A technique including a method (300, 400) and apparatus (200) for repairing a color filter (1) for a flat panel display using a plurality of high intensity light source means (203, 203A, 203B, 206A, 206B). The technique provides a color filter having anomalies and uses steps of directing a plurality of high intensity lights through apertures at the anomalies to selectively ablate portions of the anomalies. These features remove the portions of the anomalies while preventing a possibility of substantial damage to other portions of the color filter surrounding the anomalies.
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COLOR FILTER REPAIR METHOD AND APPARATUS
USING MULTIPLE/MIXED SOURCES

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is related to Application Serial No. ___________
(Attorney Docket No. 14116-005100) filed on the same date as this present invention
and to Application Serial No. ___________ (Attorney Docket No. 14116-005300)
filed on the same date as this present application, all in the name of the present
assignee. All of these documents are hereby incorporated by reference for all purposes.

BACKGROUND OF THE INVENTION

This present invention relates to techniques for fabricating flat panel
displays. More particularly, the invention is illustrated in an example related to the
manufacture and repair of a color filter for use in a flat panel display such as an active
matrix liquid crystal display (AMLCD) or the like. But it will be recognized that the
invention also can be applied to the manufacture of almost any type of color filter
media.

The use of a flat panel display such as an active matrix liquid crystal
display (AMLCD) or the like continues to grow rapidly. For example, consumer items
such as a pocket TV, a notebook computer, an engineering work-station, a high-
definition television (HDTV), and others use such a display. Based upon the continued
demand for this display, industry has made massive capital investments in creating
state-of-art manufacturing lines.

Color flat panel displays are merely an example of a flat panel display,
which is being used extensively in computers. These flat panel displays often use color
filters to provide the color to the display image. Color filters are generally made using
printing processes, which are often time consuming and difficult.

Unfortunately, the color filters are often plagued with anomalies, which
are introduced during the manufacturing process. These anomalies include, for
instance, inclusions in the color medium and color non-uniformity. Inclusions can be
found in the color medium or coating layer. They are often portions of photoresist, 
particulates, or voids, which define themselves in the color filter. Non-uniform color 
can be caused by an "overabundance" of color filter material in a pixel. For instance, a 
red color pixel may have an excessive thickness, which appears to create a deeper or 
darker display color in relation to surrounding pixels upon illumination. Alternatively, 
non-uniform color is often caused by a thinner region of color filter material in a pixel. 
This thinner region appears to lack color or appears "washed out" in relation to 
surrounding pixels.

A few techniques have been proposed or used to eliminate some of these 
anomalies. In particular, polishing or grinding tools have been used to remove an 
overabundance of color filter material from a pixel. These polishing tools generally 
have a rotatable pad member, which is abrasive. By way of rotation and pressure 
placed against the color filter material, portions of the overabundant or thicker color 
filter material are physically removed. These techniques, however, often require great 
precision to remove a desired amount of color filter material, which often causes a 
potential for additional damage to the color filter material. Additionally, as pixel sizes 
decrease, it becomes more difficult to accurately remove color filter material from a 
pixel.

Anomalies such as portions of photoresist, particulates, or voids 
generally cannot be removed to repair the color filter. In most cases, the color filter 
plate is rejected and discarded, which is generally expensive and inefficient. As much 
as 30% of filters manufactured are often discarded due to such defects. Accordingly, 
the cost of flat panel displays using color filters is often significantly more expensive 
than other types of displays. In fact, the color filter represents one of the higher cost 
components of the display. A large portion of these costs is associated with the large 
number of displays that are rejected due to anomalies, which are introduced into the 
color filter during the manufacturing process.

From the above, it can be seen that a technique for repairing color filters 
or removing anomalies from color filters that is easy, cost effective, and reliable is 
often desirable.
SUMMARY OF THE INVENTION

According to the present invention, a technique including a method and apparatus for repairing color filters or removing anomalies in color filters used in flat panel displays is provided.

In a specific embodiment, the present invention provides a method for repairing a flat panel display and in particular a color filter, having anomalies, using a plurality of high intensity light source means. The color filter includes various elements such as a plurality of color pixels being defined on a transparent substrate, and an electrode. The method includes a step to direct a first high intensity light through an aperture opening at a first anomaly to cause an ablation of a portion of the first anomaly, and a step to direct a second high intensity light through a second aperture opening at a second anomaly to cause an ablation of a portion of the second anomaly. These steps remove portions of the first and second anomalies (which can be the same anomaly) while reducing a possibility of substantial damage to portions of the color filter surrounding the anomalies.

In an alternative specific embodiment, the present method provides an apparatus for repairing a flat panel display using first and second high intensity sources emitting energy having first and second wavelengths. The apparatus uses the sources to ablate selected portions of a color filter assembly, and in particular, anomalies. The apparatus also has first and second apertures, through which energy from the first and second sources passes, and which reduce absorption of the energy beyond the selected portions of the color filter assembly.

In a further alternative embodiment, the present invention provides a computer program product (e.g., software) for repairing a color filter for a flat panel display using a plurality of high intensity light source means. The computer program product has a computer readable memory with a variety of software codes, for example. The product has a first code for directing a first high intensity light having a first wavelength from a first light source means through a first aperture of selected size at a first anomaly. The product also has a second code for directing a second high intensity light having a second wavelength from a second light source means through a second aperture of selected size at a second anomaly. The product can be stored in a memory device such as a hard drive, a floppy drive, a dynamic random access memory,
and others.

