COLOR FILTER INSPECTION METHOD AND APPARATUS

A technique including a method and an apparatus for observing defects on a color filter assembly (119) by optically scattered energy from an illumination means (107). The technique includes directing back illumination (107) from a source (109) to highlight one group of color pixels (e.g., red, green, blue) from a color filter assembly (121) under inspection to produce scattered energy substantially normal to the color filter assembly (121). A further step of observing the scattered energy in one of a plurality of fractional windows of a viewed image of the color filter assembly via a plurality of focusing elements (103) at a plurality of remote focal planes having a detection arrangement is included. The focal planes are mounted adjacent one another in an array arrangement. Observing occurs without relative motion between the color filter assembly and the fractional windows to prevent a possibility of scanning noise and permit oversampling.
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COLOR FILTER INSPECTION METHOD AND APPARATUS

BACKGROUND OF THE INVENTION

This present invention relates to defect monitoring tools and related methods for inspection of structures useful in, for example, large flat panel display construction. More particularly, the invention is illustrated in an example related to the inspection of a color filter for use in flat panel displays 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 or the like continues to grow rapidly. For example, consumer electronic 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.

These state-of-art manufacturing lines, however, still rely in most part upon human test operators for the final test and inspection of these flat panel displays. The test operator performs a visual inspection of each display for defects in order to accept or reject the display. The quality and completeness of the inspection is dependent on the test operator, who has been trained using limited samples of displays that have defects and characterized as either pass or fail. The inspection results are highly subjective and prone to error, and cannot be used effectively and efficiently to monitor, control, and improve the quality of the various manufacturing processes.
More particularly, human test operations also visually inspect color filters used in the manufacture of AMLCDs. Examples of these color filters are those made by companies such as Topan Printing or Dai Nippon Printing, both of Japan. Human test operations often look for variations in the color intensity in the color pixel assembly of the flat panel display, which is often difficult and time consuming.

These color filters are often plagued with defects introduced by the manufacturing process, which cause the variations in the color intensity. For instance, the color filter has color pixels (e.g., red, green, and blue) having imperfections such as inclusions, particulate contamination, thickness variations, and the like. These imperfections generally cause color intensity variations.

Effective process monitoring and control of flat panel display production have been made possible through quantitative inspection methods by way of automatic inspection machines. An example of one of the first pioneering automatic inspection machines was developed by Photon Dynamics, Inc. (PDI) in 1992, assignee of the present application. This first automatic inspection machine is pioneering, since a high quality inspection of flat panel displays could be performed using machines, rather than human test operators. This high quality inspection was performed on flat panel displays having completed thin film transistor components fabricated thereon.

Industry now desires an effective technique for identifying defects in color filters used for the manufacture of these flat panel displays. Unfortunately, no such technique exists for the inspection of color filters. As noted above, human test operators often inspect the quality of color filters used for the manufacture of flat panel displays. The test is subjective, time consuming, prone to error, and often fail to improve the manufacturing process.

From the above, it can be seen that a technique for identifying defects on 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 identifying anomalies in a color filter is provided. The invention provides a technique for detecting anomalies in a color filter assembly or the like using a plurality of CCD cameras without scanning.
In a specific embodiment, the invention provides a method for observing defects on a color filter assembly or plate by optically scattered energy from an illumination means. The method includes a step of directing back illumination from a light source to highlight one group of color pixels (e.g., red, green, blue) from a color filter assembly under inspection to produce scattered energy (e.g., non-specular energy) substantially normal to the color filter assembly. A further step of observing the scattered energy in one of a plurality of fractional windows of a viewed image of the color filter assembly via a plurality of focussing elements at a plurality of remote focal planes having a detection arrangement (e.g., array arrangement) is included. The focal planes are mounted adjacent one another arranged in an array arrangement adjacent one another. These steps of directing and observing occur without relative motion between the color filter assembly and the plurality of focussing elements to prevent a possibility of scanning noise and permit over sampling.

In an alternative embodiment, a system for observing defects on a color filter assembly by means of optically scattered light is provided. The system has a light source for directing illumination from a source to a backside surface of a color filter assembly to produce scattered energy (e.g., non-specular energy) substantially normal to the color filter assembly. The system also has a plurality of CCD cameras for observing the scattered energy in one of a plurality of fractional windows of a viewed image of the color filter assembly via a plurality of focussing elements at a plurality of remote focal planes having a detection arrangement. The focal planes are mounted adjacent one another arranged in an array arrangement adjacent one another. This system does not have a substantial amount of relative movement between the CCD cameras and the color filter during inspection to reduce any possible scanning noise and the permit oversampling.

