical characteristics some of which are typically associated with liquids and others which are typically unique to solid crystals. The name "liquid crystals" has become generic to substances exhibiting these dual properties. Liquid crystals are known to appear in three different forms: the smectic, nematic and cholesteric. These structural forms are sometimes referred to as mesophases thereby indicating that they are states of matter intermediate between the liquid and crystalline states. The three mesophase forms of liquid crystals mentioned above are characterized by different physical structures wherein the molecules of the compound are arranged in a structure which is unique to each of the three mesomorphic structures. Each of these structures is well known in the liquid crystal art.

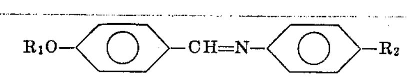
In the smectic structure the molecules are arranged in layers with their major axes approximately parallel to each other and approximately normal to the planes of the layers. Within a given layer the molecules may be organized in uniform rows, or randomly distributed throughout the layer, but in either case the major axes are still approximately normal to the plane of the layer. The attractive forces between layers are relatively weak so that layers are free to move in relation to each other thereby providing the smectic liquid crystalline substance with the mechanical properties of a planar or two-dimensional, soap-like fluid.

In the nematic structure the major axes of the molecules lie approximately parallel to each other but the molecules are not organized into definite layers as is the case in the smectic structure.

The sensitivity of the optical properties of nematic liquid crystals to electric fields makes these materials extremely useful for electro-optical applications. For example, dynamic scattering is common to many materials which exhibit nematic liquid crystalline mesophases. The so-called "dynamic scattering" state occurs when an ionic current flow is set up through the nematic liquid crystalline material and the nematogenic material assumes a non-selective light-scattering appearance. This phenomenon may be utilized in electro-optical devices such as, for example, display systems.

Heretofore a serious drawback with respect to potential uses of nematogenic materials in electro-optic devices has been the relatively high temperatures at which the majority of the known nematic materials become mesomorphic. Typically, electro-optic devices are operated at or near room temperature. Thus devices utilizing such nematic liquid crystalline materials would require additional apparatus to maintain the temperature of the liquid crystalline material within its mesomorphic range thereby undesirably complicating the overall device configuration.

Recently there was disclosed in the art a nematogenic material which is liquid crystalline at room temperature. H. Kelker and B. Scheurle, in Angew. Che., Inter. Ed. 8, 884 (1969), reported the preparation of p-methoxybenzylidene-p'-n-butylaniline (ABUTA) which has the chemical formula:



where $R_1 = CH_3$ and $R_2 = C_4H_9$ and has a nematic mesomorphic range of from about 20°C to about 41°C. While this compound has been found to be very useful in various electro-optic techniques nevertheless there exists a continuing need for liquid crystalline materials which have a nematic mesophase at or near room temperature.

SUMMARY OF THE INVENTION

It is, therefore, an object of this invention to provide liquid crystalline materials having the above-described desirable features.

It is another object of the invention to provide novel liquid crystalline compositions.

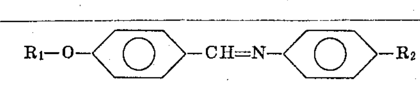
It is a further object of the invention to provide liquid crystalline compositions having nematic mesomorphic temperature ranges which are significantly larger than those of the individual components thereof.

It is a still further object of the invention to provide liquid crystalline compositions which have a nematic mesophase at or near room temperature.

Yet another object of the invention is to provide such liquid crystalline compositions which are useful in electro-optical applications.

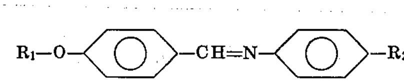
A still further object of the invention is to provide such liquid crystalline compositions which may be utilized in electro-optic display devices.

These and other objects and advantages of the invention are accomplished by providing novel liquid crystalline compositions which are formed by mixing together liquid crystalline compounds having a general formula



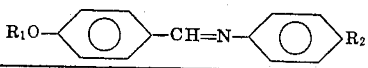
and which have a nematic mesophase which is stable at relatively low temperatures.