Benefits are achieved by way of the present invention for repairing color filters. These benefits include accurate removal of anomalies, which can repair the color filter to increase overall yields in manufacturing. Additionally, the present invention may employ high powered lasers, without hazardous chemicals or the like. The laser is cost effective and efficient to use. Accordingly, the present invention provides these benefits using a cost effective apparatus and an easy to use technique.

The invention will be better understood by reference to the following detailed description in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a simplified cross-sectional view diagram of a color filter according to the present invention;

Fig. 2A is a simplified diagram of a cutting tool employing a single housing containing two lasers used to repair the color filter of the above Fig. according to the present invention;

Fig. 2B is a simplified diagram of a cutting tool employing two housings each containing a laser, used to repair the color filter of the above Fig. according to the present invention;

Fig. 2C illustrates Gaussian and uniform intensity distributions;

Figs. 2D-2F illustrate examples of ablation using the configuration of Fig. 2A;

Figs. 2G-2H illustrate examples of ablation using the configuration of Fig. 2B;

Fig. 3 is a simplified flow diagram for removing anomalies from the color filter of the above Fig. according to the present invention;

Fig. 4 is a simplified flow diagram for removing bumps from the color filter of the above Fig. according to the present invention;

Figs. 5-7 illustrates cross-sectional view diagrams of a color filter according to the present invention; and

Figs. 8A-8C are simplified illustrations of ablation of an electrode layer of a color filter according to the present invention.
DESCRIPTION OF SPECIFIC EMBODIMENTS

As background to the present manufacturing technique, it may assist the reader to understand the numerous types of defects, which may detrimentally influence the quality of the flat panel display. Fig. 1 is a simplified cross-sectional view of one possible AMLCD color filter 1 according to the present invention. This diagram is merely an illustration and should not limit the scope of the claims herein. One of ordinary skill in the art would recognize other types of displays and defects including variations, modifications, and alternatives.

Numerous elements make up the AMLCD color filter 1 including a matrix layer 3, defined on a transparent substrate 5. The matrix layer 3 can be a black matrix or black relief layer defined by printing processes or the like. Transparent substrate 5 is often a clear rigid film or glass-type structure. For instance, the transparent glass structure can be made from materials such as a quartz glass, a borosilicate glass, a soda line glass, a transparent resin film, an optical resin plate, and other materials. The glass is often transparent and rigid, but can also be flexible in some applications. An example of such a transparent substrate is a glass plate made by Corning, Inc. of New York, which is sold under the product name of Corning 7059 glass. This glass is often used in the manufacture of flat panel displays and the like.

The glass plate has a refractive index of about 1.5, and a 1.1 mm to 0.7 mm thickness. Of course, the plate can be made of almost any relatively transparent structure or medium with a refractive index greater than one, relative to its surroundings. The thickness of the plate depends upon the application.

A colored layer 7 is formed in the matrix layer 3 and overlies the substrate. The colored layer 7 generally has a red pattern 7A, a green pattern 7B, and a blue pattern 7C, which can be arranged in a mosaic arrangement, a triangular arrangement, a stripe arrangement, and others. Each pattern includes a plurality of red, green, or blue pixels or the like. Of course, the type of arrangement depends upon the application.

A protection layer 9 is defined overlying the structure including the colored layer 7 and the matrix layer 3. The protection layer 9 is often a dielectric layer such as a silicon dioxide, a silicon nitride, or a borosilicate glass. Additionally, a
combination of layers can be used as the protection layer 9. For instance, the protection layer 9 can include a silicon dioxide having an overlying layer of silicon nitride or the like.

Electrode layer 11 overlies the protection layer 9. The electrode layer 11 is often made using an indium tin oxide (ITO), but it can also be made of other materials such as nitride or other oxides. Other types of color filters can also be repaired by way of the present techniques. An example of one of these color filters used in a display is described in U.S. Patent No. 5,501,900, assigned to Dai Nippon Printing Co., of Japan, which is hereby incorporated by reference for all purposes.

These color filters often contain a variety of anomalies generally classified as either inclusions or non-uniform color. These anomalies or defects can detrimentally influence display performance. An inclusion may be a void 13 or a particulate contamination 15 found in the color filter 1, as illustrated in Fig 1.

Inclusions can be found throughout the color filter 1 and more particularly in the protection layer 9 or colored layer 7. Examples of these inclusions include residual resist (or photoresist) material, particles, and the like. These inclusions generally become a problem when they are as large or larger than the cell gap, which effectively blocks the cell. Inclusions can also be voids or separations. These voids or separations become a problem when they become as large or larger than the cell gap.

Non-uniform color can be defined as brightness non-uniformities in the color. These brightness non-uniformities tend to cause pixels that are either darker or lighter than surrounding pixels. Non-uniform color is often caused by a non-uniform film of color filter material or the like in the color pixel region. In most cases, the non-uniform color is a "bump" 17 in the color pixel, which is predominately color filter material. Alternatively, the non-uniform color is a "depression" 19 in the color pixel, which is caused by a recessed region in the color pixel. As one may suspect, the "bump" generally causes an appearance of a darker or deeper coloring, when viewing the flat panel display by way of illumination. Alternatively, the "depression" 19 causes an appearance of a lighter region of color in the pixel. Depending upon the intensity of light illuminating from the "depression" 19 or "bump," 17 the color filter 1 may be categorized as a reject.
The above anomalies may also exist in other regions of the color filter 1. For instance, they may be present in the matrix layer 3, the transparent substrate 5, the electrode layer 11, and others. Depending upon the location and the nature of the anomaly, it may be removed or substantially reduced in size by way of the present invention. Details of the present invention including an apparatus and method are shown by way of the figures below.