Benefits are achieved by way of the present invention. In particular, the present invention provides a plurality of CCD cameras that can capture an image from a color filter assembly using a single snap-shot measurement. This single snap-shot measurement does not require scanning and can be done in a relatively efficient manner. Additionally, the invention compares the captured image from the color filter assembly against known accept and reject samples, which provides for a relatively
automatic inspection process. The automatic inspection process occurs without the subjectivity of human test operations of conventional techniques.

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 assembly;

Fig. 2 is a simplified diagram of an inspection system according to the present invention;

Fig. 3 is a simplified diagram of an array of CCD cameras for the system of the above Fig.;

Fig. 4 is a more detailed diagram of the light source for the system of the above Fig.;

Fig. 4A shows simplified response curves to filters according to the present invention;

Fig. 5 is a simplified flow diagram of an inspection technique according to the present invention; and

Fig. 6 is a simplified flow diagram of an alternative inspection technique according to the present invention.

DESCRIPTION OF SPECIFIC EMBODIMENTS

Fig. 1 is a simplified cross-sectional view diagram of a color filter 1. The diagram is merely an illustration and should not limit the scope of the claims herein. The color filter 1 is provided on a matrix layer 3, which is defined on a transparent substrate 5. The matrix layer 3 can be a black matrix or black relief defined by printing processes.

Transparent substrate 5 is often a clear glass-type structure such as a glass plate or the like. For instance, the transparent substrate 5 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. An example of such a 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 has a 1.1 mm to 0.7 mm thickness. Of course, the plate can almost be any relatively transparent structure or medium with a refractive index greater than one.

A colored layer 7 is formed overlying matrix layer 3 and transparent substrate 5. The colored layer 7 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 striped arrangement, and others. The 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 silicon dioxide, borosilicate glass, and other materials. Electrode layer 11 overlies the protection layer 9. Electrode layer 11 is often made using an indium tin oxide (ITO) material. But it can also be made of other materials. Other types of color filters can also be inspected by way of the present technique. An example of this color filter 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 references for all purposes.

During the manufacturing process, anomalies are introduced into the color filter. The anomalies can reduce the quality of images on, for example, an AMLCD flat panel display. These anomalies are often in the form of particulate contamination 13 or defects, e.g., voids 15, pattern defects 17, scratches 19, etc. Depending upon the size, shape, and location of the anomaly, the color filter may be rejected or accepted during an inspection operation of the manufacturing process. The present invention provides a technique, including a system and method, for inspecting and categorizing these anomalies.

Referring to Fig. 2, the present invention includes an inspection apparatus 100, e.g. large area defect monitoring tool. The inspection apparatus 100 (or system) of Fig. 2 is merely an illustration and should not limit the scope of the claims as defined herein.
The inspection apparatus 100 has a variety of systems and sub-systems. The apparatus 100 is provided with sub-systems in a housing 101. These sub-systems include a variety of hardware elements such as a plurality of CCD cameras 103, a stage assembly 105, an illumination apparatus 107, and a light source 109. Operation of the above sub-systems and processing capability is provided using a base unit 111, which is coupled to a central processing unit 113, a monitor 115, and a keyboard/mouse (not shown). An image processor 110 is housed in the base unit 111. Signals from the sub-systems in the housing are transferred via connection 117 to the central processing unit 113, which can be a SUN VME-based SPARC system or any other suitable system.

Inspection is provided using the CCD cameras 103 to a color filter assembly 119, such as the color filter described above. The color filter assembly 119 positions on a slidable table 121, and a hinged frame 123, which is brought down to secure the color filter assembly in place. The slidable table 121 allows for easy positioning of the plate in an x-y plane under the plurality of cameras 103, such as multiple CCD-type cameras and the like. The slidable table 121 allows for the plate to be shifted in the x-y directions relative to the cameras. Alternatively, the cameras are mounted onto an x-y stage to move the cameras relative to the plate. The multiple cameras 103 can be used to increase viewing angle of an image from the color filter assembly 119.

The x-y stage 105 can be any suitable base unit capable of moving the plate in an x-direction and/or a y-direction. The stage may include continuous movement in the x-direction and/or y-direction. Preferably, the x-y stage also increments at selected dimensions in the x-direction and the y-direction. Alternatively, a robot can move the plate in the x-y directions.