Liquid crystalline compounds which belong to the class of compounds having the general formula



and wherein R_1 and R_2 are particular combinations of alkyl groups are disclosed in copending application Ser. No. 179,732, filed Sept. 13, 1971 now abandoned, on the same day as the present application and hereby incorporated by reference herein. The compounds disclosed in the copending application are listed in Table I below:

TABLE I



R_1	R_2	Smectic (° C.)	Nematic (° C.)	Name
C_3H_7	C_4H_9	----------	39–59	*p-n*-Propoxybenzylidene-*p′-n*-butylaniline.
C_4H_9	C_4H_9	7–46	46–75	*p-n*-Butoxybenzylidene-*p′-n*-butylaniline.
C_5H_{11}	C_4H_9	24–54	54–71	*p-n*-Pentyloxybenzylidene-*p′-n*-butylaniline.
C_6H_{13}	C_4H_9	<25–70	70–78	*p-n*-Hexyloxybenzylidene-*p′-n*-butylaniline.
C_7H_{15}	C_4H_9	29–76	76–77.5	*p-n*-Heptyloxybenzylidene-*p′-n*-butylaniline.
C_4H_9	CH_3	*(49)–66	66–68	*p-n*-Butoxybenzylidene-*p*-toluidine.
C_4H_9	C_2H_5	42–52	52–67	*p-n*-Butoxybenzylidene-*p′*-ethylaniline.
C_5H_{11}	CH_3	35–45	45–64	*p-n*-Pentyloxybenzylidene-*p*-toluidine.

*Denotes monotropic transition.

It can be seen that the novel compounds disclosed in the copending application each possess a nematic mesophase which is stable at relatively low temperatures, i.e., near room temperature. These compounds have been found to be highly advantageous for use in various electro-optic applications such as, for example, display devices.

Now it has been surprisingly found that by utilizing some of the compounds listed in Table I and other members of the same generic class it is possible to form compositions which have significantly larger nematic mesomorphic temperature ranges than those of the individual compounds. The novel liquid crystalline compositions of the invention are: mixtures of p-methoxybenzylidene-p′-n-butylaniline (referred to hereinafter as ABUTA for simplicity) and p-n-butoxybenzylidene-p′-n-butylaniline (hereafter BOBUTA); mixtures of p-ethoxybenzylidene-p′-n-butylaniline ($R_1 = C_2H_5$ and $R_2 = C_4H_9$) (hereafter EOBUTA) and ABUTA; mixtures of EOBUTA and BOBUTA; mixtures of p-n-butoxybenzylidene-p′-ethylaniline (hereafter BOETHA) and ABUTA; mixtures of BOETHA and EOBUTA; mixtures of p-n-pentyloxybenzylidene-p′-n-butylaniline (hereafter PENTOBUTA) and ABUTA; and mixtures of p-n-hexyloxybenzylidene-p′-n-butylaniline (hereafter HEXOBUTA) and ABUTA. As will be seen below an extremely important characteristic of these novel compositions is that they typically have nematic mesophases which are stable at room temperature or slightly below and in some cases significantly below typically extending to below 0°C.

Thus it will be recognized that the compositions of the invention are highly advantageous when employed in various electro-optic applications since they allow overall device considerations to be desirably simplified. The novel compositions of the invention may be conveniently utilized in any number of electro-optic applications such as for example display cells since upon application of an electric field of sufficient magnitude, e.g., above about 3,000 volts/cm, the optical properties of the materials change and the liquid crystal material which is substantially transparent prior to the application of the field becomes "frosted," i.e., exhibits dynamic scattering. For a detailed description of this phenomenon see G. H. Heilmeier et al., Proc. IEEE 56, 7 (1968).

The foregoing and other objects and advantages of the invention will be more readily understood from the following detailed description of preferred embodi-

ments thereon particularly when viewed in conjunction with the accompanying drawings wherein:

FIG. 1 through FIG. 7 are graphical plots illustrating the eutectic behavior of the respective compositions of the invention with respect to varying mol fractions of the individual components thereof;

FIG. 8 is a partially schematic cross-sectional view of a liquid crystalline imaging member;

FIG. 9 is a partially schematic isometric view of an embodiment of a liquid crystalline imaging member wherein the desired image is defined by the shape of at least one of the electrodes;

FIG. 10 is a partially schematic isometric view of an embodiment of a liquid crystalline display device; and

FIG. 11 is a partially schematic cross-sectional view of an embodiment of a liquid crystalline imaging member wherein at least one of the electrodes has a photoconductive surface.

