

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization International Bureau



(43) International Publication Date
10 February 2005 (10.02.2005)

PCT

(10) International Publication Number
WO 2005/012976 A1

(51) International Patent Classification⁷: **G02B 26/08**, 27/00

(21) International Application Number: PCT/CA2004/001410

(22) International Filing Date: 28 July 2004 (28.07.2004)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data: 10/628,887 29 July 2003 (29.07.2003) US

(71) Applicant (for all designated States except US): **CREO INC.** [CA/CA]; 3700 Gilmore Way, Burnaby, British Columbia V5G 4M1 (CA).

(72) Inventor; and

(75) Inventor/Applicant (for US only): **GELBART, Daniel** [CA/CA]; 4706 Drummond Drive, Vancouver, British Columbia V6T 1B4 (CA).

(74) Agents: **RATTRAY, Todd A.** et al.; OYEN WIGGS GREEN & MUTALA, 480 The Station, 601 West Cordova Street, Vancouver, British Columbia V6B 1G1 (CA).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

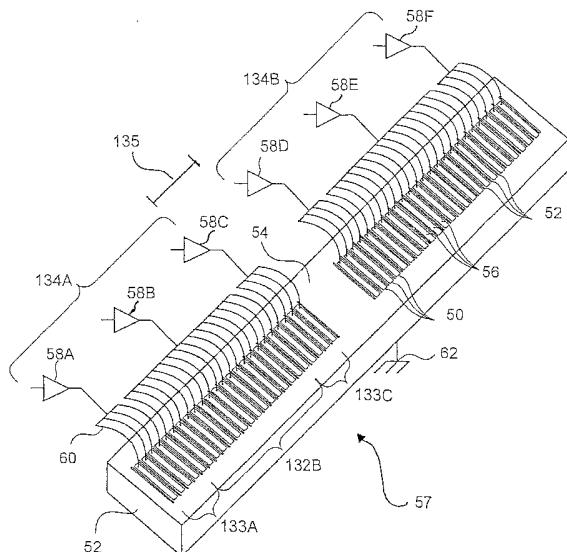
(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— with international search report

[Continued on next page]

(54) Title: NON-UNIFORM LIGHT VALVE



(57) **Abstract:** Particular embodiments of the invention provide light valves for generating a plurality of individually modulatable channels used in imaging systems. Two or more of the channels have different (non-uniform) sizes. The non-uniform channel sizes are selected to correspond with a regular pattern to be imaged. Light valves according to particular embodiments of the invention comprise at least one low resolution group of light valve elements having a low resolution number of individual light valve elements coupled to be independently driven by a low resolution driver and at least one high resolution group of light valve elements having a high resolution number of individual light valve elements coupled to be independently driven by a high resolution driver. The low resolution number and high resolution number are different from one another so as to generate low resolution and high resolution channels having different (non-uniform) sizes.

WO 2005/012976 A1



For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

NON-UNIFORM LIGHT VALVE

Technical Field

[0001] The invention relates to imaging systems. Particular 5 embodiments of the invention provide light valves for use in imaging systems.

Background

[0002] Fabrication processes for displays, polymer-based 10 semiconductor devices and other semiconductor devices typically involve a relatively large number of imaging steps. In conventional photolithographic imaging processes, each imaging step involves: coating a substrate with a resist (or other sensitive material); exposing the coated substrate to radiation through a photo-tool mask to cause a 15 corresponding change in the resist; and subjecting the exposed material to a development process.

[0003] There is commonly a finite risk of failure associated with 20 each imaging step. For fabrication processes involving a number of imaging steps, the risk of failure is compounded, thus reducing the overall process yield and increasing cost of the finished product. Fabrication of color filters for flat panel displays (e.g. liquid crystal displays (LCD's)) represents a specific example of a multi-step 25 fabrication process. Color filter fabrication can be a very expensive process because of the high cost of materials and low process yield.

[0004] Direct imaging has been proposed for use in the fabrication 30 of displays and in particular color filters. US Patent 4,965,242 to DeBoer et al. describes a direct imaging dye transfer process for making color filter elements, wherein a dye receiving element is overlaid with a dye donor element which is then imagewise heated to selectively transfer the dye from the donor element to the receiving element. The preferred method of imagewise heating is by means of a laser beam. Diode lasers

- 2 -

are particularly preferred for their ease of modulation, low cost and small size.

[0005] A drawback with the DeBoer et al. direct imaging 5 technique is that the laser beam is required to scan over the entire surface of the substrate in order to effect an imagewise dye transfer. Such an imagewise scan takes a relatively long time when compared to flood exposure through a photo-tool mask, wherein a small substrate 10 may be exposed at once, or wherein a larger substrate may be exposed using a series of quick step and repeat exposures.

[0006] One way to increase the speed of direct imaging involves simultaneously scanning the substrate with a plurality of independently modulatable laser beams. US Patent 6,146,792 to Blanchet-Fincher et 15 al. describes the production of a durable image on a receiver element, such as a color filter. The laser head suggested by Blanchet-Fincher et al. includes thirty-two 830 nm laser diodes, each having approximately 90 mW of single-mode output.

20 [0007] Independently modulatable laser beams are often referred to in the art as "channels". Imaging heads with even more channels are now commonly available. An example of such an imaging head is the SQUAREspot® thermal imaging head manufactured by Creo Inc. of Burnaby, British Columbia, Canada. This imaging head is available 25 with up to 240 independently modulatable channels, each channel having upwards of 100 mW of optical output power. For a media sensitivity of 450 mJ/cm², this imaging head is capable of imaging a small 370 x 470 mm color filter substrate in around 3 minutes.

[0008] Further improvements in imaging speed have been impeded by the trade-off between imaging resolution and speed. Fabricating color filters having desirable edge definition characteristics (i.e. high resolution) requires imaging with a correspondingly small pixel size (i.e. 5 the beam associated with each channel must be focused to have correspondingly small dimensions). However, when imaging with smaller pixel sizes, it takes longer to effect the imagewise exposure over a desired imaging area, because it takes longer scan the imaging head over the substrate to completely cover the desired imaging area. Simply 10 adding more channels to an imaging head does not entirely address this problem, since it is difficult to provide such an imaging head in an economical and practical imaging system.

[0009] There is a general trend in the display fabrication industry 15 toward processing larger substrates. Larger substrates may be used to create larger displays. In addition, larger substrates may be processed and then later separated into smaller panels to increase the economy and yield associated with the fabrication of smaller displays. For example, if there are two defects on a four panel substrate, then the yield may be 20 50%, while the same two faults on a 12 panel substrate represent an 83% yield.

[0010] In the display fabrication industry, the substrate size of the so-called "sixth generation" flat panel display is around 1500 x 25 1800 mm. For a substrate this size with a media sensitivity of 450 mJ/cm², the 240 channel SQUAREspot® thermal imaging head discussed above would have an imaging time in the vicinity of 45 minutes, which is prohibitively long.

30 **[0011]** There remains a need for higher productivity direct imaging techniques for use in various fabrication processes.

Summary of the Invention

[0012] A first aspect of the invention provides a light valve for use in an imaging system. The light valve comprises a plurality of independently drivable channels. At least two of the channels have non-uniform sizes, which correspond to a regular pattern to be imaged.

5 **[0013]** The channels may comprise non-uniform numbers of individual light valve elements. The channels may comprise one or more low resolution channels corresponding to feature(s) in the pattern to be imaged and/or one or more high resolution channels corresponding to edge(s) of the feature in the pattern to be imaged. The low resolution channel(s) may comprise a plurality of individual light valve elements electrically coupled to a driver. One or more high resolution channels may be located adjacent to a low resolution channel on either or both 10 sides thereof.

15 **[0014]** The light valve may comprise a plurality of uniformly spaced light valve elements, wherein groups of light valve elements are electrically coupled to one another to form low resolution channel(s) and high resolution channel(s). The number of light valve elements electrically coupled to form the low resolution channel(s) may be greater than the number of light valve elements electrically coupled to form the 20 high resolution channel(s). One or more of the uniformly spaced light valve elements may not be electrically coupled to either a low resolution channel or a high resolution channel.