The z-direction operates in a continuous movement mode or at selected z-positions through the use of an actuator. The actuator can be in 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 stage has movement in the z-direction, but does not adjust in the x-y direction during inspection. In further embodiments, the cameras are adjustable in the z-direction relative to the plate.
The CCD cameras can be selected from conventional high resolution CCD-type cameras. An example of such a CCD camera can use a megapixel CCD array such as the KAF1600, made by Kodak. In other embodiments, the CCD array has more than one megapixel for capturing larger surface and finer features. The type of camera used, however, depends upon the application.

In one embodiment, the CCD cameras are grouped or catenated into an array structure of similar CCD cameras. This grouping of CCD cameras allows for inspection of larger surface areas using less snap-shots of the front-side surface of the plate. The similar CCD cameras can be grouped with other similar CCD cameras to form an array structure of similar CCD cameras (e.g., four-cameras, etc.), as illustrated by Fig. 3.

Fig. 3 is a simplified diagram of a plurality of CCD cameras 300 grouped together according to another aspect of the present invention. As shown, the diagram includes four CCD cameras, which are used to capture images from a surface to be inspected. In a preferred embodiment, each CCD camera uses a 1K pixel by 1K pixel array to scan a 100 mm by 100 mm plate surface region. The plate surface region can be the top surface of the color filter assembly 119. These four CCD cameras can scan a total surface of 200 mm by 200 mm. The four similar CCD cameras can be grouped together in an another grouping of four to form an array structure of sixteen similar CCD cameras. The sixteen CCD cameras then can be grouped into another array structure to form sixty-four similar CCD cameras. Preferably, these cameras are encased with an upper body of the inspection apparatus.

In yet an alternative embodiment, the CCD cameras that are grouped together are sized differently. That is, one CCD camera can use a 1K pixel by 1K pixel array and another CCD camera can use a larger sized pixel array. CCD cameras having differing array sizes are arranged in both symmetrical and non-symmetrical configurations. The CCD cameras can be sized and arranged differently for the particular application.

Image processor 110 can be selected from a variety of conventional high performance commercially available processors. An example of such a processor is a MV200 made by DATACUBE. This processor includes features such as large memory capacity, flexible array processing, easy to use interfacing, among others. Preferably,
the image processor 110 has multiple input/output ports for multiple CCD cameras and
the like. Of course, the type of processor used depends upon the application.

Fig. 4 is a more detailed diagram of the illumination device 107 and light
source 109 for the apparatus of the above Fig. The diagram includes the light source
109 and the back illumination apparatus 107.

The back illumination apparatus 107 is connected to the light source 109
using a fiber optic bundle 401. The desired light may be in the range of 475nm to
750nm but may be narrower to simplify the optical design. The light source is
preferably a quartz halogen lamp or the like. More preferably, the light source is a
uniform source of illumination having the same intensity and other properties at each
location on the illuminator. The light source directs light through one of a plurality of
color filters 403 on a selector wheel 405. The color filter removes light in selective
wavelengths to highlight one of the groups of pixels, e.g., red, green, or blue. For
instance, a green filter highlights green pixel elements. A red filter highlights red pixel
elements, and a blue filter highlights blue pixel elements. Additionally, filtering
reduces a possibility of cross-talk between a red portion of light and a green portion of
light, for example, as illustrated by a simplified light intensity response diagram 420 by
Fig. 4A. As shown, the vertical axis represents light intensity (I) and the horizontal
axis represents wavelength of emitted light (λ). The larger peaks shown by references
numerals 421 and 425 are the color filter response. Once the filter is placed over the
illumination, the response is shown by the smaller but sharper peaks 423 and 427. As
merely an example, a red portion of the light 423 which has been filtered, does not
interfere with the green portion 427 of the light. Again, this diagram is merely and
illustration and should not limit the scope of the claims herein.

The filtered light from the source is directed through the fiber optic
bundle, which provides the filtered light to the back illumination apparatus. The back
illumination apparatus evenly distributes the filtered light to illuminate the back face of
the color filter assembly, which is a glass substrate. In some embodiments, the back
illumination apparatus includes a plurality of baffles 409 to selectively direct the filtered
light against the back face of the color filter assembly. These baffles help direct the
filtered light onto the backside of the color filter assembly.
In other embodiments, a filter is placed between the back illumination apparatus and the color filter assembly. The filter can be a polarizer or the like. Of course, other filters can also be used.

