FORM 1

605793

SPRUSON & FERGUSON

COMMONWEALTH OF AUSTRALIA

PATENTS ACT 1952

LODGED AT SUB-OFFICE
19 OCT 1987
Sydney

APPLICATION FOR A STANDARD PATENT

F Hoffmann-La Roche & Co Aktiengesellschaft, of Grenzacherstrasse 124-184, CH-4002 Basle, SWITZERLAND, hereby apply for the grant of a standard patent for an invention entitled:

FEE STAMP TO VALUE OF $160 ... ATTACHED

Liquid Crystal Display Device

which is described in the accompanying complete specification.

Details of basic application(s):-

| Basic Applic. No: | Country: | Application Date: |
|---|---|---|
| 4234/86 | SWITZERLAND | 24 October 1986 |

PATENT OFFICE 100 LODGED IN SYDNEY ONE HUNDRED DOLLARS PATENT OFFICE AUSTRALIA SIXTY DOLLARS

The address for service is:-

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Patent Attorneys
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DATED this SIXTEENTH day of OCTOBER 1987

F Hoffmann-La Roche & Co Aktiengesellschaft

By: M.J. Anderson

Registered Patent Attorney

TO: THE COMMISSIONER OF PATENTS
OUR REF: 38872
S&F CODE: 55541

ACCEPTED AND AMENDMENTS

23-10-96

5845/2

COMMONWEALTH OF AUSTRALIA

THE PATENTS ACT 1952

# DECLARATION IN SUPPORT OF A CONVENTION APPLICATION FOR A PATENT

AUSTRALIA CONVENTION STANDARD & PETTY PATENT DECLARATION

In support of the Convention Application made for a patent for an invention entitled:

~~NAN 47011/25~~

Title of Invention

Liquid Crystal Display Device

I Fridolin Klausner

Full name(s) and address(es) of Declarant(s)

of 187 Baselmattweg, 4123 Allschwil, Switzerland

do solemnly and sincerely declare as follows:-

Full name(s) of Applicant(s)

1. I am authorised by F.HOFFMANN-LA ROCHE & CO. Aktiengesellschaft, of 124-184 Grenzacherstrasse, Basle, Switzerland,

the applicant(~~s~~) for the patent to make this declaration on its/~~their~~ behalf.

2. The basic application(~~s~~) as defined by Section 141 of the Act was/~~were~~ made

Basic Country(ies) in Switzerland

Priority Date(s) on October 24, 1986

Basic Applicant(s) by [X] F. HOFFMANN-LA ROCHE & CO., Aktiengesellschaft

[ ] the inventor(s) cited in paragraph 3.

3. Full name(s) and address(es) of inventor(s)

Frans Leenhouts, 73 Violaweg, 4303 Kaiseraugst, Switzerland,

(~~respectively~~)

Set out how Applicant(s) derive title from actual inventor(s) e.g. The Applicant(s) is/are the assignee(s) of the invention from the inventor(s)

is/~~are~~ the actual inventor(~~s~~) of the invention and the facts upon which the applicant(~~s~~) is/~~are~~ entitled to make the application are as follows:

( ) the inventor(s) have assigned the invention to Hoffmann-La Roche Inc., Nutley, USA, who have re-assigned all their rights for Australia to the Applicant.

(x) the Applicant is the assignee of the invention from the inventor(~~s~~).

4. The basic application(~~s~~) referred to in paragraph 2 of this Declaration was/~~were~~ the first application(~~s~~) made in a Convention country in respect of the invention(~~s~~) the subject of the application.

