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(54) METHOD FOR MANUFACTURING COLOR FILTER HAVING LOW REFLECTION AND LIQUID CRYSTAL DISPLAY DEVICE INCORPORATING SAME

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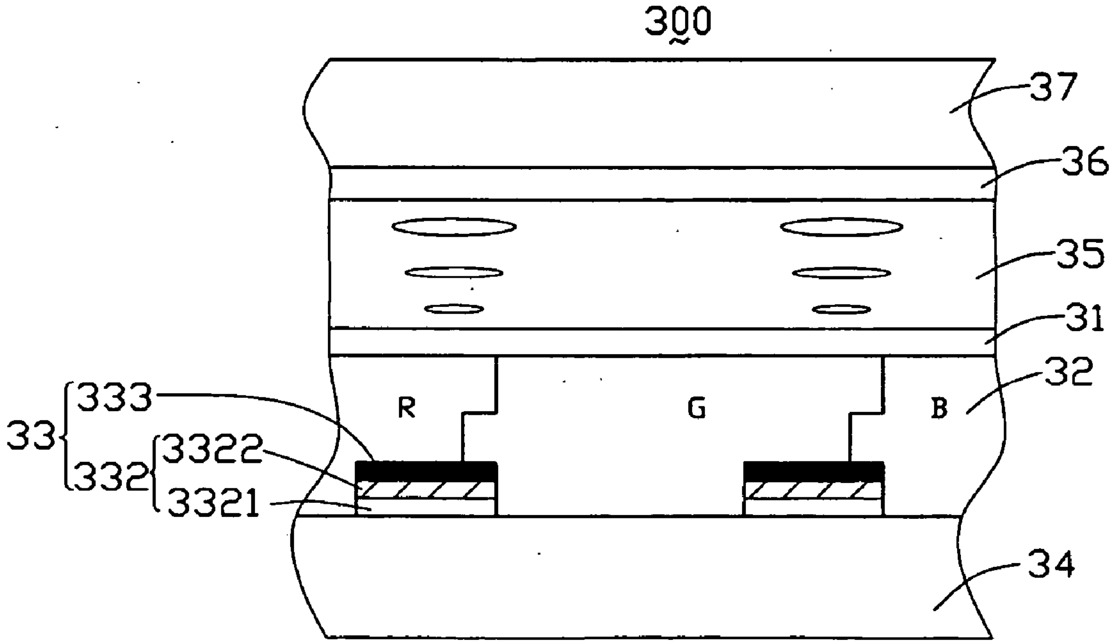
(57) ABSTRACT

A method for manufacturing a color filter **30**) includes: preparing a transparent substrate **34**); forming a black matrix **33**) on the transparent substrate, the black matrix including an antireflection layer (**332**) formed on the transparent substrate and a light-shielding layer **333**) formed on the antireflection layer, the antireflection layer including a first antireflection film **3321**) having a first index of refraction, and a second antireflection film **3322**) having a different second index of refraction, the black matrix defining a plurality of apertures arranged in an array; and coating a color resin layer **32**) on the transparent substrate and the black matrix.