Generally speaking the individual compounds used to form the compositions of the invention are prepared by condensation in refluxing ethanol of the respective p-n-alkoxybenzaldehyde and the appropriate p-n-alkylaniline. Refluxing is carried for several hours and the solvent is then removed by distillation. The crystalline products are then purified by repeated recrystallization from an appropriate solvent such as methanol or petroleum ether. For a detailed description of the procedures used in forming these compounds see the copending application referred to earlier. The compositions are prepared by weighing appropriate fractions of the desired constituents, combining them in a vessel, e.g., a glass beaker, and heating above the isotropic transition temperatures of the respective constituents with mixing to ensure a homogeneous composition.

The temperatures at which transitions from the nematic mesomorphic state to the isotropic state occur, as indicated in FIGS. 1 through 7 for the respective compositions, are determined by differential thermal analysis employing a DuPont 900 Differential Thermal Analyzer equipped with chromel alumel thermocouples. The thermograms are obtained at a heating rate of 10°C/minute and the temperature at the beginning of the state transition endotherm is taken as the characteristic temperature. The temperature is determined by linear extrapolation of the leading edge of the endotherm to its intersection with the baseline.

Verification of the state assignments is obtained by polarized optical miscoscopy. Samples of these compositions are placed in the form of thin films, between glass cover slides and viewed through a Leitz Ortholux polarizing microscope having a calibrated hot stage. Visually observed texture changes have been found to coincide within 2°C with the phase transitions observed by thermal analysis.

Referring now to FIG. 1 there is seen a graphical plot illustrating the eutectic behavior of compositions prepared from varying mol fractions of BOBUTA and ABUTA. The nematic mesomorphic temperature range for BOBUTA is from about 46°C to about 75°C and that for ABUTA from about 20°C to about 41°C. It can be seen that the compositions possess extended nematic mesomorphic temperature ranges which generally increase progressively as the weight percent of the BOBUTA increases and which reach a maximum at from about 55 to about 65 weight percent BOBUTA.

FIG. 2 illustrates the eutectic behavior of compositions prepared from varying weight percentages of

EOBUTA and ABUTA. The nematic mesomorphic temperature range for EOBUTA is from about 38°C to about 82°C. The compositions possess extended nematic mesomorphic temperature ranges which reach a maximum at from about 50 to about 70 weight percent of ABUTA.

FIG. 3 illustrates the eutectic behavior of compositions prepared from varying weight percentages of BOBUTA and EOBUTA. The compositions are seen to have extended nematic mesomorphic temperature ranges which reach a maximum at from about 55 to about 75 weight percent of EOBUTA.

The eutectic behavior of compositions prepared from varying weight percentages of BOETHA and ABUTA is shown in FIG. 4. BOETHA has a nematic mesomorphic range of from about 48°C to about 62.5°C. The compositions have extended nematic mesomorphic temperature ranges which generally increase rapidly as the proportion of the ABUTA constituent increases and which reach a maximum at from about 60 to about 80 weight percent of ABUTA.

FIG. 5 illustrates the eutectic behavior of compositions prepared from varying weight percentages of BOETHA and EOBUTA. The compositions have extended nematic mesomorphic temperature ranges which reach a maximum at from about 70 to about 90 weight percent EOBUTA.

FIG. 6 graphically illustrates the eutectic behavior of compositions prepared from varying weight percentages of PENTOBUTA and ABUTA. PENTOBUTA has a nematic mesomorphic temperature range of from about 54° to about 71°C. The compositions have extended mesomorphic temperature ranges which generally increase rapidly as the proportion of the ABUTA constituent increases and which reach a maximum at from about 50 to about 80 weight percent of ABUTA.

The eutectic behavior of compositions prepared with varying mol fractions of HEXOBUTA and ABUTA is illustrated in FIG. 7. HEXOBUTA has a nematic mesomorphic temperature range of from about 70° to about 78°C. The compositions are seen to have extended nematic mesomorphic temperature ranges which generally become larger as the proportion of the ABUTA constituent increases and which reach a maximum at from about 50 to about 70 weight percent of ABUTA.

As was discussed previously the novel compositions of the invention may be utilized in a variety of electro-optic devices and provide simplified apparatus considerations therefore because of their stability at room temperature or below.

