United States Patent [19]

Guldberg et al.

[11] **3,886,310**

[45] **May 27, 1975**

[54] **ELECTROSTATICALLY DEFLECTABLE LIGHT VALVE WITH IMPROVED DIFFRACTION PROPERTIES**

[75] Inventors: **Jens Guldberg; Harvey C. Nathanson,** both of Pittsburgh, Pa.

[73] Assignee: **Westinghouse Electric Corp.,** Pittsburgh, Pa.

[22] Filed: **Aug. 22, 1973**

[21] Appl. No.: **390,470**

[52] **U.S. Cl.**.............. **178/7.5 D;** 313/465; 315/372; 315/374; 350/161

[51] **Int. Cl.**...... **H04n 3/16;** H01j 29/12; G02f 1/28

[58] **Field of Search**............ 315/21 R; 313/91, 465; 178/7.5 D, 5.4 BD; 350/161

[56] **References Cited**

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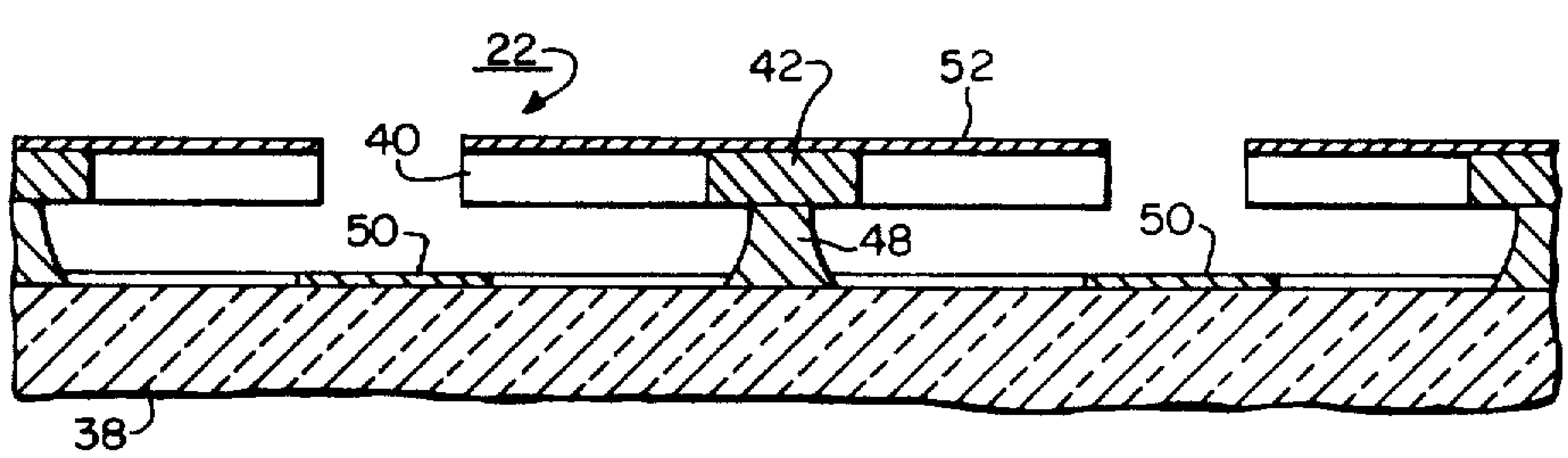
3,746,911	7/1973	Nathanson et al.	315/21 R

Primary Examiner—Maynard R. Wilbur
Assistant Examiner—G. E. Montone
Attorney, Agent, or Firm—W. G. Sutcliff

[57] **ABSTRACT**

An electrostatically deflectable light valve adapted for use in an array for producing television pictures as a projected image upon a large display screen. The light valve structure is such that a plurality of reflective wing portions are free to be deflected along directional axes which are at an angle to the prime directional axes of the overall array, so that light which is predominantly diffracted along the array axes may be decoupled or separated from the signal light produced by activated light valves and used to project the image. The contrast ratio of signal light to background light for the system is significantly improved, using this method of discrimination.