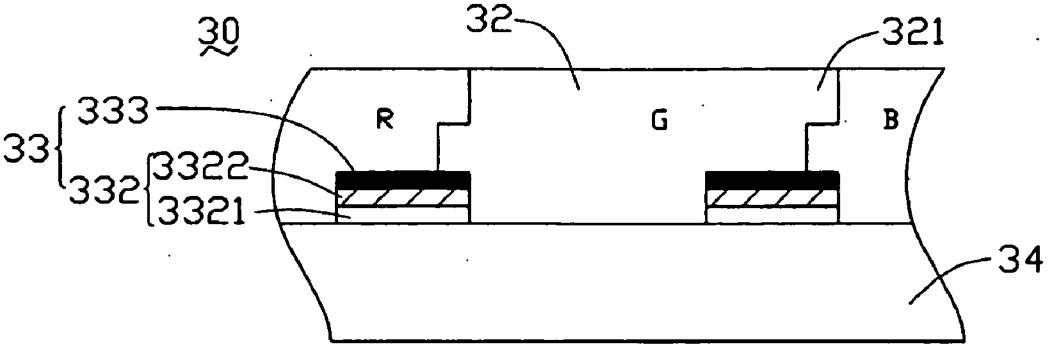


FIG. 1

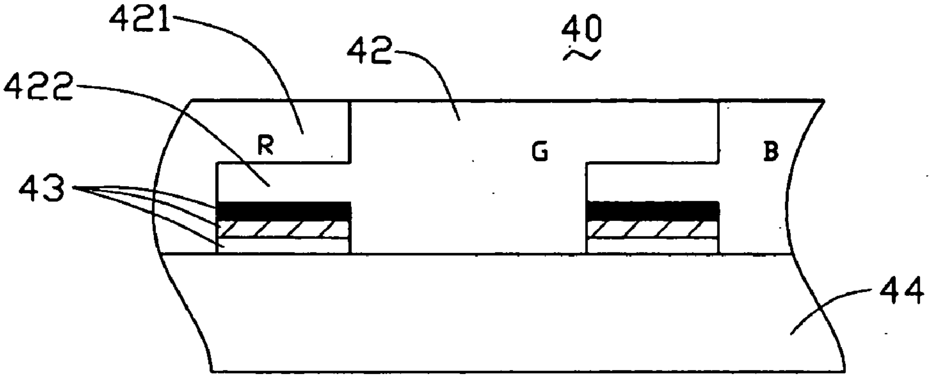


FIG. 2

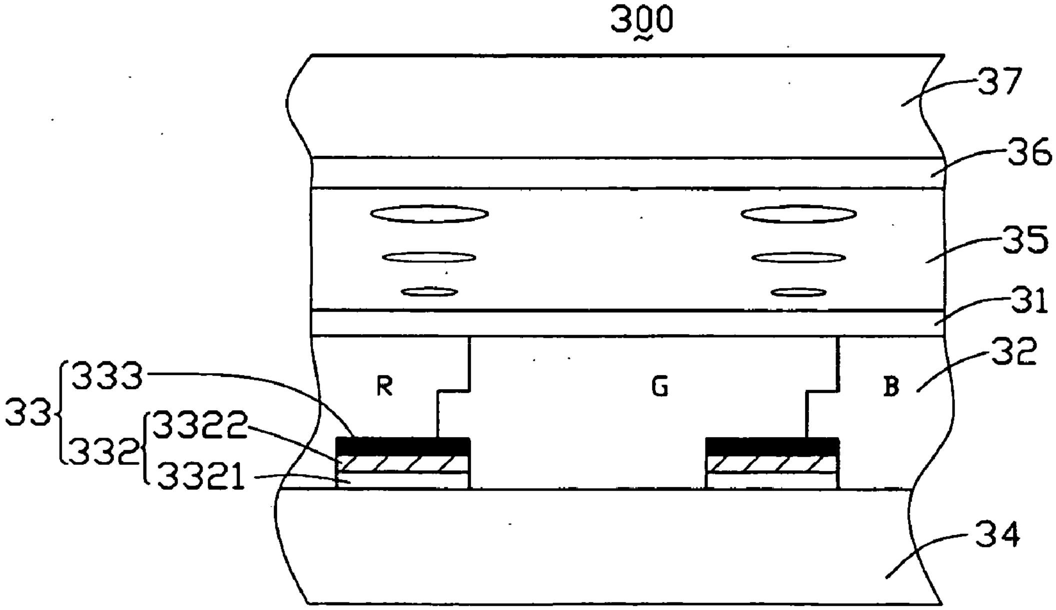


FIG. 3

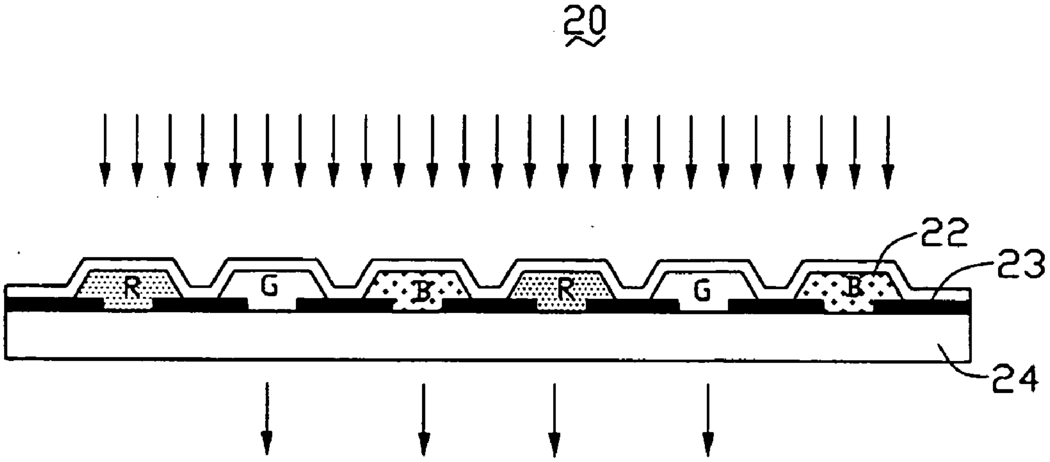


FIG. 4
(PRIOR ART)

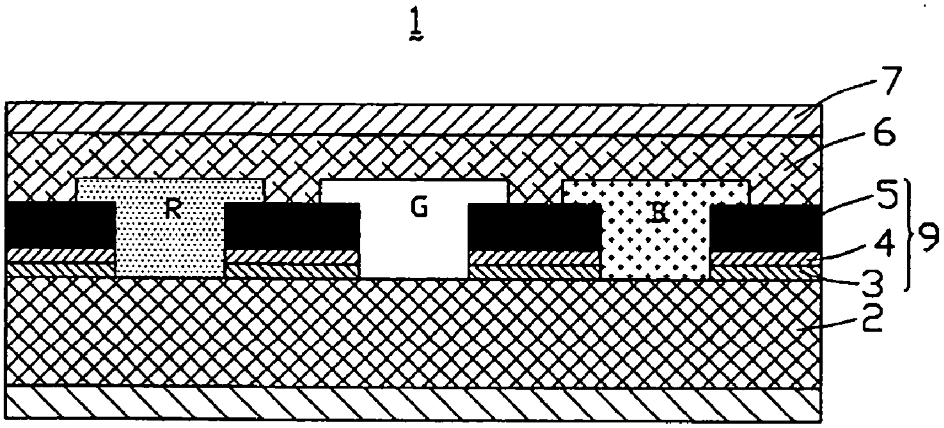


FIG. 5
(PRIOR ART)

METHOD FOR MANUFACTURING COLOR FILTER HAVING LOW REFLECTION AND LIQUID CRYSTAL DISPLAY DEVICE INCORPORATING SAME

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The invention generally relates to methods of manufacturing color filters and associated liquid crystal display (LCD) devices.

[0003] 2. The prior Art

[0004] In general, a monochrome or a color LCD device has the advantages of thinness, light weight and low power consumption. For this reason, LCD devices are widely used in various types of electronic equipment, from pocket calculators to large-scale office automation equipment.

[0005] Conventionally, a color LCD device includes a color filter at a position opposite to a liquid crystal layer. The color filter has three kinds of color (red, green and blue—RGB) resins separated by a black matrix having a plurality of apertures. The visibility of the LCD device mainly depends upon the characteristics of the black matrix of the color filter.

[0006] The basic structure of a conventional color filter is shown in **FIG. 4**. The color filter **20** includes a transparent substrate **24** with a black matrix **23** deposited thereon, the black matrix **23** defining a plurality of apertures (not labeled) therein. RGB color resins **22** are filled in the apertures of the black matrix **23** in a sequential repeating pattern. The RGB color resins **22** filter light beams passing therethrough, thus producing respective RGB color light beams.