Declared at Basle, this 17th day of September, 1987

To:

The Commissioner of Patents,
COMMONWEALTH OF AUSTRALIA

Fridolin Klausner

Signature of Declarant(s)

(12) PATENT ABRIDGMENT (11) Document No. AU-B-79880/87
(19) AUSTRALIAN PATENT OFFICE (10) Acceptance No. 605793

(54) Title
LCD OF LOW OPTICAL PATH DIFFERENCE

International Patent Classification(s)
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(56) Prior Art Documents
US 4378955

(57) Claim

1. A liquid crystal display (LCD) cell comprising a twisted nematic liquid crystal disposed between two plates having electrodes and surface orientations, and wherein the plates are disposed between two polarizers the liquid crystal having a positive dielectric anisotropy, characterized by the combination of: a twist angle $\phi$ of from 10° to 80°; an angle $\Theta$ between the surface orientation direction and the polarization direction of the plate on the light incidence side of from -30° to 60°; an angle $\psi$ between the polarization directions of the two polarizers of from 80° to 110°; and an optical path difference $\Delta n.d$ of from 0.2 to 0.7 $\mu$m.

605793

S & F Ref: 38872

FORM 10

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PATENTS ACT 1952

COMPLETE SPECIFICATION

(ORIGINAL)

FOR OFFICE USE:

Class Int Class

Complete Specification Lodged:
Accepted:
Published:

Priority:

Related Art:

This document contains the amendments made under Section 49 and is correct for printing

Name and Address of Applicant: F Hoffmann-La Roche & Co Aktiengesellschaft
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Level 33 St Martins Tower, 31 Market Street
Sydney, New South Wales, 2000, Australia

Complete Specification for the invention entitled:

Liquid Crystal Display Device

The following statement is a full description of this invention, including the best method of performing it known to me/us

5845/3

RAN 4701/125

## Abstract

A liquid crystal display (LCD) cell comprising a twist nematic liquid crystal disposed between two electrode plates and polarizers and having a positive dielectric anisotropy. The optical path difference $\Delta n.d$ is 0.2 to 0.7 µm. The absolute value of the twist angle $\varphi$ can be between 10° and 80°, the angle $\psi$ between the polarizers can be between 80° and 110° and the angle $\theta$ between the surface orientation direction and the polarization direction on the screen on the light incidence side can be between -10° and 60°, preferably so that the polarizers are symme- trical of the nematic directors.

RAN 4701/125

The invention relates to a liquid crystal display (LCD) cell comprising a twisted nematic liquid crystal layer which is disposed between two plates and polarizers having electrodes and surface orientations and which has a positive dielectric anisotropy.

The invention relates more particularly to an LCD cell of the kind set out wherein the nematic liquid crystal layer has a very low optical path difference.

If they are to have a high multiplex ratio, LCD cells must of course have a steep electro-optical characteristic. The corresponding development was concentrated on highly twisted nematic structures. The term "highly twisted nematic structures" is to be understood as denoting structures having a twist of more than 90°. Of course, doping with chiral additives is usually necessary to produce such a twist.

The advantages of liquid crystal cells having highly twisted nematic structures are a very steep electro-optical characteristic and a wide viewing angle range. The steep electro-optical characteristic leads to high multiplex ratios which are necessary to provide indications of high information density.

However, little regard was had for the fact that the main requirement for some purposes is not a high multiplex ratio but the possiblity of providing a highly differentiated grey scale. This is more particularly the case, for example, for television applications.

According to this invention there is provided a liquid crystal display (LCD) cell comprising a twisted nematic liquid crystal disposed between two plates having electrodes and surface orientations, and wherein the plates are disposed between two polarizers the liquid crystal having a positive dielectric anisotropy, characterized by the combination of: a twist angle $\varphi$ of from 10° to 80°; an angle $\theta$ between the surface orientation direction and the polarization direction of the plate on the light incidence side of from -30° to 60°; an angle $\psi$ between the polarization directions of the two polarizers of from 80° to 110°; and an optical path difference $\Delta n.d$ of from 0.2 to 0.7 µm.

For the purposes of this description the following angles are to be understood as follows:

The twist angle $\varphi$ is the angle included between the planes which are defined by the two nematic directors on the front plate - i.e., the plate on the light incidence side - and on the rear plate and which are perpendicular to the plates - i.e., in other words the angle by which the nematic directors are offset from one another. This definition corresponds to the conventional definition.

The angle $\theta$ is the angle between the surface orientation on the front plate or on the nematic director $n_1$ on the plate and the polarization direction of the polarizer associated with the last-mentioned plate. Positive values of the angle $\theta$ indicate that the polarization direction is outside the angle $\varphi$ while negative values of $\theta$ indicate a polarization direction between the nematic directors.