25 **[0015]** The channels may comprise low resolution group(s) of light valve elements having low resolution number(s) of individual light valve elements coupled to be driven by low resolution driver(s) and high resolution group(s) of light valve elements having high resolution number(s) of individual light valve elements coupled to be driven by 30

- 5 -

high resolution driver(s). The low resolution number(s) may be greater than the high resolution number(s). The low resolution number(s) and the high resolution number(s) may be selected to correspond to the pattern to be imaged. The low resolution group(s) may generate

5 corresponding low resolution channel(s) on a substrate to be imaged and the high resolution group(s) may generate high resolution channel(s) on the substrate to be imaged. The low resolution channel(s) may be larger than the high resolution channel(s). The low resolution number(s) may be selected such that a size of the low resolution channel(s) corresponds

10 to a size of an interior portion of feature(s) in the pattern to be imaged. The high resolution number(s) may be selected such that a size of the high resolution channel(s) is/are sufficiently small to meet edge resolution requirement(s) of the in the pattern to be imaged. One or more high resolution channels may be located adjacent to a low

15 resolution channel on either or both sides thereof.

[0016] The light valve may comprise additional groups of light valve elements which may be spaced apart from the low resolution and high resolution groups. The spacing may be selected to correspond with

20 a separation between features in the pattern to be imaged. The light valve may be a part of an imaging head used for imaging color elements on a color filter substrate. The light valve may be a silicon nitride ribbon-based light valve, a PLZT light valve, a TIR light valve or a grating light valve. The individual light valve elements may be mirror

25 elements having electronically alterable reflective characteristics, lens elements having electrically alterable refractive characteristics or grating elements having electronically alterable transmission characteristics.

[0017] Another aspect of the invention provides an imaging system for imaging a regular pattern of features onto a substrate. The imaging system comprises a light valve having a plurality of independently drivable channels having non-uniform sizes, the non-uniform sizes 5 which correspond to a regular pattern to be imaged. The imaging system also comprises a radiation source for illuminating the light valve and a lens for imaging the light valve onto the substrate.

[0018] Another aspect of the invention provides a method for 10 imaging a regular pattern of features onto a substrate with a multi-channel imaging head. The method involves: analyzing the pattern to identify spatial characteristics of one or more features; imaging an interior portion of each of the one or more features with a corresponding low resolution channel; and imaging an edge portion of 15 each of the one or more features with at least one corresponding high resolution channel. The at least one corresponding high resolution channel has a smaller size than the corresponding low resolution channel.

20 **[0019]** Yet another aspect of the invention provides a method for fabricating a light valve for imaging a pattern of features with a multi-channel imaging system. The method involves: analyzing the pattern of features to identify one or more spatial characteristics thereof; fabricating a plurality of uniform regularly spaced light valve elements 25 on a light valve substrate; and, based on the spatial characteristics of the pattern of features: electrically coupling at least one low resolution group of light valve elements; and electrically coupling at least one high resolution group of light valve elements.

[0020] Still another aspect of the invention provides a light valve for use in an imaging system. The light valve comprises a first group of light valve elements having a first number of individual light valve elements electrically coupled to one another and a second group of 5 light valve elements having a second number of individual light valve elements electrically coupled to one another. The first number of light valve elements and the second number of light valve elements are different from one another.

10 [0021] Further features and applications of specific embodiments of the invention are described below.

Brief Description of the Drawings

[0022] In drawings which depict non-limiting embodiments of the 15 invention:

FIG. 1 is a perspective representation of an optical system for a prior art imaging head;

FIG. 2-A is a plan view of a portion of a color filter having a stripe pattern of color elements;

20 FIG. 2-B is a plan view of a portion of a color filter having a mosaic pattern of color elements

FIG. 3-A is a schematic view of the non-uniform channel pattern of a light valve in accordance with a particular embodiment of the invention, together with the image created by the light valve on the 25 substrate during a part of an imaging process;

FIG. 3-B is a schematic view of the FIG. 3-A non-uniform channel pattern, together with the image created by the light valve on the substrate during a subsequent part of the FIG. 3-A imaging process; and

30 FIG. 4 is a perspective view of a light valve according to a particular embodiment of the present invention.

Detailed Description

[0023] Throughout the following description, specific details are set forth in order to provide a more thorough understanding of the invention. However, the invention may be practiced without these 5 particulars. In other instances, well known elements have not been shown or described in detail to avoid unnecessarily obscuring the invention. Accordingly, the specification and drawings are to be regarded in an illustrative, rather than a restrictive, sense.

10 [0024] The invention relates to imaging systems. Particular embodiments of the invention provide light valves for use in imaging systems. Such light valves are capable of generating a plurality of individually modulatable channels. Two or more of the channels have different (non-uniform) sizes. The non-uniform sizes of the channels are 15 selected to correspond with a regular pattern to be imaged. Light valves according to particular embodiments of the invention comprise at least one low resolution group of light valve elements having a low resolution number of individual light valve elements coupled to be independently driven by a low resolution driver and at least one high resolution group of light valve elements having a high resolution number of individual 20 light valve elements coupled to be independently driven by a high resolution driver. The low resolution number and the high resolution number are different from one another so as to generate low resolution and high resolution channels having different (non-uniform) sizes.

25 Other embodiments of the invention provide imaging heads and imaging systems which incorporate such light valves and methods for fabricating and using such light valves.

[0025] FIG. 1 is a representation of the optical system of an imaging head 115 which incorporates a prior art light valve 100. Light valve 100, which is fabricated on a silicon substrate 102, comprises a plurality of deformable ribbon elements 101. In the illustrated embodiment, each ribbon element 101 comprises a silicon nitride ribbon suspended over a cavity (not shown). Each ribbon element 101 is also coated with a reflective, metallic material, such as aluminum for example, which functions as both a reflecting surface and an electrode. The back side of light valve 100 comprises a common electrode (not shown), which is typically connected to ground.

[0026] A driver circuit (not shown) is typically associated with each ribbon element 101 for selectively applying a voltage thereto. In the Figure 1 illustration, ribbon element 121 represents an example of an actuated ribbon element. The driver associated with mirror 121 has applied a voltage to the electrode of ribbon element 121, creating an electrostatic force ribbon element 121 and the common electrode on the back side of light valve 100. This electrostatic force causes ribbon element 121 to deform into the cavity and to create a curved reflective surface as shown. Ribbon element 123 represents an example of a non-actuated ribbon element. Since there is no voltage applied to the electrode of ribbon element 123, it is not deformed into the cavity and maintains a flat reflective surface as shown.

[0027] Imaging head 115 also comprises a laser 104 and an anamorphic beam expander 111. Radiation 105 from laser 104 may be of a wide range of wavelengths, from ultra violet through infrared. Anamorphic beam expander 111 includes a pair of cylindrical lenses 108, 110. Beam expander 111 and laser 104 are configured such that when radiation 105 from laser 104 is directed into beam expander 111, an illumination line 106 (shown as a broken line in Figure 1) is

- 10 -

generated on light valve **100**. In the illustrated embodiment, illumination line **106** stretches across all of the ribbon elements **101** in light valve **100**, such that each of ribbon elements **101** receives some of the radiation from illumination line **106**. The process of creating 5 illumination line **106** on light valve **100** is described in United States Patent No. 5,517,359, which is hereby incorporated by reference.

[0028] Imaging head **115** also comprises a stop **116** and an imaging lens **118**. Stop **116** has a transmitting region **114** and a non-transmitting region **113**. The radiation from illumination line **106** is reflected from ribbon elements **101** of light valve **100**. When a particular ribbon element (for example, ribbon element **121**) is deformed by the application of a voltage, its curved mirror surface focuses the reflected radiation, such that the reflected radiation travels through 10 transmitting region **114** toward lens **118**. In contrast, when a particular ribbon element (for example, ribbon element **122**) is not deformed, its flat mirror surface causes the reflected radiation to be dispersed and blocked by non-transmitting region **113**. 15

[0029] Imaging lens **118** images light valve **100** to form an imaging swath **120**. Imaging swath **120** comprises a plurality of individually modulated beams or channels **126**. A substrate (not shown) may be located relative to imaging lens **118** such that imaging swath **120** is focused onto the substrate. Imaging swath **120** may be scanned over 20 the desired imaging area of the substrate to form an image thereon. If a particular ribbon element **101** is actuated, then radiation reflected from its surface will pass through transmitting region **114** and its corresponding channel **126** will contain a sufficient amount of radiation to alter the substrate. Conversely, if a particular ribbon element **101** is 25 not actuated, then a substantial amount of the radiation reflected from its surface will be blocked by non-transmitting region **113** and its 30

- 11 -

corresponding channel **126** will not contain a sufficient amount of radiation to substantially alter the substrate.