11 Claims, 6 Drawing Figures



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SHEET 1

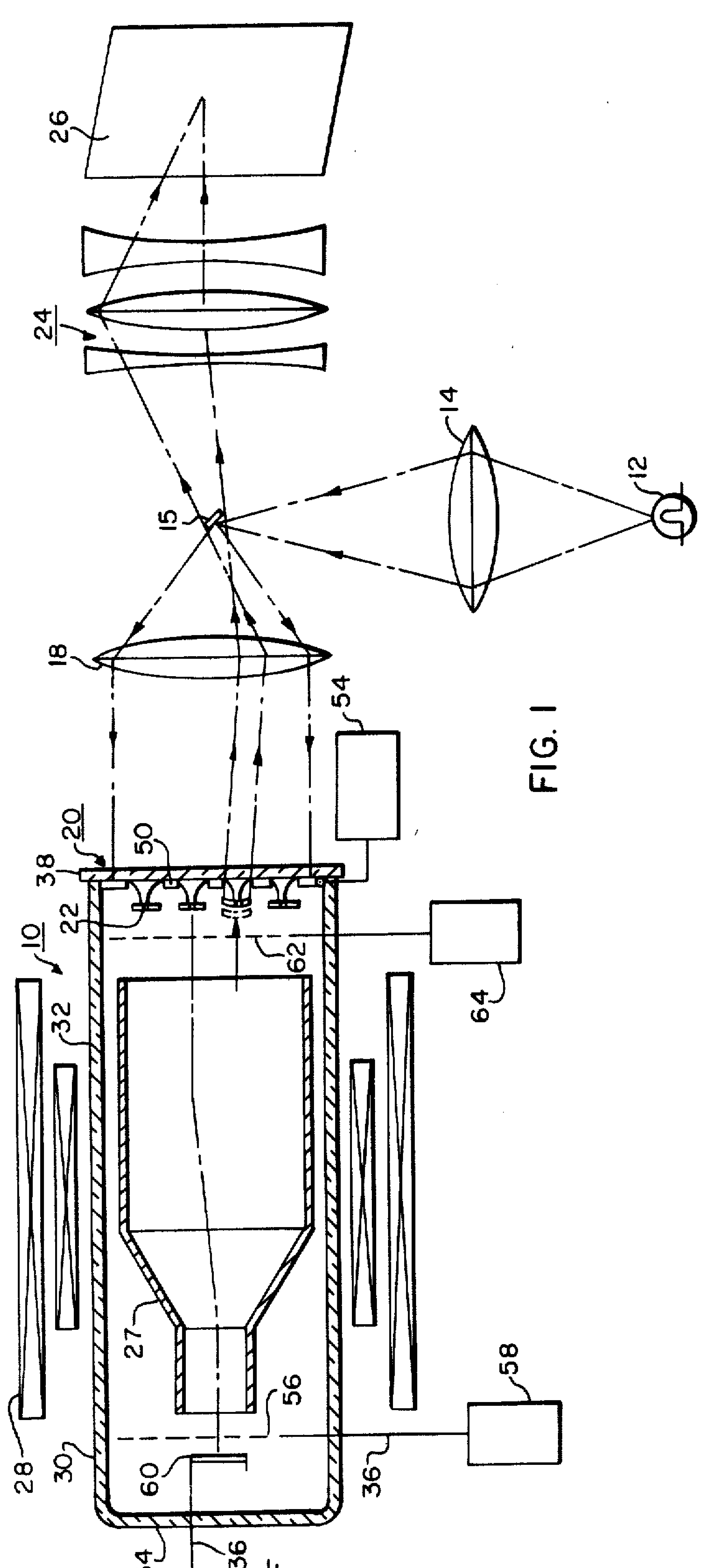

FIG. 1

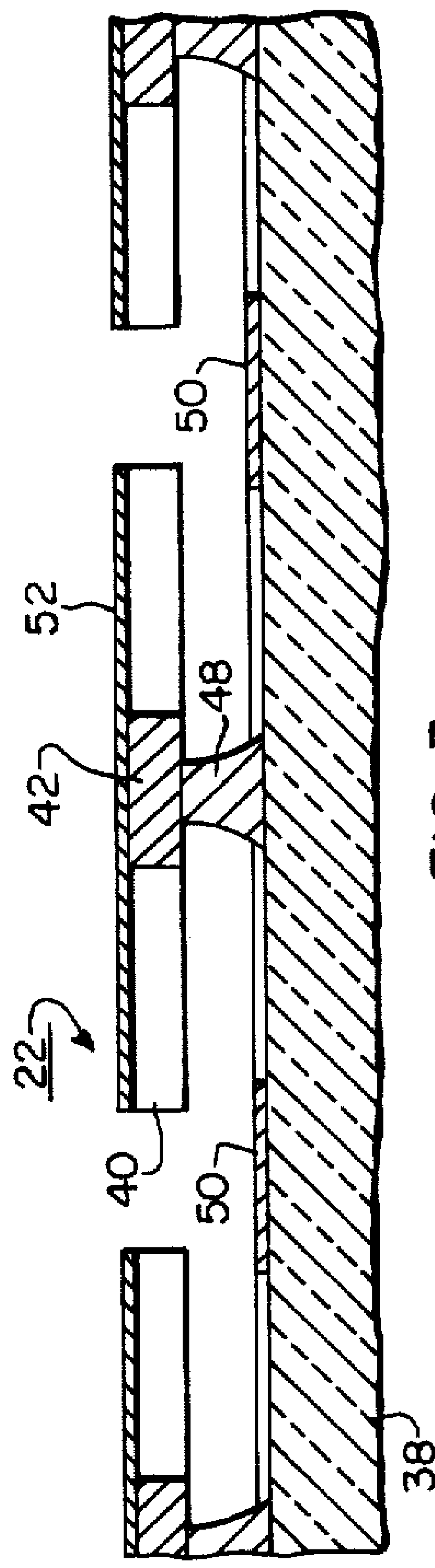

FIG. 3

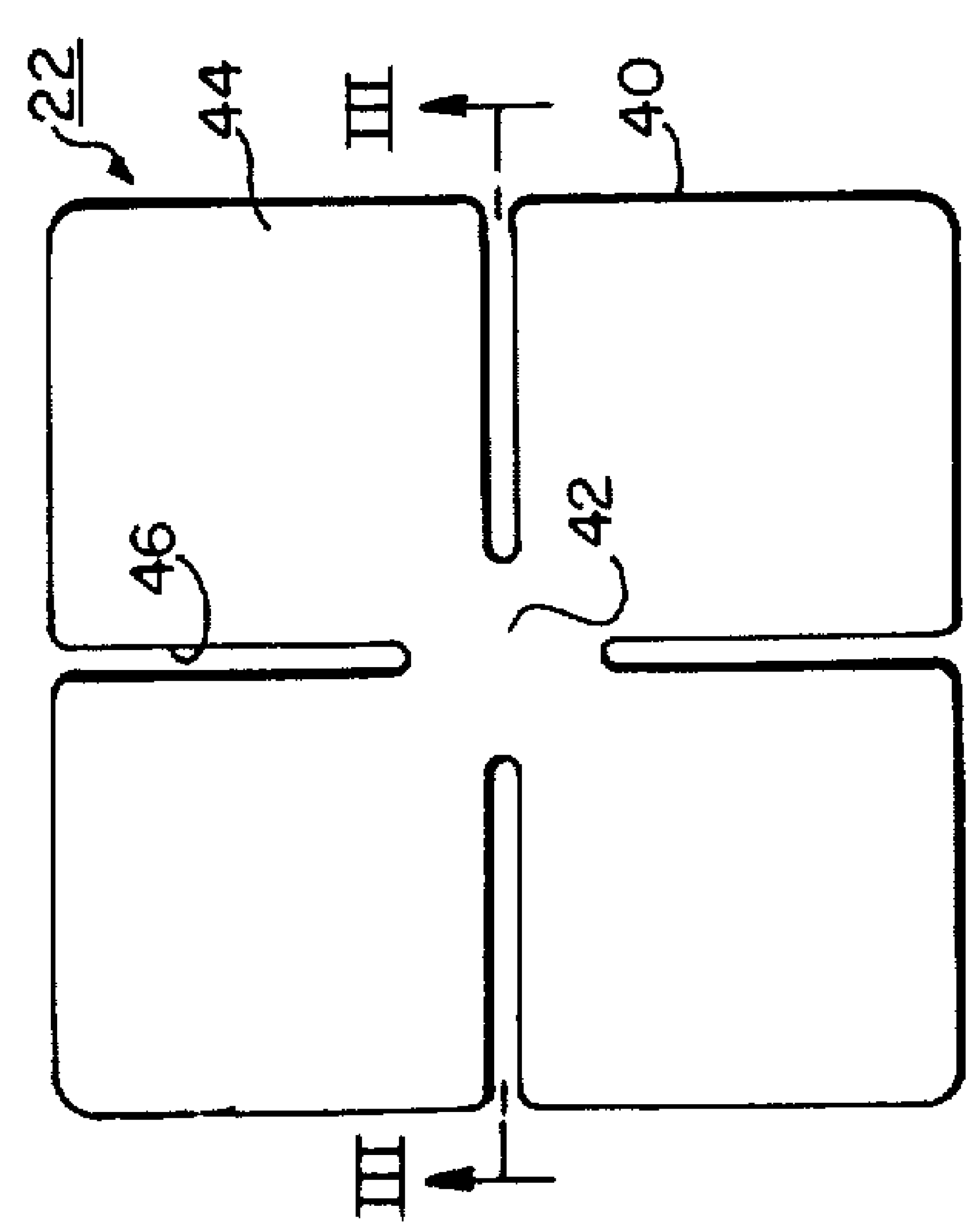

FIG. 2

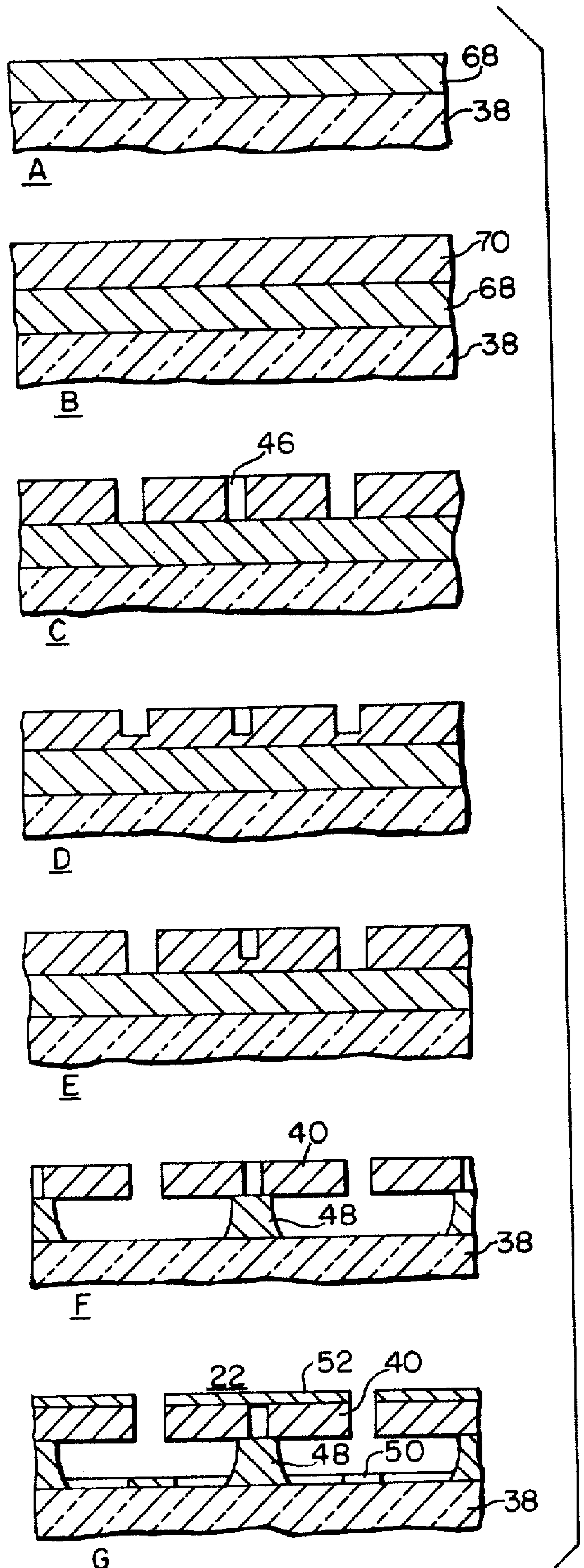

FIG. 4

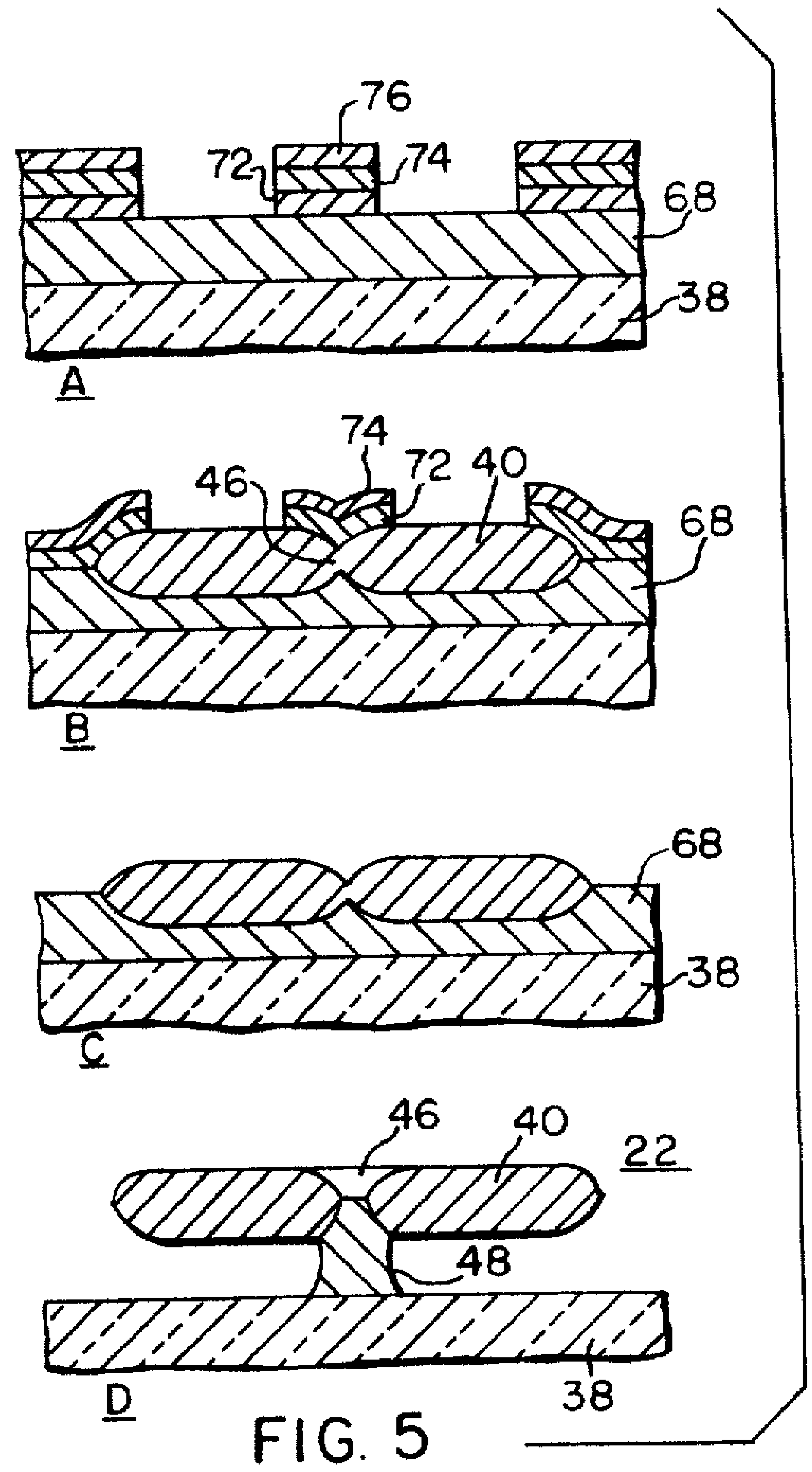

FIG. 5

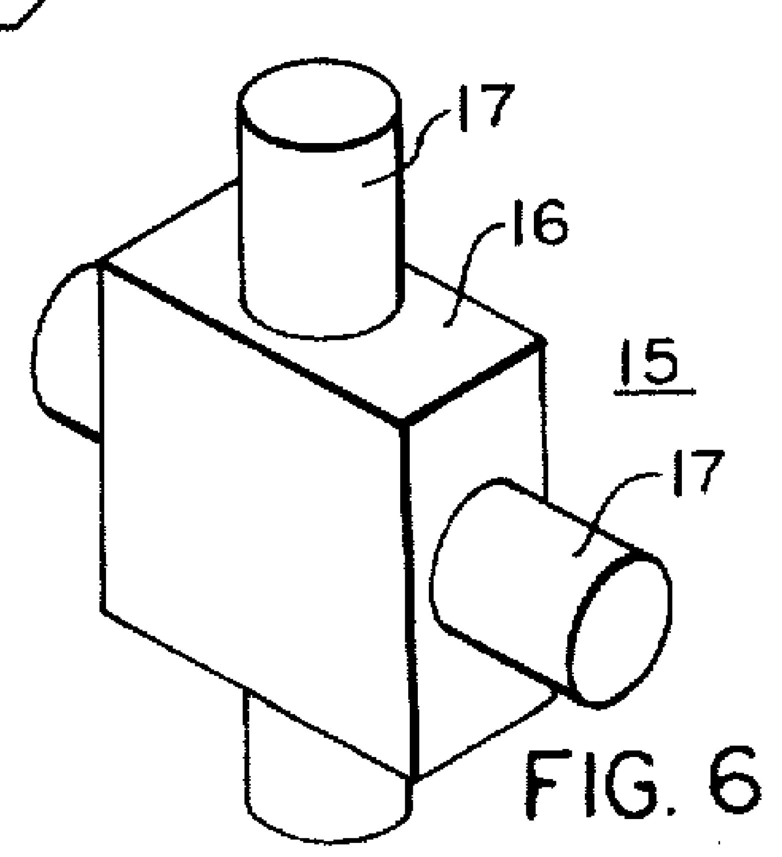

FIG. 6

ELECTROSTATICALLY DEFLECTABLE LIGHT VALVE WITH IMPROVED DIFFRACTION PROPERTIES

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to electrostatically deflectable light valves which are adpated for use with a cathode ray tube, and in conjunction with schlieren optics forming a system for projecting television images upon a large display screen, and which may be operated either as a real-time or a storage mode device.

2. Description of the Prior Art

A considerable effort has been expended in researching and developing systems for projecting television images upon a large screen. Such systems are aimed at expanding the usage of closed circuit television entertainment systems, as well as simply providing a greatly increased display area with