The angle $\psi$ is the angle by which the polarizers are offset from one another. The polarizers are called crossed when they substantially bar the passage of light without any light-influencing means between them. This means that the

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term "crossed" covers all the corresponding values of $\psi$ and is not limited exclusively to a 90° offset.

The resulting cell provides a positive contrast display and, surprisingly, is not coloured for low values of $d\Delta n$ and $\theta = 0$.

In positive contrast displays electrically energized segments appear dark on a bright background whereas in negative contrast displays the situation is the converse.

Embodiments of the invention will be described hereinafter with reference to the drawings wherein:

Figure 1 is a diagrammatic exploded view of an LCD cell according to the invention;

Figure 2 is a diagram showing the arrangement of angles, the surface orientations and the polarizers relatively to one another, and

Figure 3 illustrates a voltage-contrast curve of a preferred embodiment.

The LCD cell according to the invention is of very similar construction to known cells, such as Twisted Nematic LCDs (Schadt and Helfrich, Appl. Phys. Lett. 18, 127 [1971]), so that there is no need here to go into constructional details. The cell according to the invention comprises a liquid crystal layer 1 disposed between two plates ~~3, 4~~ 2 and 3 which are disposed substantially plane-parallel to one another and which are made of a transparent material such as glass or acrylic glass or plastic foils or the like. A polarizer 4 is disposed before the front plate 2 and is preferably connected thereto, for example, by sticking. A polarizer 5 is similar associated with the rear plate 3. The plates are separated from one another by a spacing or gap d.

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On their surfaces facing the liquid crystal the plates 2 and 3 ~~3, 4~~ have conventional electrode coatings 6 segmented for the display of symbols or dots. Also, the surfaces are so treated as to exert a directional effect on the adjacent liquid crystal molecules and thus determine the direction of the nematic director n. The treatment resides, for example, in rubbing the surface in one direction or in the oblique evaporation of orienting layers etc; it is not necessary, but neither is it disadvantageous, to provide a tilt angle. The result of this treatment will be called surface orientation for the purpose hereof. An arrow 7 indicates the surface orientation on the front plate 2. The surface orientation on the rear plate 3 is offset from that of the front plate and is indicated by an arrow 8.

The front plate polarizer is so disposed that its polarization direction includes relatively to the twist angle in the outwards direction a predetermined angle which will be described in greater detail hereinafter. The rear polarizer is so disposed that its direction of polarization crosses that of the first polarizer.

The liquid crystal 1 is a nematic liquid crystal which can have chiral additives.

Figure 2 illustrates the relative angular relationships of the nematic directors and the polarization directions. As previously stated, $n_1$ is the nematic director on the front plate 2 and $n_2$ is the nematic director on the back plate 3. The angle of twist between the two nematic directors has the reference $\phi$. This angle is approximately 50° in the present embodiment. However, it can vary on either side of 50°. Satisfactory results are obtained with absolute values of $\varphi$ between 10° to 80°, preferably 20° and 60°, more particularly 30° and 50°.

AUSTRALIAN PATENT OFFICE MTS

The front polarizer 4 has a polarization direction $P_1$. In this embodiment such direction is offset by an angle $\theta$ of 20° from the nematic director $n_1$. However, the direction $P_1$ can vary by an angle $\theta$ from the nematic director $n_1$ in a range of from $-30° < \theta < 60°$. In other words, the polarizers can be arranged symmetrically of the nematic directors. The condition for this is $\theta = (90°-\varphi)/2$ if $\psi = 90°$. Symmetry is preferable but not obligatory. The polarization direction $P_2$ of the rear polarizer 5 is offset from that of the front polarizer $P_1$ by an angle $\psi$ which is preferably 90°. However, satisfactory results are obtained with an angle $\psi$ of from 80° to 110°. The polarization directions $P_1$ and $P_2$ can be changed over without adverse results.