[0030] Further details of the operation of imaging head **115** and 5 light valve **100** are described in United States Patent No. 6,147,789, which is hereby incorporated by reference.

[0031] Particular embodiments of the invention described herein provide light valves for use in imaging heads, such as imaging head 10 **115**. The light valves of the present invention may be used in the place of light valve **100** for example.

[0032] When fabricating color filters for display panels (or when imaging other rigid substrates), imaging heads, such as imaging head 15 **115**, are typically used in flatbed imaging devices (also referred to as a "flatbed scanners"). Using a flatbed imaging device typically involves securing the substrate in a flat orientation and then moving the substrate, the imaging head and/or a combination of the substrate and the imaging head relative to one another to effect the scan. Scanning typically 20 involves relative movement between the imaging head and the substrate in a first direction (referred to as the "main scan direction"). Scanning may also involve stepping the imaging head relative to the substrate (or vice versa) in a second direction (referred to as the "sub-scan direction") and then moving the imaging head relative to the substrate (or vice 25 versa) in the main scan direction again. This process may be repeated until the desired imaging area of the substrate is completely imaged. A high speed flatbed scanner suitable for use with the present invention is disclosed in United States Patent Publication No. 2004/0004122, which is hereby incorporated by reference.

- 12 -

[0033] Flexible substrates may be secured to the internal or external surface of a drum for imaging in a drum-based imaging device. Typically, such drums are cylindrical in shape. Scanning is effected by rotating the drum about its axis, such that the substrate moves in a main 5 scan direction relative to the imaging head. Scanning may also involve stepping the imaging head relative to the drum and the substrate (or vice versa) in a sub-scan direction and then rotating the drum to create relative movement in the main scan direction again. As with the flatbed scanner, this process may be repeated until the desired imaging area of 10 the substrate is completely imaged. Drum-based imaging systems may be used to image substrates that are traditionally thought of as rigid. For example, a glass substrate may be imaged on a drum scanner provided that the substrate is sufficiently thin and the diameter of the drum is sufficiently large.

15

[0034] As discussed briefly above, a light valve typically comprises a driver circuit for each of its ribbon elements. For many light valves, the need for drivers represents a limiting factor with regard to how many ribbon elements the light valve may accommodate. For 20 example, the number of drivers associated with a light valve is typically restricted by: spatial limitations associated with providing a large number of drivers in close proximity to the light valve; heat removal limitations associated with the removal of heat generated by the switching of the driver circuitry; and/or connection limitations 25 associated with making the electrical connections between the drivers and their associated ribbon elements. These limitations also create corresponding restrictions on the number of channels that may be simultaneously imaged by a light-valve based printing head.

[0035] Fabrication of color filters for display panels may involve imaging color elements having various different spatial patterns. One particular pattern referred to as a "stripe pattern" is shown in color filter 10 of FIG. 2-A. Color filter 10 comprises a substrate 18 which has 5 been imaged with alternating elongated stripes (columns) 12, 14, 16 of red color elements R, green color elements G and blue color elements B. The individual color elements R, G, B are bounded by an opaque matrix layer 20. In the FIG. 2-A illustration, matrix layer 20 outlines a two-dimensional matrix pattern of individual color elements R, G, B, 10 wherein columns 12, 14, 16 of color elements have a single color and rows 13, 15, 17 of color elements have alternating colors. Matrix 20 prevents the backlight typically used in flat panel displays from leaking between the color elements. In the illustrated embodiment, matrix layer 20 also comprises an area 22 for masking the circuitry (typically, thin 15 film transistors (TFT's)) associated with color filter 10.

[0036] FIG. 2-B shows a color filter 24 having a different spatial pattern of color elements R, G, B referred to as a "mosaic pattern". The mosaic configuration of color filter 24 comprises a two-dimensional 20 matrix pattern of individual color elements R, G, B, wherein both the columns 12', 14', 16' and rows 13', 15', 17' of color elements have alternating colors. The mosaic pattern of color filter 24 may provide an improved color mix relative to the stripe pattern of color filter 10. Other aspects of color filter 24 are similar to those of color filter 10.

25

[0037] Color filters may also be fabricated in a "delta pattern" (not shown). In a delta pattern, the color elements are formed in a spatial pattern wherein the red, green and blue color elements have a triangular relationship to each other. Color filters fabricated with a delta pattern 30 may provide an improved color mix relative to the stripe pattern of color filter 10 and the mosaic pattern of color filter 24.

- 14 -

[0038] In one type of imaging system suitable for fabricating color filters for use in flat panel displays, a dye donor element is placed in close proximity to a dye receiving substrate. An imaging head provides laser radiation and is scanned across the surface of the substrate, causing 5 dye from the donor element to be imagewise transferred to the receiving substrate. The red, blue and green portions of the color filter may be imaged in separate steps, with each step having a different colored dye donor element. The imaging head of this type of imaging system may comprise a multi-channel light valve in accordance with the present 10 invention.

[0039] Particular embodiments of the invention comprise light valves capable of generating a plurality of individually modulatable channels, wherein two or more of the channels have different (non-uniform) sizes. FIG. 3-A schematically depicts a channel pattern 30 of 15 a light valve in accordance with a particular embodiment of the invention. The light valve is configured to generate a non-uniform channel pattern 30, which is selected to correspond with the spatial pattern being imaged. For example, light valves according to the 20 invention are capable of generating spaced apart groups of channels 34, low resolution (i.e. larger dimension) channels 32 and high resolution (i.e. smaller dimension) channels 33. In the embodiment of FIG. 3-A, non-uniform channel pattern 30 comprises a plurality of spaced apart groups of channels 34, each group 34 comprising one low resolution channel 32 and two high resolution channels 33 located on either side of 25 the low resolution channel 32. It will be appreciated that the groups of channels 34 and the distribution of low resolution channels 32 and high resolution channels 33 within each group 34 are arranged to correspond with a striped spatial pattern being imaged on substrate 18.

- 15 -

[0040] FIG. 3-A schematically depicts the application of red stripes **36** to substrate **18**. In the illustrated embodiment, groups **34** of channels are spaced apart from one another at distances which correspond to the separation of stripes **36**, although (as explained further below) this spacing is not necessary. Within each group **34**, low resolution channels **32** correspond to the interior portion (distal to the edges) of stripes **36** and high resolution channels **33** correspond to the edges of stripes **36**. Low resolution channels **32** permit imaging of a relatively large interior portion of stripes **36**, while high resolution channels **33** ensure that stripes **36** have good edge definition. In particular, the inclusion of high resolution channels **33** allows the width of stripes **36** to be precisely adjusted to suit the media (i.e. substrate **18**) or other conditions which may affect the width of image stripes **36** on substrate **18**. Moreover, the combination of low resolution channels **32** and high resolution channels **33** allows the benefit of imaging with a fixed mask light valve while still providing the flexibility to adjust the resultant image pattern within some range.

[0041] In the FIG. 3-A embodiment, stripes **36** are imaged onto substrate **18** by scanning channel pattern **30** in the main scan direction indicated by arrow **38**. After each pass in the main scan direction **38**, channel pattern **30** is stepped relative to substrate **18** in the sub-scan direction indicated by arrow **39**. A new pass in the main scan direction **38** is then commenced and the process is repeated until the entire desired area of substrate **18** is imaged.

[0042] FIG. 3-B schematically depicts the imaging of green stripes **40** after red stripes **36** were imaged in a previous part of the process (FIG. 3-A). FIG. 3-B shows that the start position of channel pattern **30** is offset in sub-scan direction **39** relative to the start position for imaging red stripes **36**, so as to coincide with the intended location of green

stripes **40**. In other respects, imaging of green stripes **40** is substantially similar to imaging red stripes **36**. In a substantially similar process, blue stripes (not shown) may be imaged after green stripes **40**.