[0007] The black matrix **23** functions as a light-shielding mask, to improve the contrast ratio of an LCD device using the color filter **20**. In particular, the black matrix **23** increases the OD (Optical Density, i.e. light-shielding) value, and reduces optical reflectivity of the top and bottom surfaces thereof. However, the black matrix **23** is conventionally made from a metal whose optical reflectivity is too high, or is made from a resin whose OD value is too low. Thus, modified color filters have been developed to solve the above-described problems.

[0008] Referring to **FIG. 5**, a color filter as described in U.S. Pat. No. 6,285,424 issued on Sep. 4, 2001 is illustrated. The color filter **1** comprises a black matrix **9** formed on a transparent substrate **2**. The black matrix **9** comprises a first antireflection film **3**, a second antireflection film **4** and a metal screening film **5** formed one on top of the other in that order. The antireflection films **3**, **4** are made of different kinds of metallic compounds having mutually different compositions. At least one of the films **3**, **4**, **5** contains chromium (Cr). In addition, RGB color resins are separately filled in apertures of the black matrix **9**. A protective layer **6** and a conductive layer **7** are sequentially formed on the RGB color resins and the black matrix **9**. The protective layer **6** functions as a layer flattening the color filter **1**, and as an insulator.

[0009] In manufacturing of the color filter **1**, firstly, the black matrix **9** having a plurality of apertures is formed on the transparent substrate **2** using exposing and developing technology. Then the RGB color resins are repeatedly and respectively filled in the apertures of the black matrix **9**, so that every three adjacent apertures have three different color resins and cooperatively define a pixel. Then the protective layer **6** is formed on the RGB color resins and the black matrix **9**, to provide an even outer surface for the color filter **1**.

[0010] The multi-layer antireflection structure of the black matrix **9** can decrease the optical reflectivity of the surface thereof adjacent the transparent substrate **2**. However, the optical reflectivity of the other surface thereof opposite to the transparent substrate **2** is still generally too great. That is, the optical reflectivity of the outer surface of the metal screening film **5** is too great. When the black matrix **9** is used in an LCD device, back light beams are reflected by the outer surface of the metal screening film **5** to an excessive degree. This creates light interference, which reduces the visibility of the LCD device.

[0011] Therefore, it is desired to obtain a color filter with low reflectivity on both surfaces thereof, and to obtain an LCD device incorporating such color filter.

SUMMARY OF THE INVENTION

[0012] A main object of the present invention is to provide a method for manufacturing a color filter with low reflectivity on both of main surfaces thereof.

[0013] According to one aspect of the present invention, a preferred method for manufacturing a color filter comprises: preparing a transparent substrate; forming a black matrix on the transparent substrate, the black matrix comprising an antireflection layer formed on the transparent substrate and a light-shielding layer formed on the antireflection layer, the antireflection layer comprising a first antireflection film having a first index of refraction, and a second antireflection film having a different second index of refraction, the black matrix defining a plurality of apertures arranged in an array; and coating a color resin layer on the transparent substrate and the black matrix.

[0014] Other objects, advantages, and novel features of the present invention will become more apparent from the following detailed description when taken in conjunction with the accompanying drawings, in which:

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] **FIG. 1** is a schematic, cross-sectional view of a part of a color filter obtained according to a preferred first embodiment of a method of the present invention;

[0016] **FIG. 2** is a schematic, cross-sectional view of a part of a color filter obtained according to a preferred second embodiment of a method of the present invention;

[0017] **FIG. 3** is a schematic, cross-sectional view of a part of an LCD device incorporating the color filter of **FIG. 1**;

[0018] **FIG. 4** is a schematic, cross-sectional view of a part of a conventional color filter; and

[0019] **FIG. 5** is a schematic, cross-sectional view of a part of another conventional color filter.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0020] The preferred first embodiment of the method for manufacturing a color filter according to the present invention will be described with reference to **FIG. 1**. The color filter is designated with the numeral **30**, and the method comprises three basic steps (1), (2), (3) as detailed below:

[**0021**] (1) Preparing and cleaning a transparent substrate **34**. The transparent substrate **34** is a flat transparent glass.