In a specific embodiment, a cutting tool system 200 is used to direct a plurality of high intensity light sources towards a plurality of anomalies for ablation purposes, as illustrated by Fig. 2A. This diagram is merely an illustration and should not limit the scope of the claims. The cutting tool system 200 includes a housing 201, lasers 206A, 206B in a laser unit 203, an x-y-z stage assembly 205, a base unit 207, and other elements.

The housing 201 encloses the lasers 206A, 206B, which are positioned over the x-y-z stage assembly 205. The lasers 206A, 206B may be contained in a single laser unit 203, as shown, or in multiple laser units 203A, 203B as discussed below (see Fig. 2B and associated discussion). The x-y-z stage assembly 205 holds a color filter 209, which is positioned for repair. The color filter 209 is positioned on a slidable table 202, and a hinged frame 204, which is brought down to secure the color filter 209 in place. The slidable table 202 allows for easy positioning of the color filter assembly 209 in an x-y plane under the lasers 206A, 206B.

The slidable table 202 allows the color filter 209 to be shifted in the x-y directions relative to the lasers 206A, 206B. The slidable table 202 can be any suitable unit capable of moving the color filter 209 in an x-direction and/or a y-direction. The x-y-z stage assembly 205 may include continuous movement in the x-direction and/or y-direction. Preferably, the x-y-z stage assembly 205 also increments at selected dimensions in the x-direction and the y-direction. Movement of the x-y-z stage assembly 205 occurs by way of actuators, drive motors, and the like. The x-y-z stage assembly 205 accuracy is less than about 1 micron. Alternatively, the lasers 206A, 206B are mounted onto an x-y stage (not shown) to move the lasers 206A, 206B relative to the color filter 209.

In a preferred embodiment, the x-y-z stage assembly 205 is a hybrid mechanical and air bearing stage with a linear servo. An example of this stage is made
by Anorad sold under the trade name FP720. This stage has a maximum speed of 320mm/s, a step speed of 30mm in 300ms, an accuracy of 5μm, a resolution of 5μm, and a travel of 720mm × 720mm. This stage provides for fast and accurate movement between anomalies. In this embodiment the stage is large enough to accommodate an array for repair.

Movement of the x-y-z stage assembly 205 in the z-direction also operates in a continuous movement mode or at selected z-positions through the use of an actuator (not shown) such as a drive motor or the like. The actuator can be a two-stage or multi-stage actuator. The z-direction may also operate in a stepping mode. Of course, exact incremental dimensions in the x-direction, the y-direction, and the z-direction depend upon the particular application. In other embodiments, the x-y-z stage assembly 205 has movement in the z-direction, but does not adjust in the x-y direction during inspection. Stage accuracy in the z-direction is less than about 2 micron. In further embodiments, the lasers 206A, 206B are adjustable in the z-direction relative to the color filter 209.

The lasers 206A, 206B can be any suitable design capable of ablating portions of the color filter 209. These portions of the color filter 209 include anomalies and the assembly itself. The lasers 206A, 206B each need a sufficiently rich energy source to remove or ablate portions of the color filter 209, which remove anomalies or substantially reduce anomalies in size. These anomalies can be inorganic materials such as certain types of particulate contamination in the protective layer. Alternatively, anomalies can be made of organic material such as photoresist or a portion of material making up the color filter 209. In most cases, the lasers 206A, 206B ablate portions of the color filter 209 in a few seconds or less, which does not substantially damage the color filter 209.

In most embodiments, the lasers 206A, 206B should have sufficient strength to ablate the protection layer 9, which is generally made of an inorganic material, e.g., silicon dioxide, silicon nitride, etc. (see Figs. 5A-5C). Suitable lasers can have energy sources that radiate energy at a wavelength in the UV range, in the visible range, and/or infra-red range. Preferably, the wavelengths are in the 350-400 nm range and are often at about 355 nm or less. Energy sources with described qualities will be able to selectively remove desired portions of the color filter 209.
including anomalies.

Examples of these energy sources are solid state pulsed lasers such as ruby lasers or frequency multiplied Nd:YAG lasers, pulsed lasers with boosters such as pulsed dye lasers or Raman Shifter, and also continuous wave lasers with pulsed modifications. Other lasers that can be employed include CW ion lasers (Ar, Kr), as well as pulsed metal vapor lasers, for example, copper vapor lasers or gold vapor lasers, or high capacity pulsed semiconductor lasers, and also pulsed gas lasers such as excimers and the like.

Other characteristics of the lasers 206A, 206B would include adjustable parameters to accompany the material to be removed or ablated. For instance, the lasers 206A, 206B may have adjustable pulse content, pulse shape, and pulse duration. Additionally, the lasers 206A, 206B have adjustable apertures to increase or reduce the size of the selected target area or region. These parameters are adjusted to selectively remove the desired material from the color filter 209 or the like.