5 [0043] FIG. 4 depicts a light valve **57** according to a particular embodiment of the invention. Light valve **57** is configured to generate channel patterns similar to channel pattern **30** of FIG. 3-A and FIG. 3-B. Light valve **57** of the FIG. 4 embodiment comprises a plurality of silicon nitride ribbon elements **50** formed on a silicon substrate **52**. A
10 slot corresponding to each ribbon element **50** is etched into upper surface **54** of substrate **52**. The substrate material is also etched away from under ribbon elements **50**, leaving ribbon elements **50** suspended over a cavity (not shown) in substrate **52**. Each ribbon element **50** is coated with a metallic material **56**, which acts as both an electrode and a
15 reflective layer. Light valve **57** also comprises a common electrode **62** on the underside of substrate **52**, which is connected to a system ground.

20 [0044] Light valve **57** comprises a plurality of wire-bond connections **60**, each of which is coupled to the electrode **56** of a corresponding ribbon element **50**. Light valve **57** also comprises a plurality of drivers **58**, which are electrically coupled to wire-bond connections **60**. In the illustrated embodiment, each driver **58** is electrically coupled to a group of connections **60** and to a corresponding
25 group of ribbon elements **50**. Advantageously, various groups of ribbon elements in light valve **57** contain different (non-uniform) numbers of individual ribbon elements **50**. For example, group **133A** comprises 4 individual ribbon elements **50** which are all electrically coupled to driver **58A**, group **132B** comprises 16 individual ribbon elements **50** which are all electrically coupled to driver **58B** and group **133C** comprises 4
30

individual ribbon elements **50** which are all electrically coupled to driver **58C**.

[0045] Operation of light valve **57** is similar to that of light valve **100** depicted (FIG. 1) and described above and further detailed in United States Patent No. 6,147,789. When a voltage is applied to the electrode **56** of a ribbon element **50**, an electrostatic force between electrode **56** and common electrode **62** causes the associated ribbon element **50** to deform into the cavity, thereby forming a curved mirror. As discussed above, when a ribbon element is deformed in this manner, radiation incident on its reflective surface is focused and may consequently be transmitted through the transmitting region of a stop to thereby image a substrate.

[0046] In accordance with the present invention, however, groups of light valve elements having non-uniform numbers of individual light valve elements may be simultaneously actuated by a single driver. For example, driver **58A** may cause a voltage to be applied to the electrodes **56** of the 4 individual ribbon elements **50** in group **133A**, causing the individual ribbon elements **50** in group **133A** to deform. Similarly, driver **58B** may independently cause a voltage to be applied to the electrodes **56** of the 16 individual ribbon elements **50** in group **132B**, causing the ribbon elements in group **132B** to deform.

[0047] Light valve **57** may be used in an imaging head (e.g. imaging head **115** of FIG. 1) to generate a channel pattern having high resolution channels and low resolution channels similar to the high resolution channels **33** and low resolution channels **32** of channel pattern **30** (FIG. 3-A). Those skilled in the art will appreciate that groups of ribbon elements having smaller numbers of individual ribbon elements **50** (e.g. groups **133A**, **133C**) may be used to generate high resolution

- 18 -

channels and that groups of ribbon elements having larger numbers of individual ribbon elements **50** (e.g. group **132B**) may be used to generate low resolution channels. Each group of ribbon elements **50** connected to a single driver **58** may be referred to as a channel of light valve **57**. Accordingly, it may be said that light valve **57** comprises a plurality of non-uniform channels, wherein smaller (high resolution) channels of light valve **57** correspond to groups of ribbon elements having smaller numbers of individual ribbon elements **50** and wherein larger (low resolution) channels of light valve **57** correspond to groups of ribbon elements having larger numbers of individual ribbon elements **50**.

[0048] Depending on the resolution requirements, the media being imaged, the patterns being imaged and the size of the individual ribbon elements, light valve **57** may comprise channels (i.e. groups of ribbon elements) having larger or smaller numbers of individual ribbon elements **50** or even a single individual ribbon element **50**. Each such group of ribbon elements may be independently actuated by a single driver.

20

[0049] Light valves according to the invention may be configured such that the spatial arrangement of the various groups of light valve elements and the number of individual light valve elements within each group of light valve elements may be selected to correspond to the spatial pattern being imaged. For example, light valve **57** of FIG. 4 incorporates groups of ribbon elements **133A**, **133C** having a relatively small number of individual ribbon elements **50**, which are located on the outsides of a group of ribbon elements **132B** having a relatively large number of individual ribbon elements **50**. This arrangement of groups is capable of generating smaller high resolution channels located on the outsides of a larger low resolution channel, which, as discussed above,

is well suited for imaging a stripe pattern, such as the stripe pattern of FIG. 2-A and stripes **36, 40** in FIG. 3-A and FIG. 3-B. Those skilled in the art will appreciate that this same arrangement of groups of ribbon elements is also well suited for imaging a mosaic pattern such as the 5 mosaic pattern of FIG. 2-B.

[0050] Light valves according to the invention may also comprise channels (i.e. groups of light valve elements) that are spaced apart from one another to further correspond with the spatial pattern being imaged. 10 For example, light valve **57** comprises groups of ribbon elements **134A, 134B**, which are spaced apart from one another by a distance **135**. This spaced apart arrangement of groups of ribbon elements is capable of generating correspondingly spaced apart groups of non-uniformly sized channels, such as groups **34** of FIG. 3-A. As discussed above, such 15 spaced apart groups **34** of non-uniformly sized channels are well suited for imaging a pattern having pluralities of spaced apart features, such as the spaced apart stripes **36, 40** of FIG. 3-A and FIG. 3-B. Those skilled in the art will appreciate that the spacing between groups of ribbon elements may also be non-uniform.

20 [0051] The non-uniform configuration of light valve **57** comprises a relatively small number of drivers **58** for the resolution which it is capable of providing. More specifically, groups of ribbon elements having relatively large numbers of individual ribbon elements **50** (i.e. 25 groups of ribbon elements corresponding to low resolution channels) are connected to a single driver. Thus, for imaging particular patterns, such as the stripe pattern of FIG. 3-A, light valve **57** is capable of providing the resolution associated with the groups of ribbon elements having small numbers of individual ribbon elements **50** (i.e. groups of ribbon 30 elements corresponding to high resolution channels), but with a smaller number of drivers. Because of this reduced number of drivers, light

valves according to the invention are less restricted by driver-based limitations, such as spacing requirements, heat removal requirements and electrical connection requirements.

5 [0052] The particular configuration of light valve **57** (i.e. having one or more high resolution channels **133A**, **133C** on the outsides of a low resolution channel **132B**) represents merely one illustrative example of a non-uniform light valve according to the invention. As discussed above, light valve **57** is well suited for imaging the stripe pattern of
10 FIG. 2-A and the mosaic pattern of FIG. 2-B. Those skilled in the art will appreciate that the use of light valves having non-uniform channels (i.e. groups of light valve elements with non-uniform numbers of individual light valve elements) may be used to generate a variety of different channel patterns and is not limited to the stripe patterns
15 discussed herein. In recognizing the regularity of features in certain imaging patterns, light valves according to the invention offer improved imaging performance for a given number of light valve elements and a given number of drivers. In accordance with the invention, non-uniform light valves comprising individually modulatable groups of light valve
20 elements having non-uniform numbers of individual light valve elements can be used wherever the spatial pattern to be imaged comprises recognizable pattern of low resolution features.

[0053] Embodiments of the present invention are generally
25 applicable to any imaging systems comprising multi-channel light valves. In addition, embodiments of the present invention are applicable not only to methods of fabricating color filters for flat panel displays, but also to many other processes involving imaging. Non-limiting examples of other processes involving imaging include semiconductor
30 device fabrication and biomedical imaging for Lab-on-a-chip fabrication.

[0054] As will be apparent to those skilled in the art in the light of the foregoing disclosure, many alterations and modifications are possible in the practice of this invention without departing from the spirit or scope thereof. For example:

5 • In light valve **57** of the FIG. 4 embodiment, groups of ribbon elements **50** are fabricated in spaced apart locations corresponding to the pattern to be imaged. For example, group **134A** is fabricated in a location spaced apart from group **134B**. In alternative embodiments, light valves are fabricated to have a plurality of uniformly spaced ribbon elements and groups **134A**, **134B** are subsequently formed by connecting desired ribbon elements to desired drivers and leaving other ribbon elements disconnected. For example, in a light valve having uniformly spaced ribbon elements, any ribbon elements located in space **135** may be left disconnected. In practice, many light valves are initially fabricated without connections and then connections are subsequently made by wire-bonding. Light valves of the present invention may thus be fabricated on a substrate and then configured by connecting various groups of light valve elements in accordance with the pattern (or range of similar patterns) to be imaged.