[**0022**] (2) Forming a black matrix **33** on the transparent substrate **34**. First, a first antireflection film **3321** and a second antireflection film **3322** are sequentially formed on the transparent substrate **34**. The two antireflection films **3321**, **3322** combined together act as an antireflection layer **332**, and respectively have a first index of refraction and a different second index of refraction. For example, the first refraction index may be less than the second refraction index. In addition, the two antireflection films **3321**, **3322** preferably have thicknesses in the ranges from 20 to 60 nm and from 20 to 100 nm respectively. Further, the two antireflection films **3321**, **3322** are preferably made principally from chromium oxide (CrO_X, X denoting the ratio of the number of atoms of O to the number of atoms of Cr) and chromium nitride (CrN_Y, Y denoting the ratio of the number of atoms of N to the number of atoms of Cr) respectively. A light-shielding layer **333** is made principally from chromium, and has an index of refraction less than the second refraction index of the second antireflection film **3322**.

[**0023**] The first antireflection film **3321** is formed using a reactive sputtering method. That is, the transparent substrate **34** is placed in a chamber (not shown), and a metal or alloy is placed as a target substrate (not shown) at a position opposite to the transparent substrate **2**. The pressure in the chamber is reduced to a first pressure **P1** (or less, if required), and argon gas as an inactive gas (rare gas) is introduced into the chamber. A reactive gas (at least any one of oxygen gas, nitrogen gas, and carbon dioxide gas, or a mixture thereof) to be reacted with a metal of the target substrate (Cr, Mo, W, Ni, or Ge) is introduced into the chamber, and the pressure in the chamber is held at a second pressure **P2**. The temperature of the transparent substrate **34** is monitored and held at a first temperature **T1**, while a first sputtering power **W1** is applied to the target substrate to generate plasma. Thus, the metal of the target substrate is subjected to sputtering. The reaction between the sputtered metal atoms or molecules and the reactive gas introduced into the chamber results in the formation of the first antireflection film **3321** on the transparent substrate **34**.

[**0024**] The second antireflection film **3322** is also formed using a reactive sputtering method. That is, the second antireflection film **3322** is formed as follows. After the formation of the first antireflection film **3321**, without taking the transparent substrate **34** out of the chamber, the gas in the chamber is evacuated until the pressure in the chamber becomes a third pressure **P3** or less. Argon gas as an inactive gas (rare gas) is introduced into the chamber. Further, a reactive gas (at least any one of oxygen gas, nitrogen gas, and carbon dioxide gas, or a mixture thereof) to be reacted with a metal of target (Cr, Mo, W, Ni, or Ge) is introduced into the chamber, and the pressure in the chamber is held at a fourth pressure **P4**. The temperature of the transparent substrate **34** is monitored and held at a second temperature **T2**, while a second sputtering power **W2** is applied to the target substrate to generate plasma. Thus, the metal of the target substrate is subjected to sputtering. The reaction between the sputtered metal atoms or molecules and the reactive gas introduced into the chamber results in the formation of the second antireflection film **3322** on the first antireflection film **3321**.

[**0025**] Second, the light-shielding layer **333** is formed on the antireflection layer **332**. The light-shielding layer **333** functions as a mask that shields light. The light-shielding layer **333** is formed as follows. After the formation of the second antireflection film **3322** of the antireflection layer **332**, the gas in the chamber is evacuated until the pressure in the chamber becomes a fifth pressure **P5** or less. Argon gas is introduced into the chamber until the pressure in the chamber becomes a sixth pressure **P6**. The temperature of the transparent substrate **34** is monitored and held at a third temperature **T3**, while a third sputtering power **W3** is applied to the target substrate to generate plasma. Thus, the metal (Cr, Mo, W, Ni, or Ge) of the target substrate is subjected to sputtering. The sputtered metal atoms or molecules are deposited on the second antireflection film **3322**, resulting in the formation of the light-shielding layer **333**. The light-shielding layer **333** and the antireflection layer **332** in combination define the black matrix **33** having a plurality of apertures, as seen in **FIG. 1**.