In a preferred embodiment, lasers 206A, 206B include the following characteristics. Either laser 206A, 206B may be a Nd:YAG source capable of providing multiple wavelengths. The lasers 206A, 206B generally operate in the UV wavelength range, but can also be operated in the IR and visible wavelength ranges. Energy from the lasers 206A, 206B passes through variable apertures (not shown) ranging from about 1μm to about 50μm in both x and y directions. Intensity distributions of energy from the lasers 206A, 206B are generally uniform in nature across the aperture rather than a conventional Gaussian profile as is common with lasers (see Fig. 2C). The uniform distribution may be referred to as a "top hat" distribution and is illustrated in Fig. 2C. This distribution has a substantially constant intensity distribution across the aperture. The intensity may often vary, however, up to approximately 10% across the aperture. Additional features of the lasers 206A, 206B include, but are not limited to, a 40mW average power, a 15ns pulse time, a 30mJ fundamental pulse energy, a 20 pulse/sec pulse rate, a flash lamp pump source, a 10 million pulse lifetime, and an attenuator capable of 0% to 95% attenuation. Of course, other parameters could be used depending upon the application.

Using two lasers 206A, 206B in a single laser unit 203 allows ablation of multiple anomalies simultaneously. The apertures may be a single aperture through
which energy from both lasers 206A, 206B passes. Also, wavelengths of the energy from lasers 206A, 206B may be different. In this case, referring to Fig. 2D, the energy from the lasers 206A, 206B may impinge upon the color filter 300 with substantially the same cross section. Due to the different wavelengths, however, different anomalies may be ablated simultaneously, even from different layers of the color filter 209.

Alternatively, as shown in Figs. 2E-2F, energy from the lasers 206A, 206B may pass through different apertures, may impinge upon different areas of the color filter 209 and may have different cross sections.

The lasers 206A, 206B may also be contained in separate laser units 203A, 203B as shown in Fig. 2B. Using this configuration also allows simultaneous ablation of multiple anomalies. The lasers 206A, 206B may emit different wavelengths of energy to ablate different anomalies, or similar anomalies in different layers of the color filter 209. Alternatively, the lasers 206A, 206B may use substantially the same wavelength to ablate similar anomalies in the same layer of the color filter 209. The lasers 206A, 206B may also ablate a single anomaly, the speed of ablation increasing due to the use of multiple lasers (see Fig. 2G). A reflective surface 217, as shown in Fig. 2H, may be used to ablate anomalies from various angles. The reflective surface 217 may also be used with the configuration of Fig. 2A.

Returning to Fig. 2A, the cutting tool 200 is controlled via base unit 207, which is coupled to the cutting tool 200 through the housing via lines 211. The base unit 207 can be any suitable control unit for controlling the movement of the lasers 206A, 206B and/or x-y-z stage assembly 205 for positioning purposes. The base unit 207 also controls the intensity and duration of the laser pulses, which are directed at the anomalies. Other features of the base unit 207 would include easy programmability, sufficient memory, and network capability. The base unit 207 generally includes, among other elements, a central processing unit 213, a keyboard and mouse interface (not shown), and a color display 215. In a preferred embodiment, the base unit 207 includes a SPARC 5 station manufactured by Sun Microsystems, Inc. This embodiment includes a 170MHz clock speed, a 1.2GB hard disk drive, a 1.44MB floppy disk drive, a 64MB RAM, and 20" monitor. The base unit should have sufficient memory to store programs or recipes, which will be described by way of methods below.

The present cutting tool 200 provides an apparatus which can be used to
remove or substantially eliminate portions of anomalies in the color filter 209. This cutting tool 200 generally has lasers 206A, 206B such as the one described above, which direct high intensity light at anomalies for ablation purposes. The lasers 206A, 206B can selectively remove anomalies from the color filter 209 in an easy and cost efficient manner. This apparatus provides for the repair of the color filter 209 used for the manufacture of flat panel displays and the like.

In a specific embodiment, as shown by the flow chart in Fig. 3, the invention provides a technique 300 for ablating anomalies from a color filter 209. This ablating technique 300 generally sears, burns, or vaporizes the anomalies. In most embodiments, the anomalies include particulate, portions of photoresist, pattern defects, inclusions of foreign material, and the like, which were described above. The technique 300 for ablating anomalies can be briefly described as follows:

1. Provide a color filter having anomalies (step 302);
2. Direct cutting devices (e.g., lasers) toward the defect(s) (step 307);
3. Set the aperture(s) of the cutting devices to encompass a desired portion of the anomaly (-lies) (step 309);
4. Direct energy through the aperture(s) to remove a portion of the electrode layer between the cutting devices and the anomaly (-lies) (step 310);
5. Direct energy through the aperture(s) to ablate the anomalies (step 311);
6. Repeat, if necessary, steps (3) and (4) until the defect(s) is(are) substantially removed (steps 307-313);
7. Perform remaining fabrication steps. (step 315)

As shown, the technique 300 generally directs the cutting devices toward the anomalies and directs high energy waveforms (i.e., energy from lasers) to ablate the anomalies. If needed, the aperture of either or both cutting devices are adjusted and the cutting devices are directed to remaining portions of the anomalies for removal. This sequence of steps can be repeated, as necessary. This flow diagram is merely an illustration and should not limit the scope of the claims herein. As discussed, the lasers may share a single aperture and/or may be directed at a single anomaly. The description to follow uses reference numbers from Figs. 1 and 2A-2B for elements shown therein to assist the reader.
The flow diagram begins at step 301 and provides a defective color filter 1 at step 302. This defective color filter 1 includes inclusions and color non-uniformities. Details of these anomalies were previously described.

At step 303 the color filter 1 is placed on a stage of a cutting tool, such as the x-y-z stage assembly 205, described by way of Fig. 2A, and secured at step 305. The color filter 1 is firmly placed on the x-y-z stage assembly 205, which allows for accurate positioning of high intensity light sources onto selected portions of the color filter 1. In preferred embodiments, the color filter 1 is secured at step 305 using a cover to prevent any substantial movement of the color filter 1 during processing.