its obvious advantages. The present commercial systems utilize an oil film surface as the target of a cathode ray tube, with the electron beam being used to produce a diffraction pattern on the film. An external light source is directed upon the film and an optical system with schlieren bars is utilized to project the desired image upon the display screen correspondence to the informational pattern upon the film. This oil film system is expensive and suffers from the inherent problem of having a fluid film operate within an evacuated cathode ray tube.

A variety of other display systems have tried to circumvent the problems associated with the use of oil films. Substitution of elastomer layers for the oil film results in very small deflections and consequently requires a sophisticated and expensive optical projection system. Techniques utilizing electro-optical materials, primarily KD_2PO_4 crystals, suffer from a basic problem of incompatibility in using the material in a vacuum. Another approach uses a taut metal membrane suspended on thin metal ribs and segmented to form an array of picture elements addressable by an electron beam. Energetic electrons of about 20 kilovolt potential penetrate the film and deposit a charge on the transparent glass substrate. The resulting electrostatic forces will deflect the metal membrane and the image is read out with ordinary schlieren optics.

Another feasible system utilizes an array of electrostatically deflectable light valves or very small mirrors, which are deflectable corresponding to the informational pattern. Such a system is disclosed in U.S. Pat. No. 3,746,911. In such systems an array of the deflectable light valves form the target of a cathode ray tube. An external light source is directed onto this target which is modulated to deflect individual valves of the array in an informational pattern. The light is reflected from the light valves, and for deflected valves the light is stopped while for deflected valves the light passes the schlieren stop and is projected upon the display screen with suitable magnification.

A problem with these prior art television image projection systems is the poor screen contrast caused by optical diffraction effects related to the target array. In general, such arrays have