10 • In some embodiments, light valves according to the invention may comprise light valve elements having non-uniform size in addition to or as an alternative to groups of light valve elements having non-uniform numbers of individual light valve elements.

15 • Other light valve-based imaging heads are well known in the art. The light valves of these imaging heads employ a variety of alternative techniques to provide a plurality of individually modulatable channels which may be used to image a substrate.

20 • Non-limiting examples of alternative light valves include: PLZT (lead lanthanum zirconate titanate) light valves, such as those

disclosed in United States Patent No. 5,517,359 for example; TIR (total internal reflection) light valves, such as those disclosed in United States Patent No. 6,169,565 for example; and grating light valves, such as those disclosed in United States Patent No.

5 disclosed in United States Patent No. 5,661,592 for example. The teachings of these patents are hereby incorporated by reference. Those skilled in the art will appreciate that the present invention may be implemented using these or any other alternative types of light valves and in imaging systems incorporating these or any other alternative types of light valves.

10 • The particular embodiments of light valves described above comprise ribbon elements capable of deforming to form a curved mirror or a flat mirror. Those skilled in the art will appreciate that the invention may be applied to other types of light valves which comprise different light valve elements in the place of mirror-type ribbon elements. For example, light valves in accordance with the invention may comprise lens-type light valve elements or grating type light valve elements. Light valves according to the invention may incorporate any type of light valve elements.

15 • In the preferred embodiments described above, groups of light valve elements having non-uniform numbers of individual light valve elements are electrically coupled to a single driver. This is not necessary. In some embodiments, groups of light valve elements having non-uniform numbers of light valve elements are electrically coupled to a plurality of drivers. Such pluralities of drivers may be activated at the same time, so as to substantially simultaneously actuate the individual light valve elements in a group of light valve elements.

20 Accordingly, the scope of the invention is to be construed in accordance with the substance defined by the following claims.

WHAT IS CLAIMED IS:

1. A light valve for use in an imaging system, the light valve comprising a plurality of independently drivable channels, at least 5 two of the channels having non-uniform sizes, the non-uniform sizes corresponding to a regular pattern to be imaged.
2. A light valve according to claim 1 wherein the at least two of the channels comprise non-uniform numbers of individual light valve 10 elements.
3. A light valve according to any one of claims 1 to 2 wherein the at least two of the channels comprise a low resolution channel corresponding to a feature in the pattern to be imaged.
4. A light valve according to claim 3 wherein the low resolution channel comprises a plurality of individual light valve elements 15 electrically coupled to a driver.
- 20 5. A light valve according to any one of claims 3 to 4 wherein the at least two of the channels comprise a high resolution channel corresponding to an edge of the feature in the pattern to be imaged.
- 25 6. A light valve according to any one of claims 3 to 5 wherein the at least two of the channels comprise: a plurality of low resolution channels corresponding to a plurality of features in the pattern to be imaged; and a plurality of high resolution channels located adjacent to each low resolution channel, the high resolution 30 channels corresponding to edges of the features in the pattern to be imaged.

- 24 -

7. A light valve according to claim 6 comprising at least one high resolution channel located on each side of each low resolution channel.
- 5 8. A light valve according to any one of claims 1 to 7 comprising a plurality of uniformly spaced light valve elements, wherein groups of light valve elements are electrically coupled to one another to form at least one low resolution channel and at least one high resolution channel, wherein a number of light valve elements 10 electrically coupled to form the at least one low resolution channel is greater than a number of light valve elements electrically coupled to form the high resolution channel.
- 15 9. A light valve according to claim 8, wherein one or more of the plurality of uniformly spaced light valve elements are not electrically coupled to either a low resolution channel or a high resolution channel.
10. A light valve according to any one of claims 1 to 9, wherein the 20 light valve comprises a plurality of low resolution channels spaced apart so as to correspond with a plurality of spaced apart features in the pattern to be imaged.
- 25 11. A light valve according to any one of claims 1 to 2 wherein the at least two of the channels comprise a high resolution channel corresponding to an edge of a feature in the pattern to be imaged.

- 25 -

12. A light valve according to claim 1 wherein the at least two of the channels comprise:
 - 5 a low resolution group of light valve elements having a low resolution number of individual light valve elements coupled to be driven by a low resolution driver; and
 - 10 a high resolution group of light valve elements having a high resolution number of individual light valve elements coupled to be driven by a high resolution driver, wherein the low resolution number is greater than the high resolution number.
- 15 13. A light valve according to claim 12 wherein the low resolution number and the high resolution number are selected to correspond to the pattern to be imaged.
- 20 14. A light valve according to claim 13 wherein the low resolution group generates a low resolution channel on a substrate to be imaged and the high resolution group generates a high resolution channel on the substrate to be imaged, the low resolution channel larger than the high resolution channel.
- 25 15. A light valve according to claim 14 wherein the low resolution number is selected such that a size of the low resolution channel corresponds to a size of an interior portion of a feature in the pattern to be imaged.
- 30 16. A light valve according to claim 15 wherein the high resolution group is located adjacent the low resolution group and wherein the high resolution number is selected such that a size of the high resolution channel is sufficiently small to meet an edge resolution requirement of the in the pattern to be imaged.

- 26 -

17. A light valve according to claim 12 wherein the at least two of the channels comprise a plurality of high resolution groups of light valve elements, each high resolution group having a corresponding high resolution number of individual light valve elements coupled to be driven by a corresponding high resolution driver, the low resolution number greater than each of the corresponding high resolution numbers.
5
18. A light valve according to claim 17 wherein the low resolution number and each of the corresponding high resolution numbers are selected to correspond to the pattern to be imaged.
10
19. A light valve according to claim 18 wherein the low resolution group generates a low resolution channel on a substrate to be imaged and each of the corresponding high resolution groups generates a corresponding high resolution channel on the substrate to be imaged, the low resolution channel larger than each of the corresponding high resolution channels.
15
20. A light valve according to claim 19 wherein the low resolution number is selected such that the size of the low resolution channel corresponds to a size of an interior portion of a feature in the pattern to be imaged.
20
21. A light valve according to claim 20 wherein at least a first high resolution group is located on a first side of the low resolution group and at least a second high resolution group is located on a second side of the low resolution group, and wherein the corresponding high resolution numbers of the first and second high resolution groups are selected such that a size of the first corresponding high resolution channel is sufficiently small to meet
25
- 30

- 27 -

an edge resolution requirement of a first edge of the feature in the pattern to be imaged and a size of the second corresponding high resolution channel is sufficiently small to meet an edge resolution requirement of a second edge of the feature in the pattern to be imaged.

10 22. A light valve according to any one of claim 20 to 21 wherein two or more high resolution groups are located adjacent the low resolution group on one side thereof and wherein the corresponding high resolution numbers of the two or more high resolution groups are selected such that together the corresponding high resolution channels of the two or more high resolution groups are capable of meeting an edge resolution requirement of the feature in the pattern to be imaged.

15 23. A light valve according to any one of claims 1 to 22 comprising a plurality of uniformly spaced light valve elements.

20 24. A light valve according to claim 12-22 comprising a plurality of uniformly spaced light valve elements and wherein the at least two of the channels comprise a third group of light valve elements having a third number of individual light valve elements.

25 25. A light valve according to claim 24 wherein the individual light valve elements in the third group are coupled to be driven by a third driver, the third group is spaced apart from low resolution and high resolution groups and a space between the third group and the low resolution and high resolution groups is selected to correspond with a separation between features in the pattern to be imaged.

- 28 -

26. A light valve according to any one of claims 12 to 22 wherein the at least two of the channels comprise a third group of light valve elements having a third number of individual light valve elements and wherein the third group is spaced apart from low resolution and high resolution groups and a space between the third group and the low resolution and high resolution groups is selected to correspond with a separation between features in the pattern to be imaged.
- 5
- 10 27. A light valve according to any one of claims 1 to 26 wherein the light valve is a part of an imaging head used for imaging color elements on a color filter substrate.
- 15 28. A light valve according to any one of claims 1 to 26 wherein the light valve comprises one of: a silicon nitride ribbon-based light valve; a PLZT light valve; a TIR light valve; and a grating light valve.
- 20 29. A light valve according to any one of claims 1 to 26 wherein the individual light valve elements comprise at least one of: mirror elements having electronically alterable reflective characteristics; lens elements having electrically alterable refractive characteristics; and grating elements having electronically alterable transmission characteristics.