The back illumination apparatus provides a relatively uniform distribution of light onto the backside of the color filter assembly. That is, the relatively uniform distribution is a relatively uniform intensity of light. Preferably, the uniformity value of the light intensity on the backside of the color filter assembly is greater than about 90%. The uniform light intensity allows the CCD cameras to capture images of anomalies, which appear darker or lighter than surrounding filter surfaces on the color filter assembly.

In an embodiment, a color filter inspection method according to the present invention may be briefly described as follows:

1. Provide a color filter assembly for inspection;
2. Place the color filter assembly onto a stage of an inspection apparatus;
3. Selectively illuminate a group of color pixels (e.g., red, green, blue) from the color filter assembly from the back using backside illumination;
4. Focus surface of color filter assembly onto at least one of a plurality of imaging device;
5. Highlight anomalies which can be in the group of color pixels by capturing a different light intensity from light illuminating from the group of color pixels around the anomalies;
6. Capture the light intensities derived from the color filter through at least one of the plurality of imaging devices;
7. Convert the intensity of light into a digitized image which can highlight the anomalies in the group of color pixels;
8. Compare the intensity of light from at least one of the anomalies to identify a possible defect;
9. Accept or reject the color filter assembly based upon the step of comparing;
10. Perform remaining inspection or assembly steps, including repair of the color pixel group.
The above sequence of steps can be used to identify defects in a color filter assembly using a plurality of imaging devices such as CCD cameras or the like. This sequence is merely an example and should not limit the scope of the claims herein. One of ordinary skill in the art would recognize other modifications, alternatives, and variations.

Details of the above sequence are further described in the Fig. below.

Fig. 5 is a simplified flow diagram of an inspection method according to the present invention. This method is merely an example and should not limit the scope of the claims herein. The method 500 begins at step 501. A color filter assembly 503 is provided. The color filter assembly 503 is placed onto a stage 505, where it is secured firmly using a clamping means. An upper surface of the color filter is placed facing a plurality of CCD cameras. The upper surface is the transparent electrode layer and the lower surface of the color filter is the glass substrate.

A light source selectively illuminates (step 507) light from the backside of the color filter assembly through the substrate to highlight one group of color pixels, e.g., red, green, blue. In most embodiments, a color filter selector mounted on the light source selectively allows a certain wavelength of light to be illuminated through the color filter using backside illumination. The light source can be similar to the one shown in the above Figs.

An imaging device (step 509) is focussed onto a top surface of the color filter assembly. The imaging device can be a plurality of CCD cameras such as the ones shown above. In most cases, the imaging device captures the entire surface of the color filter assembly, or larger portions thereof. Anomalies are captured from the color pixel groups using the imaging device from differences in brightness uniformity values. The differences in brightness uniformity values are caused by non-specular energy captured using a CCD camera from an anomaly.

The light source can be adjusted to highlight (step 511) anomalies in the color filter assembly. In certain embodiments, the light source either increases or decreases the intensity of light being illuminated through the color filter assembly to highlight the anomalies. In an alternative embodiment, the light source is set at a selected intensity level and is not adjusted to highlight anomalies. In this embodiment, the light source is calibrated to a standard.
The CCD cameras capture (step 513) an image of the anomaly from scattered non-specular energy from the color filter assembly. The CCD cameras also capture an image of the color pixels from specular energy derived from the color filter assembly. These images are captured without moving the relative position between the color filter assembly and the CCD cameras. In most cases, the color filter assembly and the CCD cameras are substantially stationary during the capturing step to eliminate a possibility of any scanning noise or the like according to this embodiment.

The captured image(s) is converted (step 515) into digital form using an image processor. The digital form is essentially a digital mapping of the color filter having pixels. The digital mapping has various levels of intensities which can correspond to the different levels of light intensity being illuminated from the color filter assembly. The different levels of light intensity can correspond to anomalies on the color filter assembly.

The digital mapping is compared to a standard image in digital form in step 517. Depending upon the difference in intensity values of the digital mapping and the standard image in digital form, the color filter assembly is categorized as a rejected or accepted in step 519. A rejected assembly is transferred to repair in step 512. An acceptable assembly undergoes remaining assembly or fabrication steps (step 522).

In an alternative embodiment, the present invention provides a technique 600 for reducing the influence of interference patterns, e.g., Moire' pattern, as illustrated by the flow diagram of Fig. 6. Aliasing is a well-known phenomena that may manifest itself as a Moire' pattern, which is a periodic modulation of an image voltage signal created by the camera array. The Moire' phenomenon is due to the display or color pixels not being mapped onto the camera detecting pixels in exactly a one-to-one correspondence.