FIG. 8 illustrates a typical liquid crystalline electro-optic cell in which the novel compounds of the invention may be utilized. Referring now to FIG. 8 there is seen a liquid crystalline electro-optic cell 10, sometimes referred to as an electroded imaging sandwich, which is shown in partially schematic cross-section and wherein a pair of plates, generally designated 12, comprise a parallel pair of electrodes at least one of which is substantially transparent. An electro-optic cell wherein both electrodes are transparent is preferred when the cell is to be viewed using transmitted light; however a liquid crystalline electro-optic cell may also be viewed using reflected light thereby requiring only a single transparent electrode while the other is opaque. For purposes of illustration both electrodes 12 are shown as being substantially transparent and are comprised of, in this illustrative instance, a substantially transparent conductive layer 13 upon the contact surface deposited on a transparent support member 14. A typical suitable electrode for use in electro-optic cell 10 is commercially available under the name NESA glass from Pittsburgh Plate Glass Company and is made up of a thin transparent electrically conductive layer of tin oxide overlying a transparent glass substrate.

The transparent electrodes 12 are separated by spacing member 16 which contains voids which form one or more shallow cups which contain the liquid crystalline film or layer 17 which comprises the active element of the electro-optic cell. Liquid crystalline film 17 may be comprised of any of the novel liquid crystalline compounds of the invention or mixtures thereof. A field is created between the electrodes by means of an external circuit, generally designated 18 which typically comprises a source of potential 20 which is connected across the two electrodes through leads 22. The circuit 18 may also contain suitable switching means. The potential source 20 may be either D.C., A.C., or a combination thereof.

When an electric field of sufficient magnitude, e.g. above about 3,000 volts/cm, is applied across the liquid crystalline film the optical properties of the liquid crystalline material change and the liquid crystal film, which is substantially transparent prior to the application of the field, becomes "frosted," i.e., exhibits dynamic scattering. Thus the electro-optic cell can function as a light shutter since a large percentage (e.g. about 90 percent of incident light would be scattered and removed from the incident light while only a small percentage, e.g., about 10 percent would be transmitted.

In the liquid crystalline electro-optic cell described in FIG. 8 the electrodes may be of any suitable transparent conductive material. Typical suitable transparent, conductive electrodes include glass or plastic substrates having substantially transparent and continuous conductive coatings of conductors such as tin, indium oxide, aluminum, chromium, tin oxide or any other suitable conductor. These substantially transparent conductive coatings are typically evaporated onto the more insulating transparent substrate. Where an opaque electrode is employed in the electro-optic cell any suitable electrode material may be used. In FIG. 8 the spacer 16, which separates the transparent electrodes and contains the liquid crystal film 17 between the electrodes is typically chemically inert, transparent, substantially insulating and has appropriate dielectric characteristics.

Materials which are suitable for use as typical insulating spacers include cellulose acetate, cellulose triacetate, cellulose acetate butyrate, polyurethane elastomers, polyethylene, polypropylene, polyesters, polystyrene, polycarbonates, polyvinylfluoride, polytetrafluoroethylene, polyethylene terephthalate, and mixtures thereof. These spacers, which also approximately define the thickness of the imaging layer or film 17 of liquid crystalline material, are preferably of a thickness in the range of about 10 mils or less. Optimum results are typically attained with spacers in the thickness range between about ¼ mil and about 5 mils.

FIG. 9 describes a liquid crystalline electro-optic imaging cell. In this preferred embodiment the desired image is defined by the shape of an electrode and, therefore, by the shape of the corresponding electric field. The imaging cell here comprises transparent plates **14** separated by spacer gasket **16** having void area **24** filled with liquid crystalline material, said area comprising substantially the entire area of spacer member **16.** The desired image is defined by the shape of the substantially transparent conductive coating, designated **26** affixed to the inner surface of one or both of transparent substrates **14.** The embodiment illustrated in FIG. **9** shows only one of the two electrodes in image configuration; however it will be understood by those skilled in the art that both electrodes could easily be made in a matched pair to define the same desired image. When the single image electrode configuration is used the second electrode will comprise transparent substrate **14** with substantially transparent conductive coating **13** upon the entire area of the inner surface of the transparent electrode. It is noted that a very thin, or substantially invisible conductor **28** is typically used in this embodiment to electrically connect the electrode in the desired image configuration to an external circuit which is similarly connected to the conductive coating of the opposite electrode. In operation this embodiment will produce an electric field only in areas where there are parallel electrodes, i.e., between the electrode in the desired image configuration and the opposite electrode, whether or not the second electrode is also in the desired image configuration. Again here, one of the electrodes may be opaque if it is desired to observe the imaged cell by reflected light rather than transmitted light.