30. An imaging system for imaging a regular pattern of features onto a substrate, the imaging system comprising:
 - 5 a light valve having a plurality of independently drivable channels, at least two of the channels having non-uniform sizes, the non-uniform sizes corresponding to a regular pattern to be imaged;
 - 15 a radiation source for illuminating the light valve; and a lens for imaging the light valve onto the substrate.
- 10 31. An imaging system according to claim 30 wherein the at least two of the channels comprise:
 - 20 a low resolution group of light valve elements having a low resolution number of individual light valve elements coupled to be driven by a low resolution driver; and
 - 25 a high resolution group of light valve elements having a high resolution number of individual light valve elements coupled to be driven by a high resolution driver; wherein the low resolution number is greater than the high resolution number.
- 20 32. A method for imaging a regular pattern of features onto a substrate with a multi-channel imaging head, the method comprising:
 - 25 analyzing the pattern to identify spatial characteristics of one or more features;
 - 30 imaging an interior portion of each of the one or more features with a corresponding low resolution channel; and imaging an edge portion of each of the one or more features with at least one corresponding high resolution channel, wherein the at least one corresponding high resolution channel has a smaller size than the corresponding low resolution channel.

- 30 -

33. A method according to claim 32 wherein imaging an interior portion and imaging an edge portion occur in a single pass of the imaging head relative to the substrate.
- 5 34. A method according to any one of claims 32 to 33 wherein analyzing the pattern comprises determining a dimension of the low resolution channel corresponding to each of the one or more features and determining a dimension of the at least one high resolution channel corresponding to each of the one or more features.
- 10 35. A method according to any one of claims 32 to 34, wherein the pattern of features comprises a regular pattern of color elements to be imaged on a color filter substrate and wherein imaging an interior portion and imaging an edge portion comprise sequentially imaging each color.
- 15 36. A method according to any one of claims 32 to 35 wherein imaging the interior portion and imaging the edge portion further comprise locating a dye donor element adjacent to the substrate and imagewise heating the dye donor element to transfer dye to the substrate.

20

37. A method for fabricating a light valve for imaging a pattern of features with a multi-channel imaging system, the method comprising:
 - 5 analyzing the pattern of features to identify one or more spatial characteristics thereof;
 - fabricating a plurality of uniform regularly spaced light valve elements on a light valve substrate; and
 - based on the spatial characteristics of the pattern of features:
- 10 electrically coupling at least one low resolution group of light valve elements; and
- electrically coupling at least one high resolution group of light valve elements.
- 15 38. A method according to claim 37 wherein the low resolution group of light valve elements has a low resolution number of individual light valve elements and the high resolution group of light valve elements has a high resolution number of individual light valve elements and wherein the low resolution number is greater than the high resolution number.
- 20 39. A light valve for use in an imaging system, the light valve comprising:
 - 25 a first group of light valve elements having a first number of individual light valve elements electrically coupled to one another; and
 - a second group of light valve elements having a second number of individual light valve elements electrically coupled to one another,
- 30 wherein the first number of light valve elements and the second number of light valve elements are different from one another.