[**0026**] It is noted that the first antireflection film **3321**, the second antireflection film **3322**, and the light-shielding layer **333** may be formed using a CVD (chemical vapor deposition) method or a vacuum evaporation method, instead of using the above-described sputtering method.

[**0027**] Next, a positive photo resist layer is coated onto the outer surface of the light-shielding layer **333**, followed by pre-baking. The photo resist layer is irradiated with light, so that a pattern having a plurality of apertures therein to be photosensitized is transferred onto the photo resist layer. The photosensitized region of the photo resist layer is dissolved using a solvent; that is, the photosensitized region is developed. Post-baking is carried out, thereby forming a photo resist layer having a plurality of apertures in the light-shielding layer **333**.

[**0028**] Further, using the photo resist layer as a mask, an etchant is applied to the light-shielding layer **333**, the second antireflection film **3322** and the first antireflection film **3321** immediately under the apertures of the photo resist layer. A contact area is thus etched. After the completion of etching, the photo resist layer is removed from the top of the screening film **333** using a solvent, thereby forming the black matrix **33** having a plurality of apertures. It is noted that, in the manufacturing of the black matrix **33** having the above-described structure, it is preferable to use an etchant mainly composed of ammonium cerium (IV) nitrate. In such case, it is possible to etch the light-shielding layer **333**, the second antireflection film **3322** and the first antireflection film **3321** at the same time.

[**0029**] (3) Coating a color resin layer **32** on the transparent substrate **34** and the black matrix **33**. There are two main sub-steps required to form the color resin layer **32**. That is, a first color resin sub-layer (not labeled) is formed on the transparent substrate **34** and the black matrix **33**, and then a second color resin sub-layer (not labeled) is formed on the first color resin sub-layer. The first and second color resin sub-layers together constitute the color resin layer **32**. As seen in **FIG. 1**, the color resin layer **32** comprises adjacent regions of red (R), green (G) and blue (B) resin. The red, green and blue resins are positive color resins containing appropriate respective pigments. Each region adjoins an adjacent region at a same side of a corresponding light-shielding layer **333**. Each two adjoining color regions are lapped one over the other above part only of the light-shielding layer **333**.

[**0030**] The first color resin sub-layer is formed on the transparent substrate **34** and the black matrix **33** as follows. A blue resin is coated onto the black matrix **33** from a dispenser disposed above the transparent substrate **34**, so that the blue resin is charged in all the apertures of the black matrix **33**. The transparent substrate **34** coated by the blue resin is subjected to pre-baking, thereby forming a blue resin layer having a uniform height above the transparent substrate **34**. It is noted that the transparent substrate **34** may be rotated about a rotation axis running along its thickness, so that the height of the blue resin layer above the transparent substrate **34** is uniform prior to pre-baking.

[**0031**] Then, a first full exposure is performed using a photo mask. All the blue resin is removed using a solvent, except for blue resin remaining on regions corresponding to every third aperture in each row and in each column of the black matrix **33** array. Each remaining blue resin region overlies more than half of a corresponding light-shielding layer **333** at one side thereof, and overlies less than half of another corresponding light-shielding layer **333** at an opposite side thereof.

[**0032**] Next, a green resin is coated onto the black matrix **33** so that the green resin is charged in all vacant apertures of the black matrix **33**. Then a first full exposure is performed using the same photo mask. All the green resin is removed using a solvent, except for green resin remaining on regions corresponding to every third aperture in each row and in each column of the black matrix **33** array. Each remaining green resin region overlies more than half of a corresponding light-shielding layer **333** and adjoins a blue resin region at one side thereof, and overlies less than half of another corresponding light-shielding layer **333** at an opposite side thereof.

[**0033**] After that, a red resin is coated onto the black matrix **33** so that the red resin is charged in all vacant apertures of the black matrix **33**. That is, the red resin is disposed in regions corresponding to every third aperture in each row and in each column of the black matrix **33** array. Each red resin region overlies more than half of a corresponding light-shielding layer **333** and adjoins a green resin region at one side thereof, and overlies less than half of another corresponding light-shielding layer **333** and adjoins a blue resin region at an opposite side thereof. Thus, the contiguous R, G, and B resin regions cooperatively form the first color resin sub-layer, which is continuous, flat and smooth.