Additionally, where the desired image is defined by the shape of one or more electrodes, an electrode may be shaped in the configuration of the background of the desired image and an imagewise electrode and such a corresponding background electrode may be coplanar and insulated from one another by an open space or insulating material. Such a coplanar pair of electrodes may be operated simultaneously as a substantially full-area electrode.

FIG. **10** describes a preferred embodiment of a liquid crystalline imaging cell embodying an *x-y* grid and comprising two transparent planar substrates **32** and **34** which are parallel. On the inner surface **36** of substrate **32** are arranged an array of transparent conductive strips all running in one direction. Four strips or electrodes, designated **38***a*, **38***b*, **38***c*, **38***d*, and which have parallel longitudinal axes are shown; however it will be understood that in actual practice a much larger number of electrodes may be used. On the inner surface **40** of substrate **34** are arranged an array of transparent conductive electrodes **42***a*, **42***b*, **42***c*, **42***d* having parallel longitudinal axes and being positioned substantially perpendicularly to the direction of the conductive strips **38***a*–**38***d* on substrate **32.** Again it will be understood that in actual practice a much larger number of electrodes may be arranged on inner surface **40** of substrate **34.** The space between substrates **32** and **34** is filled with liquid crystalline which can be any of the novel compounds of the invention or mixtures thereof.

It will be understood by those skilled in the art that when two electrode strips, each being perpendicular to the other, are energized with an applied voltage, the portion of the liquid crystal cell corresponding to the intersection of the two electrodes which have been energized will become darker than the remaining area of the cell. By energizing more than one electrode strip from each set, a plurality of predetermined areas are made to appear darker.

FIG. **11** describes still another preferred embodiment of a liquid crystalline electro-optic imaging cell wherein one of the electrodes comprises a photoconductor and imaging is effected by applying a uniform potential across the entire area of the electrodes and subsequently exposing the photoconductor to an imagewise pattern of activating electromagnetic radiation corresponding to a desired image configuration. Referring now to FIG. **11** there is seen an electro-optic imaging cell, generally designated **50,** wherein a pair of plates, generally designated **52** and **54** respectively, comprise a parallel pair of electrodes at least one of which is substantially transparent. For purposes of illustration both electrodes are shown as being transparent. Electrode **52** is made up of a photoconductive insulating material layer **53** overlying a conductive substrate which in this instance is shown as a substantially transparent conductive layer **51** deposited on a substantially transparent support member **55.** Electrode **54** is shown as a substantially transparent conductive layer **56** deposited on substantially transparent substrate **57.**

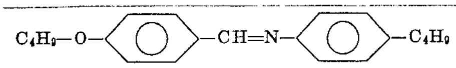
When it is desired to view the electro-optic cell using transmitted light it is preferred that both electrodes be substantially transparent. Of course in this instance there is required a photoconductive insulating material layer which is substantially transparent to the activating electromagnetic radiation. Typical suitable substantially transparent photo-conductive materials include, for example, relatively thin, e.g., about 5 microns, layers of selenium. However the electro-optic imaging cell may also be viewed using reflected light thereby requiring only a single transparent electrode while the other may be opaque. In this instance one of the electrodes is preferably made up of an opaque photoconductive insulating layer deposited on an opaque substrate which may be any suitable conducting material such as a metallic layer.

The transparent electrodes are separated by spacing member **16** which contains voids which form one or more shallow cups which contain the liquid crystalline film or layer **17.** The electrodes are connected to opposite terminals of an external circuit **18.** When a potential is applied to the conducting surface **51** of electrode **52** in the dark no current will flow and no field will be established across the liquid crystal film since layer **53** is insulating under these conditions. However when the imaging cell is exposed to an imagewise pattern of activating radiation, the light-struck areas of photoconductive insulating layer **53** become conductive causing current to flow and establishing a field across the liquid crystal film in the light-struck areas. The electric field causes the optical properties of the liquid crystalline material to change and the liquid crystal film, which is substantially transparent prior to the application of the field, becomes "frosted," i.e., exhibits dynamic scattering thereby effecting imaging. When the imaging cell is viewed by reflected light the image will typically appear as milky-white image areas on a dark background. When the imaging cell is viewed using transmitted light the image will typically appear as dark image areas with transparent non-image or background areas.