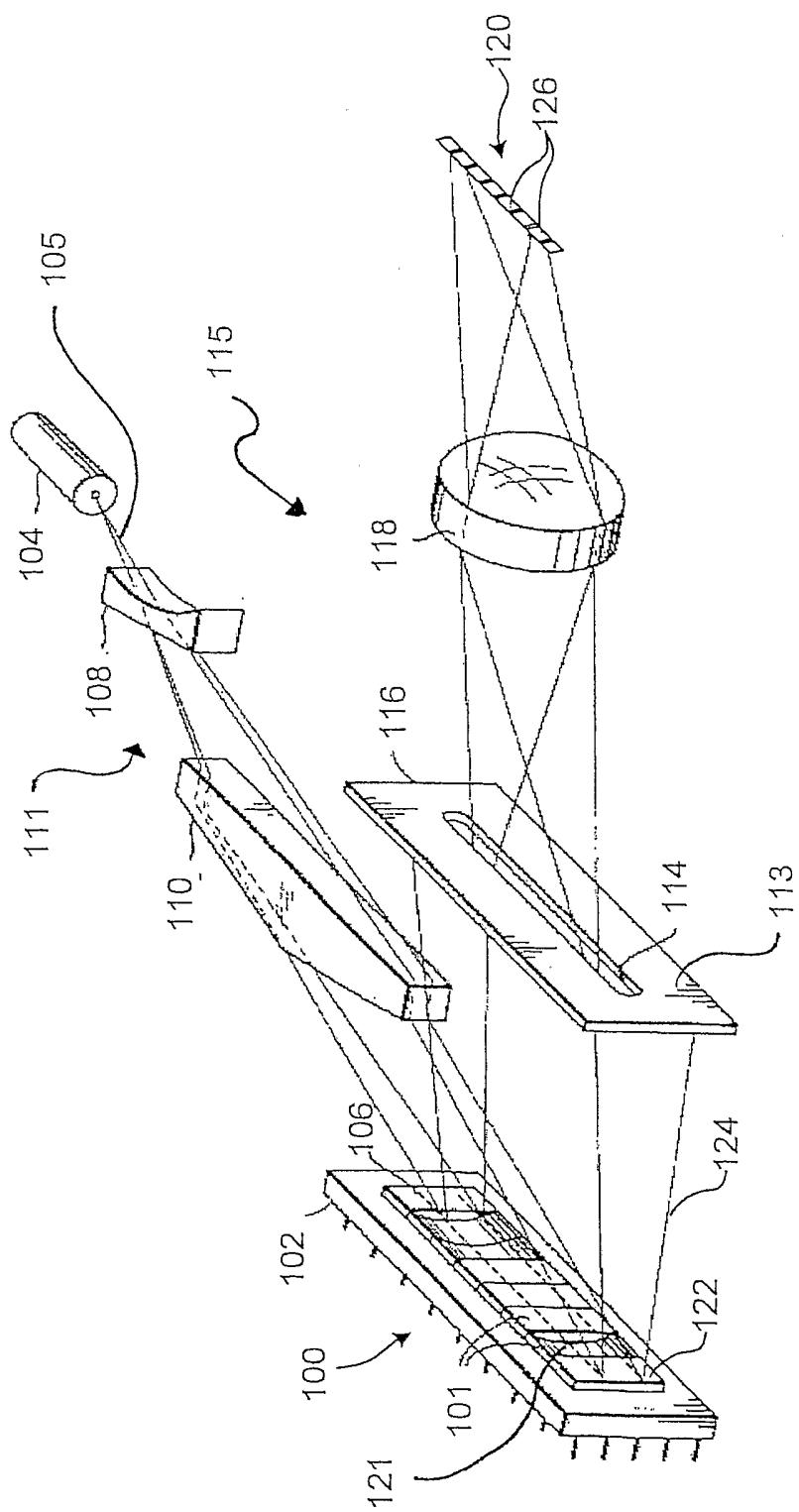


FIG. 1
PRIOR ART

2/5

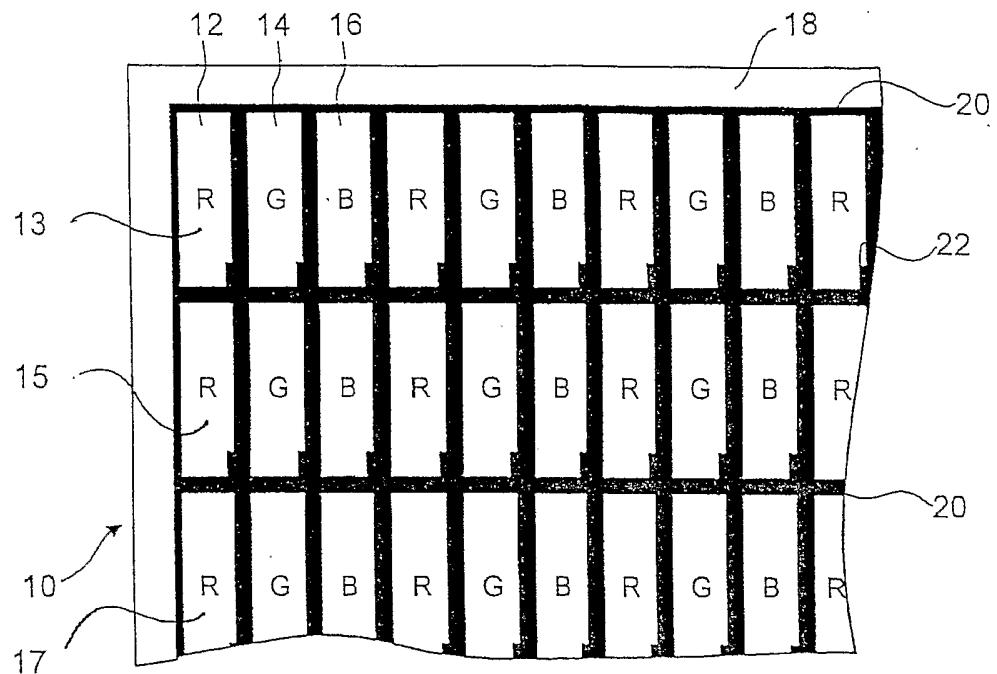


FIG. 2-A
PRIOR ART

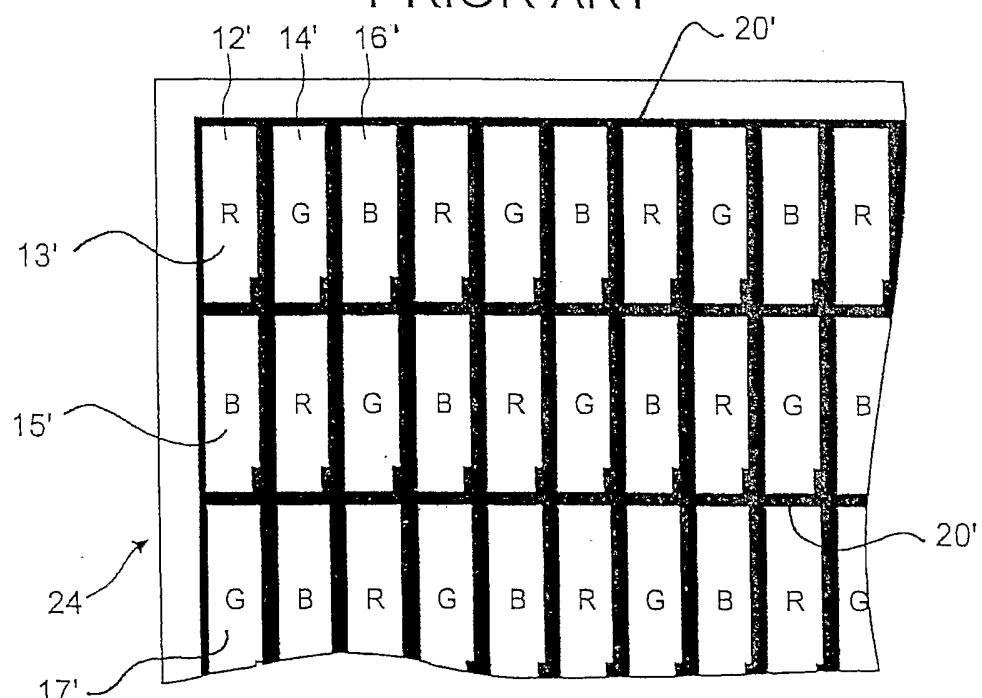


FIG. 2-B
PRIOR ART

3/5

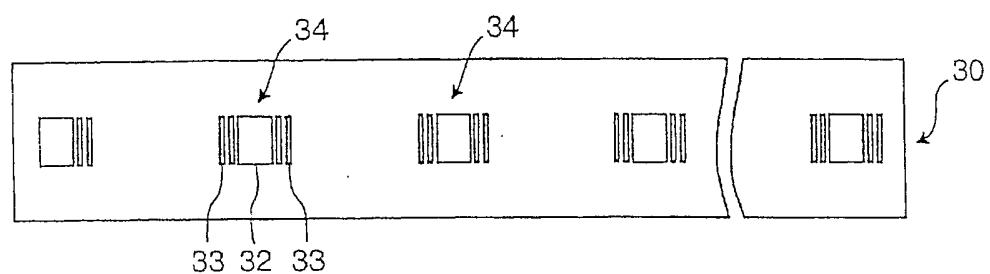
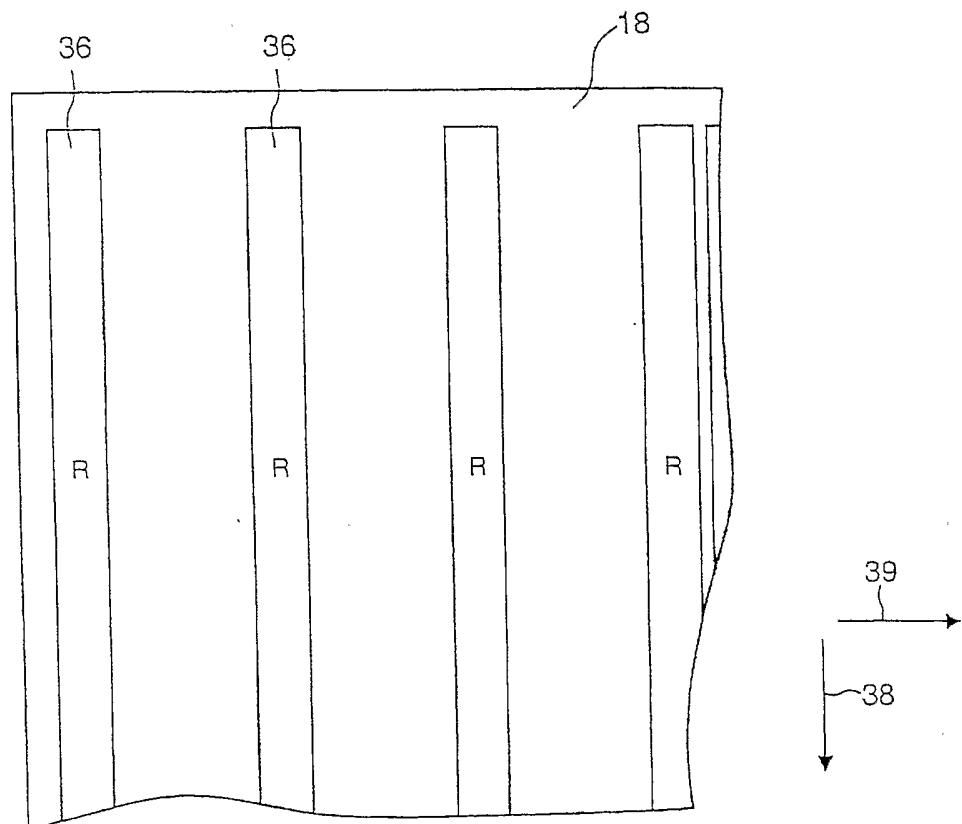


