HIGH-BRIGHTNESSS COLOR LIQUID CRYSTAL DISPLAY PANEL EMPLOYING LIGHT RECYCLING THEREIN

[0001] Backlighting Panel For Use In Computer-Based Display Systems And Portable Light Projection Device For Use Therewith" by Sadeg M. Faris, filed Apr. 21, 1994, now U.S. Pat. No. 5,828,427; which is a Continuation-in-Part of application Ser. No. 08/126,077 entitled "Electro-Optical Display System For Visually Displaying Polarized Spatially Multiplexed Images Of 3-D Objects For Use In Stereoscopically Viewing The Same With High-Image Quality And Resolution" by Sadeg M. Faris filed Continuation of application Ser. No. 07/536,190 entitled "A System For Producing 3-D Stereo Images" by Sadeg M. Faris, filed Jun. 11, 1990, now abandoned; each said Application being commonly owned by Reveo, Inc., and incorporated herein by reference in its entirety.

BACKGROUND OF INVENTION

[0002] 1. Technical Field

[0003] The present invention relates to a high-brightness color liquid crystal display (LCD) panel with improved image contrast employing non-absorptive spectral filtering, light recycling among neighboring subpixels and ambient glare reduction, and also to methods and apparatus for manufacturing the same.

[0004] 2. Brief Description of The Prior Art

[0005] Without question, there is a great need for flat display panels capable of displaying video imagery in both direct and projection modes of viewing. Examples of equipment requiring such display structures for direct viewing include notebook computers, laptop computers, and palmtop computers, and equipment requiring such display structures for projection viewing include LCD projection panels and LCD image projectors.

[0006] In general, prior art color LCD display panels have essentially the same basic construction in that each comprises the following basic components, namely: a backlighting structure for producing a plane of uniform intensity backlighting; an electrically-addressable array of spatial-intensity modulating elements for modulating the spatial intensity of the plane of backlight transmitted therethrough; and an array of color filtering elements in registration with the array of spatial intensity modulating elements, for spectral filtering the intensity modulated light rays transmitted therethrough, to form a color image for either direct or projection viewing. Examples of such prior art LCD panel systems are described in "A Systems Approach to Color Filters for Flat-Panel Displays" by J. Hunninghake, et al, published in SID 94 DIGEST (pages 407-410), incorporated herein by reference.

[0007] In color LCD panel design, the goal is to maximize the percentage of light transmitted from the backlighting structure through the color filtering array. However, using prior art design techniques, it has been impossible to achieve this design goal due to significant losses in light transmission caused by the following factors, namely: absorption of light energy due to absorption-type polarizers used in the LCD panels; absorption of light reflected off thin-film transistors (TFTs) and wiring of the pixelated spatial intensity modulation arrays used in the LCD panels; absorption of light by pigments used in the spectral filters of the LCD panels; absorption of light energy by the black-matrix used to spatially separate the subpixel filters in the LCD panel in order to enhance image contrast; and Fresnel losses due to the mismatching of refractive indices between layers within the LCD panels. As a result of such design factors, the light transmission efficiency of prior art color LCD panels is typically no more than 5%. Consequently, up to 95% of the light produced by the backlighting structure is converted into heat across the LCD panel. Thus, it is impossible to produce high brightness images from prior art color LCD panels used in either direct or projection display systems without using ultra-high intensity backlighting sources which require high power supplies, and produce great amounts of heat necessitating cooling measures and the like.

[0008] The light transmission efficiency of prior art LCD panels has been severely degraded as a result of the following factors: absorption of light energy due to absorption-type polarizers used in the LCD panels; absorption of light reflected off thin-film transistors (TFTs) and wiring of the pixelated spatial intensity modulation arrays used in the LCD panels; absorption of light by pigments used in the spectral filters of the LCD panels; absorption of light energy by the black-matrix used to spatially separate the subpixel filters in the LCD panel in order to enhance image contrast; and Fresnel losses due to the mismatching of refractive indices between layers within the LCD panels. As a result of such light energy losses, it has been virtually impossible to improve the light transmission efficiency of prior art LCD panels beyond about 5%.

[0009] In response to the shortcomings and drawbacks of prior art color LCD panel designs, several alternative approaches have been proposed in order to improve the light transmission efficiency of the panel and thus the brightness of images produced therefrom.

[0010] For example, U.S. Pat. No. 5,822,029 entitled "Illumination System and Display Device" discloses a LCD panel construction comprising a broad-band CLC reflective polarizer **(32)** disposed between the backlighting structure **(10, 12, 30** and **34)** and a reflective color filtering structure **(18** in **FIG. 1A)** made from a pair of cholesteric liquid crystal (CLC) film layers, as shown in **FIGS. 1A and 1B** of the accompanying Drawings which are identical to **FIGS. 5 and 6** in U.S. Pat. No. 5,822,029. As shown in **FIG. 1A**, the reflective color filter structure **(18** in **FIG. 1A)** has a first layer with portions which reflect red, green and blue light while transmitting other colors ,and a second layer identical to the first layer but out of alignment therewith so that each region of the spectral filter transmits only one color of light from the light source of backlighting structure (illustrated in **FIG. 1C**), while all other colors are reflected back towards the backlighting structure. During operation, the spectral components which are not transmitted through its respective subpixel structure, are reflected back through the broad-band CLC reflective polarizer **(32)** and recycled within the backlighting structure, after polarization state conversion in order to improve the light transmission efficiency of the LCD panel and thus the output brightness thereof.

[0011] In order to recycle light striking the TFT areas and wiring regions associated with each subpixel region on the LCD panel, U.S. Pat. No. 5,822,029 discloses the use of a reflective-type black matrix about the transmission apertures