At step 307 the cutting tools 200 and in particular lasers 206A, 206B are directed toward defects (i.e., anomalies) in the color filter 1. This directing step is performed by moving the x-y-z stage assembly 205 such that the anomalies are directly underneath the apertures of the lasers 206A, 206B if the lasers 206A, 206B are arranged to emit energy downwardly. Alternatively, the lasers 206A, 206B are moved via the x-y-z stage assembly 205 relative to the color filter 1, which is fixed in location. As a further alternative, the lasers 206A, 206B may be pivoted or aimed at selected portions of the color filter 1 with or without moving the x-y-z stage assembly 205 or the lasers 206A, 206B relative to the housing 201.

At step 309 the aperture(s) are adjusted to provide selected amounts of light intensity onto selected regions of the color filter 1 to ablate the anomalies. In one embodiment, the apertures are opened to point where the light directed there through encompasses each anomaly entirely. This allows a top portion of the anomaly to be ablated or removed.

At step 310 energy is directed through the aperture(s) to remove a portion of the electrode layer 11 between the cutting devices and the anomalies. This step removes the portion of the electrode layer that may otherwise prevent ablation of an underlying anomaly. This step may be omitted if not needed.

A step of directing high intensity light sources at the anomalies is performed at step 311. This step can remove all or substantial portions of the anomalies. In one embodiment, an upper portion of the color filter 1 is removed by way of the high intensity light source if an anomaly is disposed in a center portion of the protection layer 9 of the color filter 1 or the like. Alternatively, wavelengths of
energy may be chosen, depending upon the material employed, that do not substantially affect layers for which energy absorption is not desired. The light sources are preferably directed to the anomaly in a perpendicular direction to the surface of the color filter 1.

Step 310 may require more energy than that required to ablate an anomaly at step 311. Thus, one of the lasers may produce a high-energy beam during step 310, but may then be reduced in energy or even shut off during step 311.

Step 310 may require a different wavelength of energy than step 311. In this case, one laser may produce a wavelength of light needed to remove the electrode layer and another laser may produce a second wavelength of light needed to ablate an anomaly. These wavelengths may be produced simultaneously, or the first wavelength during step 310 and the second wavelength during step 311. Alternatively, a single laser may produce both wavelengths of light, simultaneously or consecutively.

After abrating a portion of one or both anomalies, the color filter 1 is inspected at step 313. Inspection can occur using simple visual inspection techniques under magnification, e.g., microscope, magnifying glass, etc. Alternatively, inspection can occur by observing the ablated region using a high quality CCD camera or the like. Or course, the type of inspection used depends upon the particular application. Inspection determines whether a given anomaly has been adequately ablated. Adequate ablation includes, but is not limited to, substantially complete removal.

If either anomaly has not been removed adequately, the method returns to step 307 via branch 312. Here, the lasers 206A, 206B are re-directed to any anomaly requiring further ablation, the apertures are readjusted to allow a selected amount of light intensity therethrough, and a high intensity light source is directed through each aperture (if needed) to ablate a remaining portion of any anomaly requiring further ablation. Steps 307-312 may include beginning with a small aperture size and increasing the aperture size each time the light is reapplied. Alternatively, steps 307-312 may include beginning with a large aperture size and decreasing the aperture size each time the light is reapplied. The technique 300 includes reinspecting the re-ablated anomalies.

When the anomalies have been adequately removed, the color filter 1 is returned to the manufacturing process and additional process steps are performed at
step 315. These remaining process steps include assembly, fill, seal, test, and others. The technique 300 ends at step 317. Of course, this ending depends upon the particular application.

The above sequence of steps is merely an example. These steps can be further combined or even separated into additional steps. Steps can even be inserted, depending upon the application. These and other steps are performed by way of the present invention.

In an alternative embodiment, as shown by the flow chart in Fig. 4, the invention provides a technique 400 for reducing the size of anomalies (e.g., bumps) on a color filter pixel. This technique 400 may be briefly outlined as follows:

1. Provide a color filter having a bump (step 403);
2. Position at least one cutting device toward the anomaly (step 409);
3. Set the aperture(s) of the cutting device(s) directed toward the anomaly to encompass an outer periphery of the anomaly (step 411);
4. Direct at least one high intensity light source through its aperture to ablate a portion of the anomaly (step 413);
5. Reduce the aperture(s) of the cutting device(s) to encompass an inner periphery of the anomaly (step 415);
6. Direct at least one high intensity light source through the reduced aperture(s) to ablate an inner periphery of the anomaly (step 417);
7. Repeat, if necessary, steps (5) and (6) until the anomaly is adequately removed (steps 415-420);
8. Perform remaining fabrication steps (step 421).

The above sequence of steps selectively reduces the size of the anomaly by way of each step of directing the high intensity light source to ablate a portion of the anomaly. These steps "surgically" remove or eliminate the anomaly from the color filter 1 in an accurate and easy manner. In particular, adjusting the aperture opening(s) of the cutting device(s) to selectively remove portions of the bump in multiple steps removes the bump without causing severe damage to the color filter 1. Details of the technique are shown in the figures described below.

Fig. 4 is a simplified flow diagram for the technique 400 for removing bumps from the AMLCD color filter 1. This diagram is merely an illustration and should not limit the scope of the claims herein. One of ordinary skill in the art would recognize other variations, modifications, and alternatives. As discussed, the lasers
may share a single aperture and/or may be directed at a single anomaly. The technique for removing bumps is also illustrated by way of Figs. 5-7.