If the mapping is not precisely a one-to-one correspondence, the photons associated with certain color pixels will fall onto non-sensitive portions (if any) of the camera array, and, conversely, the "streets and alleys" between the color pixels will be imaged onto sensitive areas of the camera array. The result of this less than optimal pixel relationship results in a Moire' pattern, such as those described in U.S. Patent Application Serial No. 08/394,668, commonly assigned, which is hereby incorporated.
by reference for all purposes. This Moire pattern generally distorts the true relative brightness levels of the color pixels.

The present system employs a special multi-frame image translation technique to eliminate any inaccuracies in a detected color pixel image due to aliasing.

The method begins at step 601. In a specific embodiment used by the present system, a first inspection of the color pixels is conducted in the manner describe above at a first alignment position of the color filter pixel and the camera pixel array (step 603). The brightness level signal generated by each of the camera detector pixels for this first alignment position is cross-referenced to a specific color pixel which gave rise to the brightness level signal and then mapped into a memory within computer.

In a second step of detecting the brightness uniformity of the color filter assembly, the color filter pixel is slightly shifted relative to the camera detector pixels, such as by either physically shifting the relative position of the color filter assembly to the camera(s), or by changing the relative position of the camera and the color filter assembly by optics. After this shifting step (step 605), another image of the color filter pixel is detected and mapped into memory (step 607).

The color filter pixel is then shifted again relative to the camera detector pixels (step 609). This process is repeated until each of the color filter pixels has, during any of the detection stages, been detected by a camera detector pixel located entirely within an image of the color pixel. A camera detector pixel which is located entirely within a color pixel image (i.e., completely superimposed by the color pixel image) will detect an accurate relative brightness level of the color pixel.

The number of required shifts of the color pixel with respect to the camera detector pixels may include four small incremental shifts to the left or right and four small incremental shifts up or down before the Moire pattern is repeated. In a more preferred embodiment, the camera is displaced relative to a zero point on the color filter pixel in a first x-direction at a distance \( x_1 \), a second x-direction at a distance \( x_2 \), a first y-direction at a distance \( y_1 \), and a second y-direction at a distance \( y_2 \). The distance \( x_2 \) is equal to about the distance \(-x_1\) or \( 2x_1 \), and the distance \( y_2 \) is equal to about the distance \(-y_1\) or \( 2y_1 \). Of course, the required number of shifts and magnitude of the shifts will need to allow each of the color pixels to be detected by a camera detector pixels residing wholly within the projected image of the color pixel. A single
map is then made of only those maximum intensity signals associated with each color pixel. This information is then used to analyze the entire color filter assembly.

The above-described method is considered a specific embodiment. An alternative to first determining the maximum intensity ratio associated with each color pixel after all the incremental shifts and mapping these maximum intensities ratios into a single map is to simply average (step 611), over all the incremental shifts, the brightness level output signals of a camera detector pixel receiving any portion of a corresponding color pixel image. This average intensity level for each color pixel over all the incremental shifts would then be mapped so that each color pixel would be associated with an accurate relative intensity level.

In an alternative preferred embodiment, the present method also employs use of several images to average out a periodic modulation of a Moire' interference pattern. The present method includes a step of capturing from a color filter assembly a first image which contains the periodic modulation. The first image is captured by way of a CCD type camera or the like, and preferably stored into memory by way of standard mapping techniques.

A step of displacing the CCD camera relative to the color filter assembly is then performed. The color filter assembly is displaced in an x-direction and/or a y-direction relative to the CCD camera array. Alternatively, the CCD camera is displaced in an x-direction and/or a y-direction relative to the color filter. Alternatively, both the CCD camera and color filter are displaced in x and/or y-directions to create a relative spatial displacement between each of them. The relative displacement between the CCD camera and the color filter is preferably about one-half of a color pixel period in the x-direction when displacement occurs in the x-direction. Alternatively, the relative displacement between the CCD camera and the color filter assembly is preferably about one-half of a color pixel period in the y-direction when displacement occurs in the y-direction. The relative spatial displacement between the CCD camera and the color filter assembly is one-half of a color pixel period in the x or the y directions.

The preferred embodiment also includes a step of capturing (or acquiring) a second image of the color filter assembly, and storing such second image into memory also by way of standard mapping techniques. The second image also
contains the same periodic modulation with the same period as the first image. But the placement of the periodic modulation of the second image will be displaced by one-half of a period in either the x-direction or the y-direction relative to the first image by way of the displacing step. Of course, the placement of the periodic modulation cannot be positioned onto another color pixel at the same relative location of the color pixel in the first image acquisition step.