In other preferred embodiments, for example, $\theta = 30°$, $\varphi = 30°$ and $\psi = 90°$, the following liquid crystal mixture (mixture "A") being used in a layer of a thickness d = 3.4 µm:

Mixture "A"

| Component | | Concentration (weight %) |
|---|---|---|
| ød(4)CP | p-[trans-4-(4-pentenyl) cyclohexyl]benzonitrile | 8,000 |
| 5CP | p-(trans-4-pentylcyclo-hexyl)benzonitrile | 11,000 |
| 4P(1)P | p-(5-butyl-2-pyrimidinyl)-benzonitrile | 3,000 |
| 5CAP02 | p-[2-(trans-4-pentylcyclo-hexyl)ethyl]-ethoxybenzene | 6,000 |

| | | |
|---|---|---|
| 3CEC3 | trans-4-propylcyclohexane carboxylic acid-trans-4--propylcyclohexyl ester | 8,000 |
| 4CEC4 | trans-4-butylcyclohexane carboxylic acid-trans-4--butylcyclohexyl-ester | 11,000 |
| 5CEC3 | trans-4-pentylcyclohexane carboxylic acid-trans-4--propylcyclohexyl-ester | 11,000 |
| 5CPAC4 | 1-[2-(trans-4-butylcyclohexyl)-ethyl]-4-(trans-4--pentylcyclohexyl)benzene | 9,500 |
| 5CPPAC4 | 4-[2-(trans-4-butylcyclohexyl)-ethyl]4'-(trans-4--pentyl-cyclohexyl)biphenyl | 5,500 |
| 5CPAPAC4 | 4-(trans-4-pentylcyclohexyl)-4'-[2-(trans-4-butylcyclohexyl)-ethyl]-1,1'-ethylene-dibenzene | 7,000 |
| 4CEPO2 | trans-4-butylcyclohexane carboxylic acid-p-ethoxy--phenylester | 11,000 |
| 5CEPO1 | trans-4-pentylcyclohexane carboxylic acid-p-methoxy-hexylester | 9,000 |

A second example was prepared with the following mixture "B":

| Mixture "B" | | Concentration |
|---|---|---|
| Component | | (weight %) |
| 4P(1)P | p-(5-butyl-2-pyrimidinyl)-benzonitrile | 8,820 |
| ød(3)CP | p-[trans-4-(3-butenyl)-cyclohexyl]benzonitrile | 7,390 |
| 1d(3)CP | p-[trans-4-(3E-pentenyl)-cyclohexyl]benzonitrile | 7,420 |
| ød(4)CPP | 4'-[trans-4-(4-pentenyl)-4-biphenylcarbonitrile | 6,170 |
| 3CEC3 | trans-4-propylcyclohexane carboxylic acid-trans-4-propylcyclohexyl ester | 21,050 |
| 4CEC4 | trans-4-butylcyclohexane carboxylic acid-trans-4-butylcyclohexylester | 28,100 |
| 5CEC3 | trans-4-pentylcyclohexane carboxylic acid-trans-4-propylcyclohexylester | 21,050 |

The designation of the components is known to the skilled addressee. Reference is made in this connection, for example to the publication of Schadt, M. et al in Mol. Cryst. Lig. Cryst. 122 (1985) 241ff and in Proc. Int. Displ. Res. Conf., San Diego (1985).

The following Table 1 lists the relevant parameters of the two mixtures "A" and "B".

Table 1

| | Mixture "A" | Mixture "B" |
|---|---|---|
| Clearing point $T_{Cl}$ [°C] | 72 | 42.5 |
| Melting point $T_m$ [°C] | <-20 | <0 |
| $n_o$ | 1,432 | 1,476 |
| Optical anisotropy $\Delta n$ | 0,086 | 0,072 |
| Viscosity $\eta$ / (at 22°C) [m pa. s] | 23 | 21 |

The electro-optical results compiled in the following Table 2 were obtained with these mixtures. The results achieved with the novel cell according to the invention are in each case compared with the values obtained with the same liquid crystal mixtures in a conventional twisted nematic cell and listed in the third column.