Referring to Fig. 4, the flow diagram begins at step 401 and provides a color filter 1 at step 403. The color filter 1 is similar to the one described above, but can also be others. The color filter 1 has a plurality of pixel elements (e.g., red, green, and blue). One of these pixel elements includes an anomaly such as the one shown in Fig. 5. The anomaly can be categorized as a "bump" 501 or protrusion, which increases the intensity of the color at this region. The increased intensity of color appears to look like a deeper or darker color than surrounding regions.

Returning to Fig. 4, at step 405, the color filter 1 is placed on a stage of a cutting tool, such as the x-y-z stage assembly 205 described by way of Fig. 2A. The color filter 1 is firmly placed on the x-y-z stage assembly 205, which allows for accurate positioning of the high intensity light source onto the color filter 1. In preferred embodiments, the color filter 1 is secured at step 407 using a cover to prevent any substantial movement of the color filter 1 during processing.

The aperture of at least one high intensity light source is adjusted to target the bump 501 in step 411. This aperture is adjusted to allow the lasers 206A, 206B to target a region 503 of the entire bump 501, which begins at an outer most periphery of the bump 501, as illustrated by Fig. 5. The aperture is adjusted to selectively remove an upper layer of the bump over the entire upper surface of the bump.

The high intensity light source is directed through the aperture in step 413. The high intensity light (or particle source) can be from a laser such as previously described. Alternatively, other lasers or light sources can be used, depending upon the application. As can be seen from Fig. 6, the high intensity light source removes an upper layer portion 505 of the bump 501 over the entire upper surface region creating a reduced bump 506. The reduced bump 506 is now reduced in size, e.g., height and width.

The aperture is reduced to target an inner portion 507 of the original bump 505 at step 415. The technique 400 selects a reduced aperture size to remove another portion of the reduced bump 506. At step 417 high intensity light is directed onto the reduced target area to remove a second portion of an upper layer of the
reduced bump 506, which further reduces the size of the reduced bump 506 including the width and height.

The ablated structure is inspected at step 419. If additional ablation is needed, steps 415 and 417 are repeated until the bump has been substantially removed via branch 420. The ablated structure which has been repaired is shown in Fig. 7. As shown, the ablated color filter 1 does not have a "bump." The ablated structure includes upper surface region 509, which is substantially free from damage.

Remaining fabrication steps are then performed on the color filter 1 at step 421. These steps can include coating the ablated structure using a clear film of protective layer. The coating layer tends to protect the underlying color filter 1. The coating layer can be a dielectric layer and others. A variety of additional processing steps also can be performed, depending upon the application. The technique 400 ends at step 423.

While the preceding discussion described use of only one of the light sources, the description applies equally to use of more than one light source simultaneously on the same bump. Also, as an alternative to the above description, the aperture may be set to encompass an inner periphery of the anomaly at step 411 and increased to encompass a larger periphery, and eventually an outer periphery, of the anomaly at step 415.

The techniques for removing bumps can also be applied to removing large inclusions found near a surface region of the color filter 1. Alternatively, the techniques can be applied to anomalies within the color filter 1. That is, the anomalies can be in the protection layer 9, in the electrode layer 11, in the matrix layer 3, or the transparent substrate 5. Accordingly, above techniques can be used to remove a variety of anomalies to repair a color filter or the like.

The techniques above are described in terms of a sequence of steps. These steps can be performed using a variety of hardware and software combinations, which can be combined or separated. For example, the hardware can be in the form of a microprocessor based unit with software. The software can include a variety of recipes to carry out the above techniques as well as others. The software can be described as a computer program product (e.g., software, firmware), which is stored in memory, but can also be stored on a transferable medium such as a floppy disk, a CD
ROM, a removable hard drive, a tape, and others.

Figs. 8A-8C show the use of various wavelengths of light for use in cutting passivation and metal layers. For example, substrate 800 is a multi-layered structure made of glass 801, which has an overlying metal layer 803 (e.g., aluminum), which has an overlying passivation layer 805 (e.g., silicon dioxide, silicon nitride). A top surface 806 of the passivation layer 805 is exposed to air 807 or another fluid medium. High intensity light from a source(s) can be emitted in a single shot in a variety of wavelengths such as 355 nm 809, 532 nm 811, 1064 nm 813, and others. As shown in Fig. 8B, for example, the 355 nm light ablates into and through a portion of the passivation layer, but stops ablating at the metal layer. The 532 nm light ablates into and through the passivation layer, and into and through the metal layer, but stops ablating at the glass layer. The 1064 nm light ablates into and through the passivation layer, and into and through the metal layer, but stops ablating at the glass layer. The 1064 nm light ablates a larger portion of the metal layer and exposes a larger cross-sectional area B of glass layer than the portion exposed A by the 532 nm light. As shown by Fig. 8C, a second shot of the 355 nm light ablates into and through the metal layer, but not through the glass layer. The two steps of ablation of the 355 nm light produce a cleaner profile than the single-shot ablation of the sources at either the 532 nm or 1064 nm light. Of course, Figs. 8A-8C are merely examples, and should not limit the scope of the claims herein.