A step of adding the first and second images to one another are then performed by use of standard image processing techniques. The periodic patterns effectively cancel each other out and the "real" modulations in the panel are preserved. Any number of images can be added together as long as they meet the following criteria. Preferably, the number of images is at least two, and more preferably the number of images is two and greater, and more preferably the number of images is four and greater.

In a more preferred embodiment, the camera is displaced relative to a zero point on the color filter assembly in a first x-direction at a distance $x_1$, a second x-direction at a distance $x_2$, a first y-direction at a distance $y_1$, and a second y-direction at a distance $y_2$. The distance $x_2$ is equal to about the distance ($-x_1$) or $2x_1$, and the distance $y_2$ is equal to about the distance ($-y_1$) or $2y_1$. Each image that is acquired must have a matching image (or complementary image) with a relative displacement of one-half a color pixel period in the x-direction or the y-direction, or both the x and y directions. Alternatively, the camera may be displaced in the y-direction before the x-direction, or a combination thereof.

In an alternative specific embodiment, the present invention provides a method for reducing and even eliminating a periodic modulation from a color filter assembly image signal by way of filtering. The present method includes a step of filtering a modulated signal by way of a spatial filter from the color filter assembly image signal. A period of the modulated signal is determined from a period of the color filter assembly pixels and a period of the CCD pixels in spatial domain. An image processor (and computer) performs a spatial filter onto the color filter assembly image signal by convolving the CCD signal with a filter of a width designed to remove the periodic modulation. Alternatively, the CCD signal from spatial domain to a frequency domain using a techniques such as a Fourier Transform and the like.
frequency of the Moire' interference pattern can be calculated from the period of the
CCD pixels and FPD pixels. Techniques such as bandpass filtering and the like can be
used to remove selected frequencies which include the Moire' interference pattern.

Now that the accurate relative intensity for each of the color pixels has
been mapped into memory, using any of the above-described techniques, a preferred
next step is to analyze the brightness uniformity across the color filter assembly and
then take steps to correct for any brightness non-uniformity. In one embodiment, this
is accomplished by detecting the minimum color pixel brightness level and using that
minimum brightness as a baseline for the correction of all other color pixel
brightnesses. Compensation factors are then calculated for each of the color pixel
driving voltages.

These compensation factors are then loaded into a look-up table in
memory, located in computer memory. These factors in the look-up table may then be
applied to the drivers, via a compensation control circuit to lower the drive voltages for
those color pixels whose brightness levels need to be attenuated to match that of the
minimum brightness pixel. The displayed color image is then detected again using the
same process described above, and the brightness levels are again measured to
determine any non-uniformity. This process for correcting the brightness uniformity
may be reiterated until the desired brightness uniformity is established.

It will be understood by those skilled in the art that other techniques may
be substituted for the method described above relating to lowering the brightness level
of the pixels to match a minimum brightness level. One alternative technique would be
to determine an average color pixel brightness level and then raise or lower the
individual color pixel brightness levels to match this average brightness level. Such an
alternative of using the average brightness level as a baseline would be desirable if there
are pixel defects (e.g., one or more pixels have a zero brightness level, anomalies).

As an alternative to the iterative process described above, it may also be
desirable to instead successively increment the color pixel drive voltages for selected
pixels in the color filter assembly while measuring the brightness uniformity across the
color filter assembly. This alternative process of determining brightness uniformity
would be conducted for each shifted position of the color filter image relative to the
camera detector pixels. The selected pixels in the color filter assembly to be adjusted
for each image shift would be only those identified as having an image completely superimposing a single camera detector pixel to avoid the effects of the Moiré phenomenon. After all the image shifts, all the color pixels should have a predetermined same brightness level. It will be understood that a pixel darkness level may be substituted for a pixel brightness level depending on if the color pixels scatter light or if the color pixels themselves emit light.

Once the final compensation factors for each of the color pixels are stored in the look-up table, these compensation factors may then be down-loaded into a memory (e.g., EPROM chip) for that particular color filter assembly tested. The memory would then be disconnected from the test system and installed in a drive system for that particular color filter assembly to permanently control the compensation of the driver signals to achieve a uniform brightness across the color filter assembly.