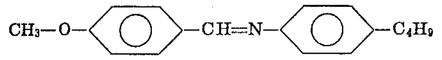
Although the invention has been described in detail with respect to various preferred embodiments thereof it is not intented to be limited thereto but rather it will be recognized by those skilled in the art that modifications and variations are possible which are within the spirit of the invention and the scope of the claims.

What is claimed is:

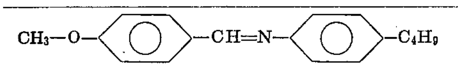
1. Liquid crystalline compositions comprising from about 55 to about 65 weight percent of



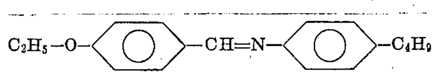
and from about 35 to about 45 weight percent of



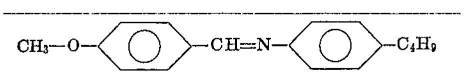
2. Liquid crystalline compositions comprising from about 50 to about 70 weight percent of



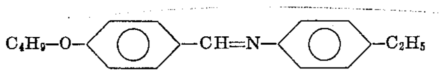
and from about 30 to about 50 weight percent of



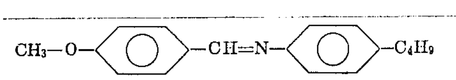
3. Liquid crystalline compositions comprising from about 60 to about 80 weight percent of



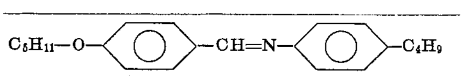
and from about 20 to about 40 weight percent of



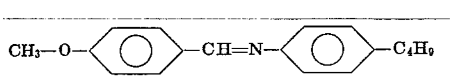
4. Liquid crystalline compositions comprising from about 50 to about 80 weight percent of



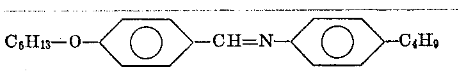
and from about 20 to about 50 weight percent of



5. Liquid crystalline compositions comprising from about 50 to about 70 weight percent of



and from about 30 to about 50 weight percent of



6. A method for transforming a liquid crystalline material from the optically transparent state to a light-scattering state comprising,

providing a liquid crystalline material comprising a composition of claim 1, and

applying an electric field across said liquid crystalline material, said electric field being of sufficient strength to transform said liquid crystalline material to a light-scattering state.

7. The method as defined in claim 6 wherein the liquid crystalline material is arranged between two electrodes at least one of which is substantially transparent.

8. The method of imaging a liquid crystalline material comprising,

providing a layer of a liquid crystalline material shaped in image configuration between two electrodes at least one of which is substantially transparent, said liquid crystalline material comprising a composition of claim 1, and

applying an electric field across said liquid crystalline material, said electric field being of sufficient strength to transform said liquid crystalline material to a light-scattering state whereby a visible image is formed.

9. The method of imaging a liquid crystalline material comprising,

providing a layer of a liquid crystalline material between two electrodes at least one of which is substantially transparent and at least one of which is shaped in image configuration, said liquid crystalline material comprising a composition of claim 1, and

applying an electric field across said liquid crystalline material, said electric field being of sufficient strength to transform said liquid crystalline material to a light-scattering state whereby a visible image is formed.

10. The method of imaging a liquid crystalline material comprising,

providing a layer of a liquid crystalline material between two electrodes at least one of which is substantially transparent and at least one of which includes a photoconductive surface, said liquid crystalline material comprising a composition of claim 1,

energizing said electrodes by applying a potential thereto,

exposing said photoconductive surface to an imagewise pattern of activating electromagnetic radiation causing an imagewise electric field to be applied across said liquid crystalline material, said electric field being of sufficient strength to transform said liquid crystalline material to a light-scattering state whereby a visible image is formed.

11. The method of producing a display comprising providing a display device comprising first and second spaced plates, at least one of which is substantially transparent, a plurality of parallel electrically conductive films on one face of said first plate, a plurality of parallel electrically conductive films on one face of said second plate, the plurality of conductive films on at least one plate being substantially transparent, said two plates being positioned with said faces bearing said parallel conductive films adjacent and parallel to each other and the direction of said conductive films on one plate being perpendicular to the direction of said conductive films on the other plate, and a liquid crystalline material comprising a composition of claim 1 filling the space between said plates, and

selectively energizing at least one conductive film on each plate causing an electric field to be selectively applied across said liquid crystalline material, said electric field being of sufficient strength to selectively transform said liquid crystalline material to a light-scattering state.

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