FIG. 3-A

4/5

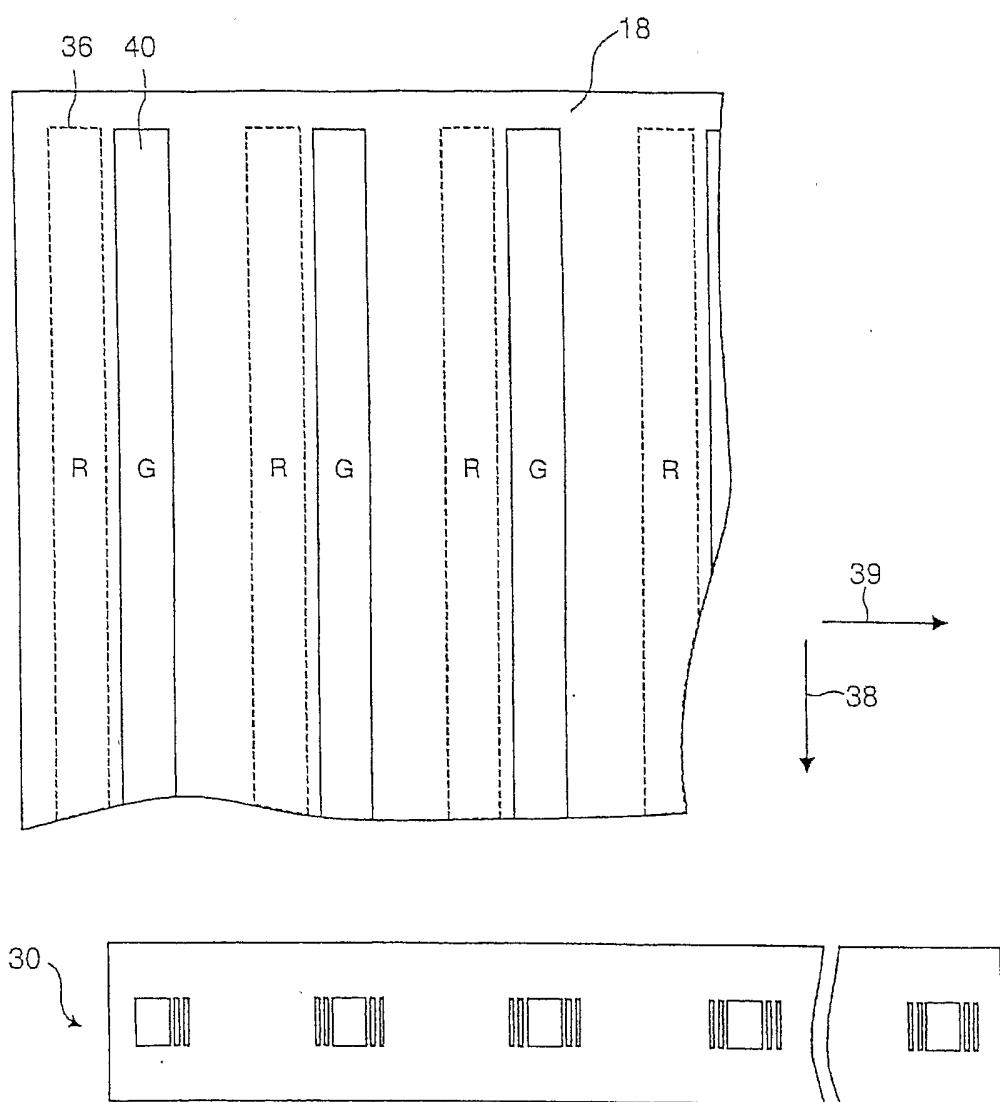


FIG. 3-B

5/5

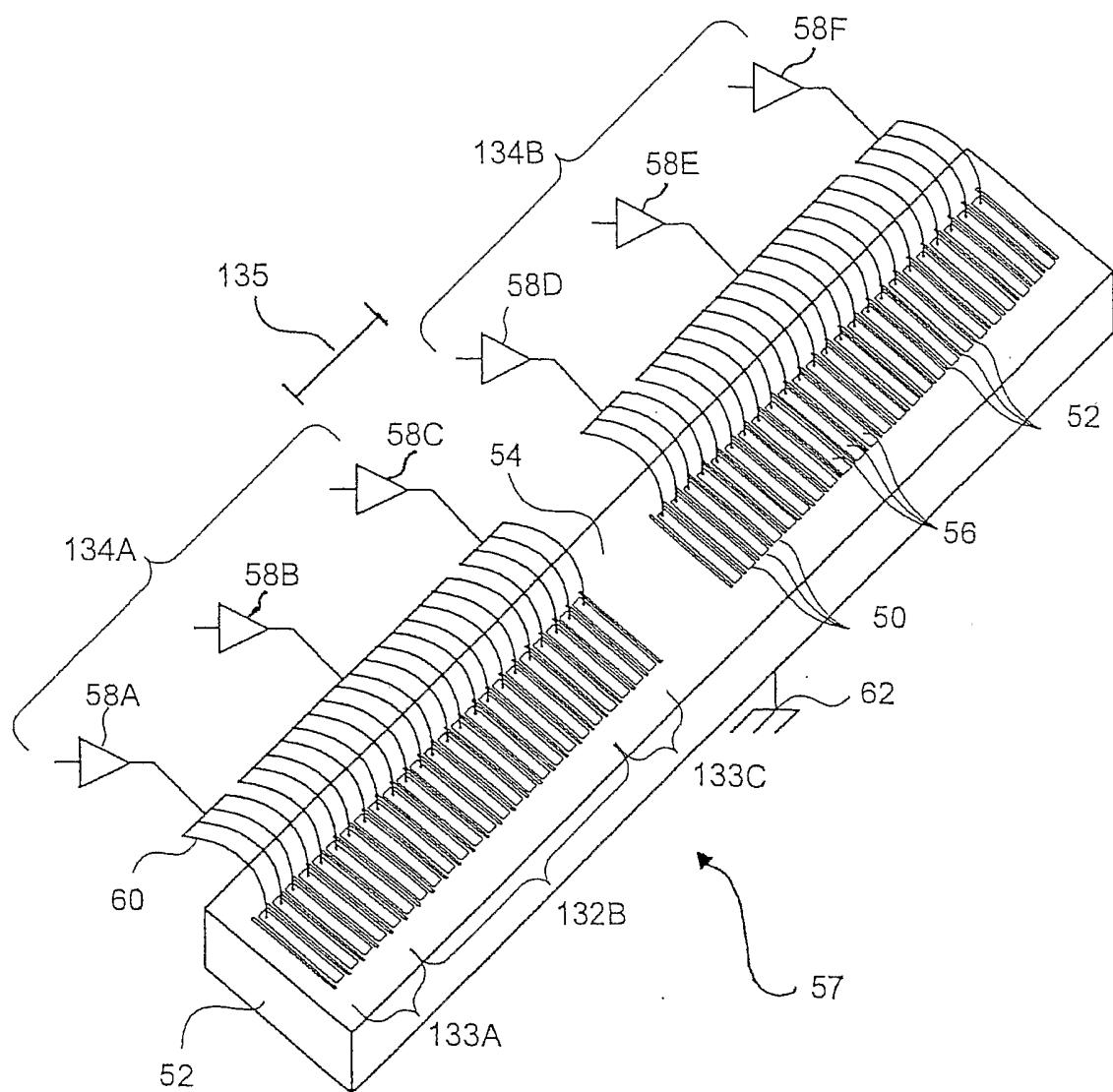


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CA2004/001410

A. CLASSIFICATION OF SUBJECT MATTER

G02B-26/08, G02B-27/00

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC⁷ G02B

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

Electronic data base consulted during the international search (name of data base, and, where practicable, search terms used)
DELPHION, ESPACENET, USPTO WEST, CANADIAN PATENT DATABASE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,X	US 6 728 023 04-27 2004 G02B-26/00 Alioshin et al.	1-8,10,12,13,17,18,23,39
P,Y		9,11,14-16,19-21, 28,29,30-34,37,38
Y	US 6 480 324 11-12-2002 G02B-26/08 Quate et al.	14-16,19-21,30-34,37-39

Further documents are listed in the continuation of Box C.

Patent family members are listed in annex.

* Special categories of cited documents :
 "A" document defining the general state of the art which is not considered to be of particular relevance
 "E" earlier application or patent but published on or after the international filing date
 "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
 "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

"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
 "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
 "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
 "&" document member of the same patent family

Date of the actual completion of the international-type search
14 Sept 2004

Date of mailing of the international-type search report
12 November 2004 (12-11-2004)

Name and mailing address of the ISA/
Commissioner of Patents
Canadian Patent Office - PCT
Ottawa/Gatineau K1A 0C9
 Facsimile No. 1-819-953-9358

Authorized officer
David E. Green 819-994-8213

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/CA2004/001410

US6728023 27-04-2004 US6728023 B1 27-04-2004
WO03102664 A1 11-12-2003

US6480324	12-11-2002	CA2273387 A1	29-11-1999
		EP0961174 A2	01-12-1999
		JP3472723B2 B2	02-12-2003
		JP2004006955 A	08-01-2004
		US6271957 B1	07-08-2001
		US6480324 B2	12-11-2002
		US2003002130 A1	02-01-2003