rows and columns of light valves which define an array having an X and a Y axes. The electrostatic deflection of each light valve modifies the diffraction pattern of the reflected light by tilting of the reflective plane as well as bending or bowing of the reflective surface. Because of constructional constraints the deflection of the light valves is also along one of these major axes. This diffraction effect causes light to pass about the schlieren optical stop primarily along one of the major axes of the array.

Consequently, a high contrast ratio with low background illumination can only be achieved with extremely large deflection angles.

This same problem exists for arrays other than rectangular arrays and for light valves other than simple square elements.

SUMMARY OF THE INVENTION

A reflective light valve element is provided having a structure which permits the elimination of transmission of background light to the screen to provide significantly improved contrast for the display. The light reflective element is adapted for use in an array as part of a projection system for displaying television images. The light reflective element comprises a central core portion supported by a central post member which extends from the underside of the core portion. A plurality of symmetrically spaced and shaped deformable reflective wing portions extend outwardly from the central core portion. The extending ends of the wing portions have slits therebetween. When such reflective elements are arrayed as a target, the slits are aligned with the predominant axes of the array. The wing portions are then free to bend or deflect along an axis which is at an angle to the predominant axes of the array. A method of providing this improved light valve structure is also detailed.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic overall view of a projection system of the present invention.

FIG. **2** is an enlarged plan view of a single light valve of the present invention.

FIG. **3** is a sectional view taken along line III—III of FIG. **2** of the light valve.

FIG. **4** illustrates the various stages of preparation of the light valve of the present invention.

FIG. **5** illustrates the various stages of another method of construction of the present light valve.