For certain types of color filter assemblies, such as LCD panels, an energizing pixel voltage may also affect at what angle the pixel element seems brightest (or darkest). Thus, it is possible by using the above techniques for compensating pixel driving voltages to adjust the energizing voltage for each of the pixels to set the angle at which the image on the color filter assembly looks brightest. This may be desirable where the intended viewer is not directly facing the color filter assembly in a particular application, such as in the cockpit of an airplane.

The above brightness uniformity test may also be used to cause the color pixels to have the greatest uniform contrast ratio (ratio of brightness to darkness) rather than simply to set a brightness level at a baseline level. For such achievement of a uniform contrast ratio across the color filter assembly, both the maximum brightness and maximum darkness of the pixels must be measured and compensation factors be generated for both brightness uniformity and darkness uniformity.

All image processing and other analysis may be conducted using digital techniques, and Fourier conversion may be used as necessary to characterize the signals.

Pixel defects and other defects (e.g., shorted or open conductors) in the color filter assembly may be simply detected by detecting a pixel brightness level below a threshold value. Such defects may be identified by the inspection system and repaired or, alternatively, the color filter assembly may be discarded. To enable such repairing
of defects, it is recommended to test the color filter assembly during a manufacturing stage where its pixel elements are exposed.

The present system is illustrated with a sample color filter assembly which may be monitored for defects, particles, and the like. The system may be incorporated on-line (or in-line) by any suitable means. This will provide an in-situ monitoring tool to detect defects or particles on, for example, the color filter assembly. As an in-situ monitoring tool, no defects or particles are introduced onto the color filter in transit between a particular process and the system.

Alternatively, the system may also be an off-line monitoring tool. As an off-line monitoring tool, it can provide for quick and accurate identification of defects or particle counts on a color filter assembly or the like. Defects or particles, however, can be introduced onto the color filter while being transported from the particular process to the off-line monitoring tool.

In both off-line and in-line embodiments, the present system also benefits from a cost advantage over the conventional techniques in that the majority of the system cost reside in the computer/image processing system, while the measurement head is relatively inexpensive due to its electronic scanning (not physical) nature. Since a computer/image processing system could in principle control and support multiple measurement heads, the resulting cost per station (measurement head) would be smaller than any conventional approach using expensive step/repeat and scanning technologies.

Each configuration of the present systems of the Figs. provide improved features to the aforementioned conventional systems. For example, the present systems use a "single-shot" approach to the measurement of particles on the wafer with enhanced signal to noise ratios. These features provide massively reduced test times with greater sensitivity to lower particle sizes. In addition, the present systems do not "scan" across the wafer surfaces as some conventional systems, thereby reducing and possibly eliminating any scanning noise and light source fluctuations. Furthermore, the present systems may be incorporated into another tool, and will therefore provide in-situ processing. These features of the present system provide benefits that simply cannot be obtained by way of the aforementioned conventional systems.

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. 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 observing defects on a color filter assembly by optically scattered energy from an illumination means, the method comprising:
   directing back illumination from a light source to highlight one group of color pixels (e.g., red, green, blue) from a color filter assembly under inspection to produce scattered non-specular energy from an anomaly which may manifest itself in said one group of color pixels; and observing said scattered non-specular energy in one of a plurality of fractional windows of a viewed image of the color filter assembly via a plurality of focussing elements at a plurality of remote focal planes having a detection arrangement, said focal planes being mounted adjacent one another arranged in an array arrangement adjacent one another, said detection arrangement corresponding to said array arrangement;
   wherein said step of observing occurs without relative motion between said color filter assembly and said fractional windows to prevent a possibility of scanning noise and permit over sampling.

2. The method according to claim 1 wherein said detection arrangement and said array arrangement are of Cartesian symmetry.

3. The method according to claim 1 wherein said detection arrangement and said array arrangement are of Polar symmetry.

4. The method according to claim 1 wherein each of said focal plane is in an imaging array of an electronic camera.

5. The method according to claim 1 wherein each of said focal plane is an imaging surface, said imaging surface being operative to convert said nonspecular energy into detectable energy.

6. The method according to claim 1 wherein each of said focusing elements is a high-quality lens having an f-number of about f/1.5 and less.
7. The method according to claim 1 wherein each of said focusing elements is a high-quality lens operative at an effective object f-number of less than f/20, said high-quality lens being a refractor.

8. The method according to 7 wherein each of said focusing elements is operative at an effective object f-number of less than f/9, said refractor having a minimum f-number of smaller than f/1.5 and greater than f/0.9.