[**0034**] The second color resin sub-layer is formed on the first color resin sub-layer in similar fashion to the above-described procedures for forming the first color resin sub-layer on the transparent substrate **34** and the black matrix **33**. The same photo mask as that used in the forming of the first color resin sub-layer is used. The R, G, and B resin regions of the second color resin sub-layer substantially correspond to but are slightly offset from the R, G, and B color resin regions of the first color resin sub-layer. With this configuration, an overlapping part **321** of each color resin region in the second color resin sub-layer is only located above a corresponding light-shielding layer **333**, and does not interfere with the corresponding adjacent pure color aperture of the black matrix **33**. The offset, contiguous R, G, and B resin regions cooperatively form the second color resin sub-layer, which is continuous, flat and smooth. Thus, the first and second color resin sub-layers cooperatively form the continuous, plane color resin layer **32**.

[**0035**] The coating of the color resin layer **32** on the transparent substrate **34** and the black matrix **33** can be performed by an alternative method to the above-described two main sub-steps. The alternative method also comprises two main sub-steps. In the first sub-step, contiguous R, G, and B color resin regions of the color resin layer **32** are formed, except that each R, G, and B color resin region is missing the overlapping part **321**. In the second sub-step, the voids corresponding to the overlapping parts **321** are charged with the corresponding R, G, and B color resins, so that the above-described configuration of R, G, and B color resin regions of the color resin layer **32** are formed. Thus the continuous, plane color resin layer **32** is formed.

[**0036**] The above-described method for manufacturing the color filter **30** utilizes conventional sub-procedures, but does not require the formation of an extra layer to provide a flat outer surface of the color filter **30**. A plane outer surface of the color filter **30** is attained without the need for the extra layer. Thus the cost of manufacturing the color filter **30** is reduced.

[**0037**] The preferred second embodiment of the method for manufacturing a color filter according to the present invention will be described with reference to **FIG. 2**. The color filter is designated with the numeral **40**, and the method is substantially similar to the preferred first embodiment of the method for manufacturing the color filter **30** described above. A black matrix **43** is formed on a transparent substrate **44**. Two overlapping parts **421**, **422** of two adjoining color resin regions cover the entire light-shielding layer of a corresponding portion of the black matrix **43**. That is, the overlapping parts **421**, **422** are lapped one on the other on an entire area of said portion of the black matrix **43**, unlike in the color filter **30** where the lapping occurs only on a part of the corresponding portion of the black matrix **33**.

[**0038**] A preferred method for manufacturing an LCD device having the color filter **30** in accordance with the present invention will be described with reference to **FIG. 3**.

[**0039**] The LCD device is designated with the numeral **300**, and the method comprises the steps of: (1) manufacturing the color filter **30**, and forming an ITO (Indium Tin Oxide) layer **31** on the color resin layer **32**; (2) manufacturing an electrode substrate **37** having a TFT (Thin Film Transistor) layer **36** formed on an inner surface (not labeled) thereof, and forming a cavity between the ITO layer **31** and the TFT layer **36**; and filling a liquid crystal layer **35** in the cavity. Alternatively, step (2) can be performed before step (1).

[**0040**] In operation of the LCD device **300**, the TFT and ITO layers **31**, **36** are connected with an IC (Integrated Circuit) device (not shown) to control rotation of liquid crystal molecules in the liquid crystal layer **35**, and thereby control the passage or blocking of light beams. Back light beams emitted by an illuminator (not shown) pass through the electrode substrate **37** and the TFT layer **36** of the LCD device **300**, and enter the liquid crystal layer **35**. Most of the light beams pass through the liquid crystal layer **35**, are filtered by the color resin layer **32** of the color filter **30**, and emit from an outer surface (not labeled) of the transparent substrate **34**. A remainder of the light beams pass through the liquid crystal layer **35**, but are blocked by the black matrix **33**.