FIG. **6** is a perspective view of the schlieren stop used in the projection system of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention can be best understood by reference to the exemplary embodiment shown in the drawings.

The projection system comprises an electron beam tube **10.** A high intensity light source **12** of preferably well balanced light is provided for illumination. The light from source **12** is focused by a lens **14** and refracted by a 45° angle reflective schlieren mirror **15.** The reflected light is collimated by lens **18** onto target **20** associated with the faceplate of cathode ray tube **10.** In the absence of actuation or deformation of individual light valve elements **22,** the light will be reflected back from element **22** to be focused on the schlieren mirror **15** and remain within the original light cone. Deflection or deformation of a light valve element due to electrostatic forces as will be explained, will result in the light passing the schlieren mirror **15** and being projected through lens system **24** to the enlarged display screen **26.** In this manner, a light image will be produced upon the screen **26**, which corresponds to the informational pattern established upon target **20** by deformation of the individual light valve elements **22**. The deformation of the elements **22** corresponds to the applied video signal.

The schlieren mirror or stop **15** is shown in an enlarged view in FIG. **6**, and comprises a generally square shaped mirror member **16** and rod support means **17**. The mirror member is inclined at the proper angle to direct the light onto the light valve target. The support means **17** here comprise opaque rods which facilitate support of the mirror member **16**, and extend from the ends of each side of mirror member **16** along the major X, Y axes corresponding to the X, Y directional axes of the mirror array. The opaque rods **17** then serve to block scattered light which can be expected along these axes, which light represents a background level that substantially degrades the display contrast.

The electron beam tube **10** comprises an outer envelope **30** having a tubular body portion **32**, and a base portion **34**. The base portion **34** is provided with lead-ins **36** for applying potential to the operative electrodes. The faceplate portion **38** is sealed to the opposite end of the body portion **32**. The target **20** is disposed on the interior surface of the faceplate **38**. An internal focusing electrode **27** is provided within envelope **30**, and external focusing and deflection means **28** are disposed about envelope **30**.

The target structure **20** comprises a plurality of light valve elements **22**, such as seen in greater detail in FIGS. **2** and **3**. The light valve elements **22** form an array, which is typically rows and columns of identical elements **22**, with the total array including typically hundreds of thousands of the very small elements **22**, which have a dimension of about 25–70 microns on a side. The elements **22** seen in FIG. **1**, are thus shown greatly enlarged in a schematic sense to facilitate understanding of the device.

The light valve elements **22**, seen in greater detail in FIGS. **2** and **3** comprise a generally planar reflective portion **40**, which comprises a central core portion **42**, and a plurality of symmetrically spaced and shaped, deformable, reflective wing portions **44**, which extend outwardly from the central core portion **42**. An opening or slit **46** separates the wing portions **44**. In this embodiment, the portion **40** is generally of square configuration, and the four slits **46**, define four wings or quadrants. The slits **46** extend in the direction of the axes of the array of elements **22**, which for this embodiment would consist of horizontal rows and vertical columns. The elements **22** are supported upon a light transmissive substrate **38**, which serves as the faceplate of the cathode ray tube **10**. The substrate **38** may be formed of a vitreous material such as quartz, sapphire or spinel. A support or spacer post member **48** extends from the substrate to the underside of the central core portion **42**. The post member **48** is typically a semi-insulator such as silicon, but can also be a conductor or insulator, and has a cross-sectional dimension of less than about 5 microns on a side, and a height of about 1.5 to 10 microns. The reflective array elements **22** are typically comprised of an electrical insulator, such as silicon dioxide, with a thin reflective layer **52** of metal, such as aluminum thereon. The material can also be metal or semiinsulating. The thickness of the planar portion **40** of element **22** is about 1,000–5000 Angstroms.

An electrically conductive grid **50** is provided on the interior surface of substrate **38** running between the spaced apart light valve elements **22**. The grid **50** is typically formed of a thin metal film of suitable material, such as gold or aluminum, which is preferably thin enough to be light transmissive. The grid is connected to an external potential source **54**. The potential source **54** may be a video signal source when the grid **50** is utilized to modulate the target voltage with the electron beam merely being a flood beam which charges the individual planar portion **40** of the light valves **22** to or near equilibrium with grid **62** which is typically located in close proximity to the target array. The grid **62** is connected to potential source **64**.