The invention has now been explained with reference to specific embodiments. Other embodiments will be apparent to those of ordinary skill in the art in light of the disclosure. For example, high intensity energy sources have been described as light sources. Energy sources for energy waveforms having wavelengths other than those for visible light may be used. It is therefore not intended that this invention be limited, except as indicated by the appended claims.
WHAT IS CLAIMED IS:

1. A method for repairing a color filter for a flat panel display using
   a plurality of high intensity light source means, said color filter having a plurality of
   anomalies, said color filter having a plurality of color pixels being defined on a
   transparent substrate, said method comprising steps of:
   - directing a first high intensity light having a first wavelength from a first
   - light source means through a first aperture of selected size at a first anomaly;
   - directing a second high intensity light having a second wavelength from a
   - second light source means through a second aperture of selected size at a second
   - anomaly.

2. The method of claim 1 wherein said directing steps are controlled
to prevent substantial damage to said filter beyond portions of said filter near said
anomalies.

3. The method of claim 1 wherein said directing steps ablate
portions of said first and second anomalies respectively.

4. The method of claim 1 wherein said directing steps occur
substantially simultaneously.

5. The method of claim 1 further including successively repeating
the step of directing the first high intensity light at successively diminishing first
aperture size.

6. The method of claim 1 further including successively repeating
the step of directing the first high intensity light at successively increasing first aperture
size.

7. The method of claim 1 wherein said anomalies are selected from
a group consisting of a particle, a photoresist, a pattern defect, a bump, and a shorting
bar.
8. The method of claim 1 wherein said anomalies are defined in first and second portions of said filter selected from a group consisting of a protective layer, a matrix layer, and an electrode layer.

9. The method of claim 8 wherein said first wavelength is absorbed by said first anomaly and is not substantially absorbed by any layers disposed between said first anomaly and a first light source means for directing said first high intensity light and said second wavelength is absorbed by said second anomaly and is not substantially absorbed by any layers disposed between said second anomaly and a second light source means for directing said second high intensity light.

10. The method of claim 1 wherein said first and said second anomalies are identical and said first and said second wavelengths are substantially similar.

11. The method of claim 1 wherein said first anomaly is defined in at least one of said pixels.

12. The method of claim 1 further comprising a step of adjusting said first aperture to direct said first high intensity light.

13. The method of claim 1 wherein said first aperture is said second aperture.

14. The method of claim 1 wherein said first light and said second light are directed into said color filter from different locations.

15. The method of claim 1 wherein said first and second lights have intensity distributions across said first and second apertures respectively selected from a group of distributions consisting of Gaussian and top hat.
16. The method of claim 1 wherein said directing step is provided in less than about 15 seconds.

17. The method of claim 1 wherein said first and second wavelengths are in ranges selected from a group of ranges consisting of infrared, ultraviolet, and visible light.

18. The method of claim 1 wherein said first high intensity light is directed perpendicularly to a top surface of said color filter.

19. The method of claim 1 further comprising the step of removing a portion of the filter disposed between a first light source means and the first anomaly.

20. The method of claim 19 wherein the portion of the filter removed is a portion of the electrode layer.

21. The method of claim 19 wherein the first and second anomalies are the same anomaly, and the first high intensity light removes the color filter portion and the second high intensity light ablates the anomaly.

22. The method of claim 19 wherein the step of directing the first high intensity light comprises directing light having a first wavelength to remove the color filter portion and directing light having a third wavelength to ablate the first anomaly.

23. The method of claim 22 wherein the step of directing the first high intensity light comprises directing light having the first and third wavelengths simultaneously.

24. The method of claim 22 wherein the step of directing the first high intensity light comprises directing light having the first wavelength then directing light having the second wavelength.
25. A method of repairing a color filter assembly for a flat panel display, said method comprising steps of:

- providing a color filter assembly, said color filter assembly having a first anomaly and a second anomaly different from said first anomaly;
- directing a first energy waveform having a first wavelength on said first anomaly to ablate said first anomaly; and
- directing a second energy waveform having a second wavelength, different from said first wavelength, on said second anomaly to ablate said second anomaly;

wherein said first and said second energy waveforms are selected to pass through non-anomaly portions of said color filter assembly substantially free of absorption.

26. The method of claim 25 wherein said first energy waveform and said second energy waveform are directed upon said first and said second anomalies simultaneously.

27. The method of claim 25 wherein said first and second energy waveforms are directed through first and second apertures adjusted to reduce undesired absorption of said first and second energy waveforms beyond said first and second anomalies respectively.

28. The method of claim 27 wherein said first aperture is successively increased in size between pulses of said first energy waveform.

29. The method of claim 27 wherein said first aperture is successively decreased in size between pulses of said first energy waveform.

30. The method of claim 27 wherein said first and second energy waveforms have first and second intensity distributions across said first and second apertures selected from a group of distributions consisting of Gaussian and top hat.
31. The method of claim 25 wherein said first and second anomalies are selected from a group consisting of a particle, a photoresist, a pattern defect, a bump, and a shorting bar.

32. The method of claim 25 wherein said first and second anomalies are defined in first and second portions of said filter respectively selected from a group consisting of a protective layer, a matrix layer, and an electrode layer.

33. The method of claim 25 wherein each of said directing steps are provided in less than about 15 seconds.

34. The method of claim 25 wherein said first and second wavelengths are each in a range selected from a group of ranges consisting of infrared, ultraviolet, and visible light.

35. The method of claim 25 wherein said first and second energy waveforms are directed perpendicularly to a top surface of said color filter assembly.

36. The method of claim 25 further comprising removing portions of said color filter to allow said first and second waveforms to ablate said first and second anomalies.