9. The method according to claim 1 wherein said light source emits a narrow wavelength range of noncoherent light.

10. The method according to claim 1 wherein said back illumination is spectrally filtered noncoherent light.

11. The method according to claim 1 wherein said back illumination is coherent light.

12. The method according to claim 1 wherein said back illumination highlights images from colored pixels selected from a group consisting of red pixels, green pixels, or blue pixels.

13. The method according to claim 1 wherein said back illumination highlights images using a color filter apparatus.

14. The method according to claim 1 further comprising a step of shifting a relative position between said plurality of focusing elements and said color filter assembly to reduce an influence of a Moire' pattern.

15. The method according to claim 14 wherein said shifting is performed at an increment of one-half a color pixel dimension.
16. A system for observing defects on a color filter assembly by means
of optically scattered light, the system comprising:
   a source for directing illumination from a light source to a backside
surface of a color filter assembly to highlight one group of a plurality of color pixels,
said light source may highlight an anomaly in one of said color pixels; and
   a plurality of CCD cameras for observing said anomaly in said one group
of color pixels in one of a plurality of fractional windows of a viewed image of the
color filter assembly via a plurality of focussing elements at a plurality of remote focal
planes having a detection arrangement, said focal planes being mounted adjacent one
another arranged in an array arrangement adjacent one another, said detection
arrangement corresponding to said array arrangement.

17. The system according to claim 16 wherein said symmetrical
detection arrangement and said symmetrical array arrangement are of Cartesian
symmetry.

18. The system according to claim 16 wherein said symmetrical
detection arrangement and said symmetrical array arrangement are of Polar symmetry.

19. The system according to claim 16 wherein each of said focal
planes is in an imaging array of an electronic camera.

20. The system according to claim 16 wherein each of said focal
planes is an imaging surface, said imaging surface being operative to convert said
nonspecular energy into detectable energy.

21. The system according to claim 16 wherein each of said focusing
elements is a high-quality lens having an f-number of about f/1.5 and less.

22. The system according to claim 16 wherein each of said focusing
elements is a high-quality lens operative at an effective object f-number of less than
f/20, said high-quality lens being a refractor.
23. The system according to 22 wherein each of said focusing elements is operative at an effective object f-number of less than f/9, said refractor having a minimum f-number of smaller than f/1.5 and greater than f/0.9.

24. The system according to claim 16 wherein said source emits a narrow wavelength range of noncoherent light.

25. The system according to claim 16 wherein said collimated illumination is spectrally filtered noncoherent light.

26. The system according to claim 16 wherein said collimated illumination is coherent light.
FIG. 4

FIG. 4A
START

1. PROVIDE COLOR FILTER
2. PLACE ON STAGE
3. ILLUMINATE FILTER
4. FOCUS IMAGING DEVICE ONTO FILTER
5. HIGHLIGHT ANOMALIES
6. CAPTURE IMAGE
7. CONVERT IMAGE TO DIGITAL FORM
8. COMPARE IMAGE AGAINST STANDARD

- Accept (Y)
  - Remaining Steps (522)
- Repair (N)

FIG. 5
START

INSPECT FILTER AT FIRST LOCATION TO OBTAIN FIRST IMAGE

SHIFT RELATIVE POSITION OF FILTER TO IMAGING DEVICE

INSPECT FILTER AT SECOND LOCATION TO OBTAIN SECOND IMAGE

REPEAT STEP OF SHIFTING AND INSPECTING

AVERAGE INTENSITY VALUES FOR IMAGES FROM FIRST LOCATION, ETC.

STOP

FIG. 6
INTERNATIONAL SEARCH REPORT

INTERNATIONAL APPLICATION
PCT/US98/18657

A. CLASSIFICATION OF SUBJECT MATTER
IPC(6) : G01N 21/88
US CL. : 356/239.2
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. : 356/239.2, 237.1, 239.1, 408, 418, 425, 430

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

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

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>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>US 5,440,648 A (ROBERTS et al) 08 August 1995 (08/08/95), see figure 1.</td>
<td>1-26</td>
</tr>
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<td>Y,P</td>
<td>US 5,764,209 A (HAWTHORNE et al) 09 June 1998 (09/06/98), see figure 2 and filter wheel 24 in figure 1.</td>
<td>1-26</td>
</tr>
</tbody>
</table>

* Further documents are listed in the continuation of Box C. See patent family annex.

Date of the actual completion of the international search
09 NOVEMBER 1998

Date of mailing of the international search report
31 DEC 1998

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