[**0041**] It is known that an optical reflectivity of the color resin layer **32** is lower than that of the light-shielding layer **333** made from chromium. Therefore the light beams impinging on an outer surface of the light-shielding layer **333** of the black matrix **33** are mostly absorbed by the color resin layer **32** rather than being reflected by the light-shielding layer **333**. Thus the phenomenon of light interference is diminished. That is, the OD value of the black matrix **33** is increased, and the visibility of the LCD device **300** is improved. In addition, the two antireflection films **3321**, **3322** of the black matrix **33** can reduce optical reflection of external light. Therefore, the color filter **30** has low reflectivity on both surfaces thereof. Accordingly, the LCD device **300** using the color filter **30** provides high brightness and contrast.

[**0042**] It is to be understood, however, that even though numerous characteristics and advantages of the present invention have been set forth in the foregoing description, together with details of the steps and associated structures of the invention, the disclosure is illustrative only, and changes may be made in detail, especially in matters of arrangement of procedures and related objects within the principles of the invention to the full extent indicated by the broad general meaning of the terms in which the appended claims are expressed.

1. A method for manufacturing a color filter, comprising:

preparing a transparent substrate;

forming a black matrix having a plurality of apertures on the transparent substrate, the black matrix comprising an antireflection layer formed on the transparent substrate and a light-shielding layer formed on the antireflection layer, the antireflection layer comprising a first antireflection film having a first index of refraction, and a second antireflection film having a different second index of refraction; and

coating a color resin layer on the transparent substrate and the black matrix.

2. The method for manufacturing a color filter as claimed in claim 1, wherein the antireflection layer comprises chromium oxide and chromium nitride, and the light-shielding layer comprises chromium.

3. The method for manufacturing a color filter as claimed in claim 1, wherein the color resin layer comprises RGB (red, green, blue) resins.

4. The method for manufacturing a color filter as claimed in claim 3, wherein the RGB resins respectively fill each three contiguous apertures.

5. The method for manufacturing a color filter as claimed in claim 4, wherein a respective portion of each of the RGB resins at each aperture covers a corresponding portion of the black matrix.

6. The method for manufacturing a color filter as claimed in claim 4, wherein respective portions of each of two adjoining RGB resins at two adjacent apertures cover a corresponding portion of the black matrix.

7. The method for manufacturing a color filter as claimed in claim 1, wherein the step of coating a color resin layer on the transparent substrate and the black matrix further comprises the steps of forming a first color resin sub-layer on the transparent substrate and the black matrix, and forming a second color resin sub-layer on the first color resin sub-layer.

8. The method for manufacturing a color filter as claimed in claim 7, wherein the second color resin sub-layer is offset from the first color resin sub-layer.

9. The method for manufacturing a color filter as claimed in claim 1, wherein the step of coating a color resin layer on the transparent substrate and the black matrix further comprises the steps of forming contiguous RGB (red, green, blue) color resin regions on the transparent substrate and the black matrix, and forming RGB color resin sub-regions in voids between adjacent RGB color resin regions.

10. The method for manufacturing a color filter as claimed in claim 9, wherein the RGB color resin regions correspond to respective apertures.

11. The method for manufacturing a color filter as claimed in claim 10, wherein the RGB color resin sub-regions correspond to respective portions of the black matrix between apertures.

12. A method for manufacturing a color filter, comprising:

preparing a transparent substrate;

forming a black matrix having a plurality of apertures on the transparent substrate; and

coating a color resin layer on the transparent substrate and the black matrix.

13. A method for manufacturing a liquid crystal display device, comprising:

preparing a transparent substrate;

forming a black matrix having a plurality of apertures on the transparent substrate;

coating a color resin layer on the transparent substrate and the black matrix;

forming an ITO (Indium Tin Oxide) layer on the color resin layer;

providing an electrode substrate having a TFT (Thin Film Transistor) layer formed on an inner surface thereof, and forming a cavity between the ITO layer and the TFT layer; and

filling a liquid crystal layer **35** in the cavity.

* * * * *