37. An apparatus for repairing a flat panel display, said apparatus comprising:
   a first high intensity source for emitting high intensity energy having a first wavelength to a first portion of a color filter assembly for ablation purposes;
   a first aperture, through which energy from said first source passes, adjusted to reduce absorption of said first wavelength beyond said first portion of said color filter assembly;
   a second high intensity source for emitting high intensity energy having a second wavelength to a second portion of said color filter assembly for ablation purposes; and
a second aperture, through which energy said second source passes,
adjusted to reduce absorption of said first wavelength beyond said first portion of said
color filter assembly.

38. The apparatus of claim 37 wherein said first source is a YAG
laser.

39. The apparatus of claim 37 wherein said first and second
wavelengths are in ranges selected from a group of ranges consisting of infrared,
ultraviolet, and visible light.

40. The apparatus of claim 37 wherein said first and second
wavelengths are different.

41. The apparatus of claim 37 wherein said first and second portions
of said color filter are identical and said first and second wavelengths are substantially
similar.

42. The apparatus of claim 37 wherein first and second intensity
distributions across said first and second apertures are selected from a group consisting
of Gaussian and top hat.

43. The apparatus of claim 37 wherein said first high intensity energy
ablates a portion of the filter disposed between the first high intensity source and a first
anomaly in the filter.

44. The apparatus of claim 37 wherein said first high intensity source
emits energy having the first wavelength and energy having a third wavelength, the first
wavelength energy for ablating a portion of the filter disposed between the first source
and a first anomaly, the third wavelength energy for ablating the first anomaly.

45. The apparatus of claim 44 wherein the first source emits the
energies having the first and third wavelengths simultaneously.

46. The apparatus of claim 44 wherein the first source emits the energy having the first wavelength then emits the energy having the third wavelength.

47. A computer program product for repairing a color filter for a flat panel display using a plurality of high intensity light source means, said color filter having a plurality of anomalies, said color filter having a plurality of color pixels being defined on a transparent substrate, said computer program product comprising a computer readable memory including,

a first code for directing a first high intensity light having a first wavelength from a first light source means through a first aperture of selected size at a first anomaly;

a second code for directing a second high intensity light having a second wavelength from a second light source means through a second aperture of selected size at a second anomaly.

48. The computer program product of claim 47 wherein said first code and said second code control said first high intensity light and said second high intensity light to prevent substantial damage to said filter beyond portions of said filter near said anomalies.

49. The computer program product of claim 47 further including a third code directed to successively repeating the step of directing the first high intensity light at successively diminishing first aperture sizes.

50. The computer program product of claim 47 further including a third code directed to successively repeating the step of directing the first high intensity light at successively increasing first aperture sizes.

51. The computer program product of claim 47 wherein said anomalies are selected from a group consisting of a particle, a photoresist, a pattern
defect, a bump, and a shorting bar.

52. The computer program product of claim 47 wherein said anomalies are defined in first and second portions of said filter selected from a group consisting of a protective layer, a matrix layer, and an electrode layer.

53. The computer program product of claim 47 wherein said first anomaly is defined in at least one of said pixels.

54. The computer program product of claim 47 further comprising a third code directed to adjusting said first aperture to direct said first high intensity light.

55. The computer program product of claim 47 wherein said first aperture is said second aperture.

56. The computer program product of claim 47 wherein said first light and said second light are directed into said color filter from different locations.

57. The computer program product of claim 47 wherein said first and second lights have intensity distributions across said first and second apertures respectively selected from a group of distributions consisting of Gaussian and top hat.

58. The computer program product of claim 47 wherein said first and second wavelengths are in ranges selected from a group of ranges consisting of infrared, ultraviolet, and visible light.

59. The computer program product of claim 47 wherein said first high intensity light is directed perpendicularly to a top surface of said color filter.

60. The computer program product of claim 47 further comprising a third code directed to removing a portion of the filter disposed between a first light source means and the first anomaly.
FIG. 1
START

PROVIDE DEFECTIVE COLOR FILTER

PLACE FILTER ON STAGE OF CUTTING DEVICE

SECURE FILTER

DIRECT CUTTING DEVICES TOWARD DEFECT(S)

ADJUST APERTURE(S) OF DEVICES

DIRECT HIGH INTENSITY LIGHT TO REMOVE ELECTRODE LAYER

DIRECT HIGH INTENSITY LIGHT TO ABLATE DEFECT(S)

INSPECT FILTER; DONE?

YES

PERFORM REMAINING STEPS

STOP

NO

FIG. 3
Depth of Penetration (λ.k)

- 1064nm
- 532nm
- 355nm

Air

Glass
Clean Cutting on Integrated Stacks

355nm (Second Shot)

Air

Glass

Fig. 8 C
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) : G02B 5/20; G02F 1/1335; B23K 26/00; G06F 19/00
US CL : 430/7, 321; 219/121.68, 121.69, 121.76; 364/474.08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 430/7, 321; 219/121.68, 121.69, 121.76; 364/474.08

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

NONE

Electronic database consulted during the international search (name of database and, where practicable, search terms used)

APS

search terms: color filter, lasers, repair, defect, ablate, anomaly

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<td>US 4,925,523 A (BRAREN et al) 15 May 1990, abstract and col. 8, line 65 to col. 9, line 19.</td>
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<td>JP 5-027111 A (SHARP CORP) 05 February 1993, abstract and figures 1-2.</td>
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[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents: "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
*A* document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document published on or after the international filing date
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

Date of the actual completion of the international search 05 FEBRUARY 1999

Date of mailing of the international search report 18 FEB 1999

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<th>Category</th>
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