Table 2

Mixture "A"

| | $\varphi$=30° $\Theta$=30 $\psi$=90 | $\varphi$=60 $\Theta$=15 $\psi$=90 | $\varphi$=90 $\Theta$= 0 $\psi$=90 |
|---|---|---|---|
| $V_{10}$ (Volt) | 2.165 | 2.058 | 1.971 |
| $V_{50}$ (Volt) | 2.895 | 2.617 | 2.265 |
| $P_o$ | 0.337 | 0.271 | 0.149 |
| d [µm] | 3.4 | 3.8 | 4.0 |
| $d\Delta n$ [µm] | 0.29 | 0.33 | 0.34 |

Mixture "B"

| | φ=30° θ=30 ψ=90 | φ=60 θ=15 ψ=90 | φ=90 θ= 0 ψ=90 |
|---|---|---|---|
| $V_{10}$ (Volt) | 1.562 | 1.614 | 1.441 |
| V50 (Volt) | 2.092 | 2.015 | 1.671 |
| Po | 0.339 | 0.248 | 0.159 |
| d [µm] | 4.5 | 6.0 | 7.0 |
| dΔn [µm] | 0.32 | 0.43 | 0.50 |

Key to Table 2:

$V_{10}$ denotes the optical threshold voltage at 10% extinction (or 90% transmission).

$V_{50}$ denotes the voltage at 50% extinction or transmission.

$p_o$ denotes the steepness of the transmission curve at a viewing or light incidence angle ß = 0° in accordance with the formula:

$$p_o = \frac{V_{50} - V_{10}}{V_{10}}$$

Figure 3 shows the contrast curves characteristic of the electro-optical behaviour as compared with a conventional twisted nematic cell, the curves having been taken in white light at φ = 30°, θ = 30° and ψ = 90° (curve I) at φ = 60°, θ = 15° and ψ = 90° (curve II) and at φ = 90°, θ = 0° and ψ = 90° (twisted nematic cell, curve III). Clearly, the curve becomes steeper as the angle of twist increases.

The cell hereinbefore described can be operated in transmission and in reflection.

The claims defining the invention are as follows:

1. A liquid crystal display (LCD) cell comprising a twisted nematic liquid crystal disposed between two plates having electrodes and surface orientations, and wherein the plates are disposed between two polarizers the liquid crystal having a positive dielectric anisotropy, characterized by the combination of: a twist angle $\varphi$ of from 10° to 80°; an angle $\theta$ between the surface orientation direction and the polarization direction of the plate on the light incidence side of from -30° to 60°; an angle $\psi$ between the polarization directions of the two polarizers of from 80° to 110°; and an optical path difference $\Delta n.d$ of from 0.2 to 0.7 $\mu$m.

2. A cell according to claim 1, characterized by an optical path difference $\Delta n.d$ of from 0.3 to 0.5 $\mu$m.

3. A cell according to claim 1, characterized by a twist angle $\varphi$ of from 20° to 60°.

4. A cell according to claim 1, characterized by a twist angle $\varphi$ of from 30° to 50°.

5. A cell according to claim 1, characterized in that the angle $\theta$ is defined by the condition $\theta = (90° - \varphi)/2$, the angle $\psi$ between the polarizers being 90°.

6. A cell according to claim 1, characterized by an angle $\theta$ of from 0° to 60°.

7. A cell according to claim 1, characterized by an angle $\theta$ of from -30° to 0°.

8. A cell according to claim 1, characterized by an angle $\psi$ of 90°.

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9. A liquid crystal display (LCD) cell comprising a twisted nematic liquid crystal layer which is disposed between two plates and polarizers having electrodes and surface orientations and which has a positive dielectric anisotropy which cell is substantially as herein described with reference to Figs. 1 to 3.

DATED this TWELFTH day of OCTOBER 1987

F.Hoffmann-La Roche & Co Aktiengesellschaft

Patent Attorneys for the Applicant

SPRUSON & FERGUSON

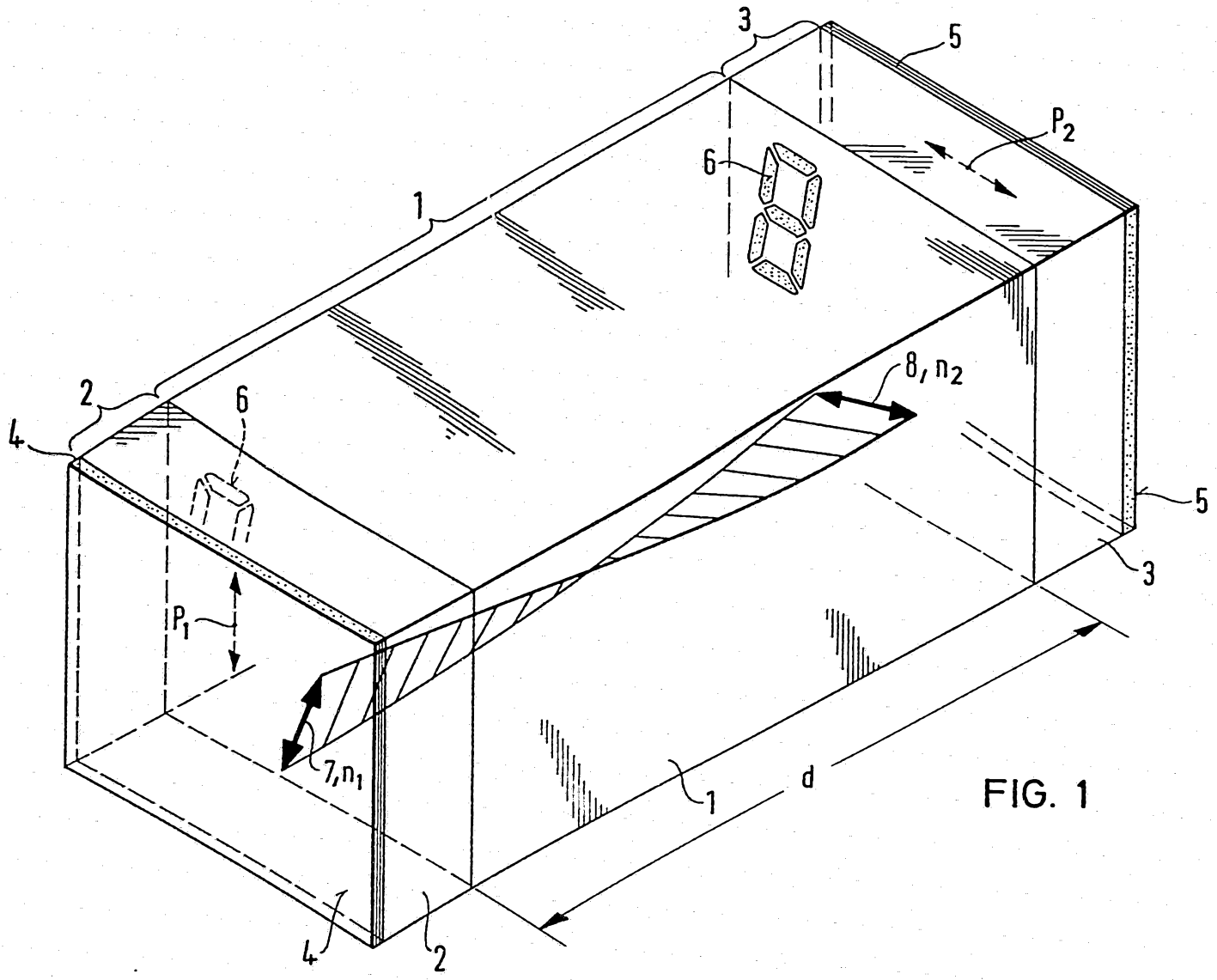
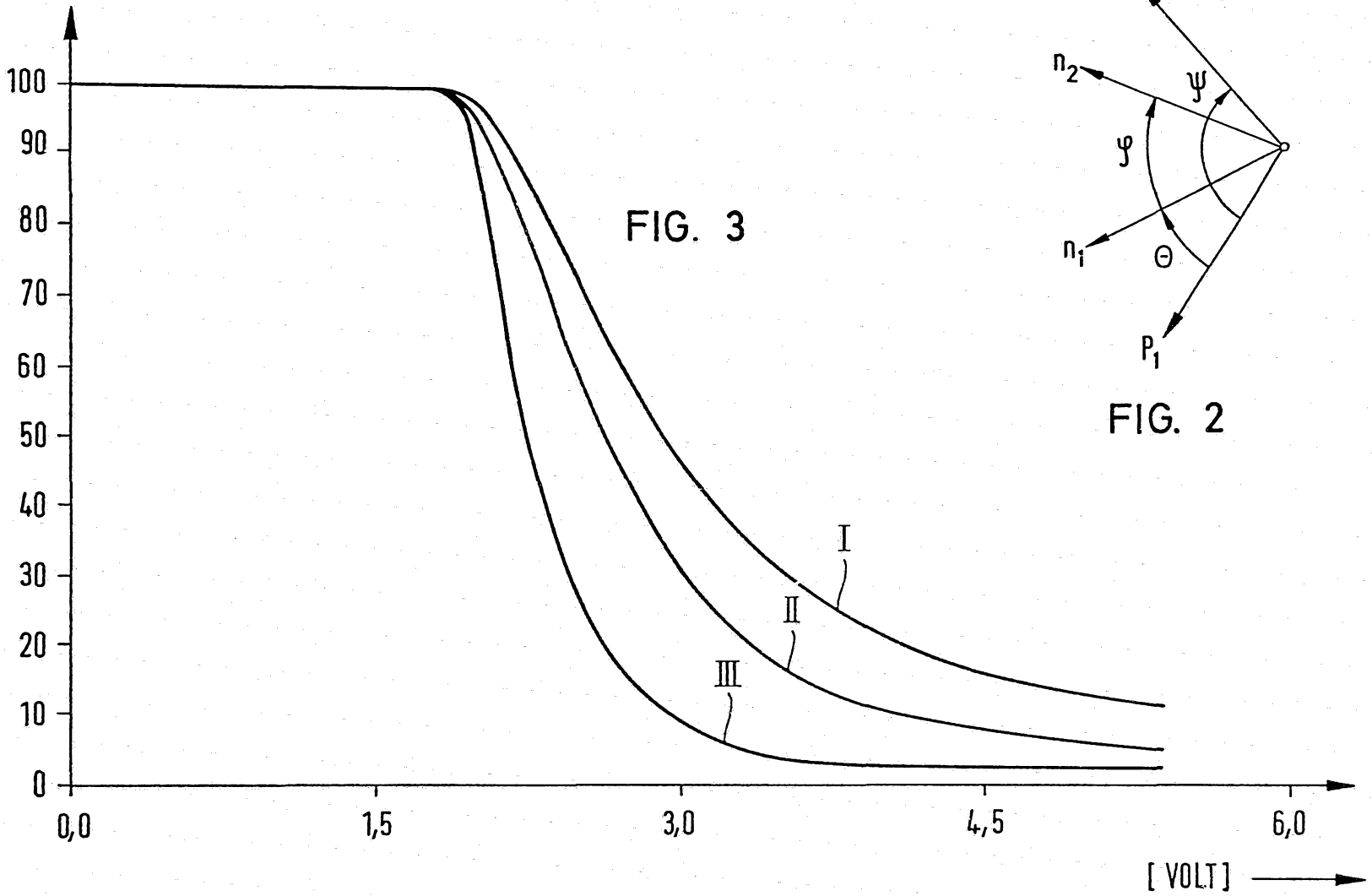



FIG. 1

79 880/87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60
50
40
30
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[VOLT]
I
II
III

FIG. 3

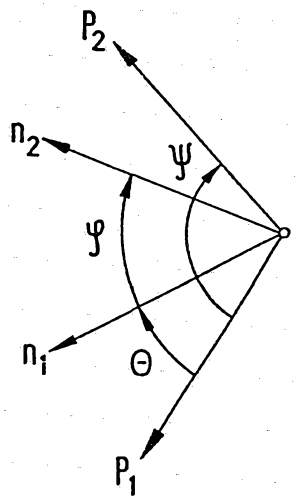
P2
n2
Ψ
φ
n1
Θ
P1

FIG. 2