The electron beam may also be modulated, with the video signal applied via grid **56** proximate the cathode or beam source **60**. A fixed bias would then be applied to electrode **27**, grid **62**, and grid **50**. In this case the grid **50** on the target **20** merely serves as a reference electrode necessary to produce electrostatic deflection of the planar portion **40** of light valves **22**. The electrostatic bias is determined by the amount of charge deposited by the beam in accordance with the instantaneous value of the video signal.

The array of light valve elements **22** may be fabricated according to the method outlined in the aforementioned U.S. Pat. No. 3,746,911, but with the modification as outlined in FIG. **4**. The substrate **38** has a heteroepitaxially grown layer of silicon **68** which is oxidized to a thickness of 3,000–8,000 Angstrom to provide silicon dioxide layer **70** thereon. The oxide layer is delineated by a photoresist process to define the generally square configuration of element **22**, and the slits **46** within elements **22** as seen in FIG. **4C**. A reoxidation is carried out to a thickness of 2,000–4,000 Angstroms to partially close the slits and the spacing between elements **22** as seen in FIG. **4D**. The oxide between elements **22** is then removed by another photoresist operation which does not effect the oxide at the central core of the elements **22** or of the slit areas as seen in FIG. 4E. The silicon dioxide is then undercut by etching with a solution of nitric, acetic, and hydrofluoric acid in a ratio of approximately 25/10/1. A slight oxide etch follows to ensure that any oxide between the slits is removed to provide the structure of FIG. 4F. The reflective metal layer 52 is then deposited upon the planar portions 40, and also upon substrate 38 to form grid 50 as seen in FIG. 4G.

The above described process requires accurate successive alignment of the exposure mask in first delineating the elements, and then redelineating them following the reoxidation process, which ensures proper junction of the central post **48** and the planar portion **40**. The fabrication can also be arranged with other materials and deposition materials, and the material temporarily closing the slits does not have to coincide with the material chosen for the planar portion **40**.

Another process which obviates this realignment problem is to use a self-alignment technique which is generally depicted in FIG. **5**. The substrate **38** has the silicon layer **68** thereon.

Through a process of successive depositions and appropriate photolithographic operations a mask matrix can be built upon the silicon **40**. The mask comprises a thin silicon dioxide layer **72**, a silicon nitride layer **74** thereon, and a top thin layer **76** of silicon dioxide. These three mask layers are typically vapor deposited over the substrate and the silicon. The mask is photolithographically delineated, removing selected portions of the three layers to provide the matrix as seen in FIG. 5A. The silicon layer is then thermally oxidized to provide the planar portions **40** for light valve **22** as seen in FIG. 5B. The remaining mask portions can then be etched away, and the silicon dioxide undercut to the final shape and to form the support post as seen in FIGS. 5C and 5D. The slits are opened by a separate etch, which is followed by metallization of the surface of light valve **22** to ensure high reflectivity.

In the self-aligning mask technique the silicon dioxide layer **72**, silicon nitride layer **74**, and silicon dioxide layer **76**, have typical layer thicknesses of 200–500 Angstroms, 1,000–3,000 Angstroms, and 1,000–3,000 Angstroms, respectively. The etching is carried out with conventional solutions. The generally planar silicon dioxide portion **40** is produced by thermal oxidation to a thickness of for example 3,000–10,000 Angstroms. This thermally grown layer **40** is only produced in windows in the nitride mask. In the presence of the thin intermediate silicon dioxide layer **72** the edges of portions **40** will grow and merge in the slit area **46** as seen in FIG. 5B. After removal of the silicon nitride layer **74**, the structure can be further etched to open the slit areas **46**, while also forming the post **48** from layer **68**. In general the slit widths should be less than 2μ, while the grids between light valve elements is larger than $2–3\mu$ for this technique to work.

We claim:

1. An electrostatically deflectable light valve system comprising an array of spaced apart, deformable, light reflective elements supported upon a substrate, each of said reflective elements comprising a central core portion supported by a centrally located post member which extends from one side of the reflective elements to the supporting substrate, a plurality of generally planar, symmetrically spaced apart and shaped independently deformable and reflective wing portions extending outwardly from the central core portion, which wing portions are defined by an equal plurality of thin slits provided between said wing portions which slits extend from the central core portion to the outer edge of the wing portions.

2. The system specified in claim **1**, wherein an electrode grid is disposed upon the supporting substrate.

3. The system specified in claim **1**, wherein the substrate is a light transmissive material.

4. The system specified in claim **1** wherein four generally square wing portions are provided with thin slits separating the wing portions.

5. The system specified in claim **4**, wherein the slits are aligned with the axes of the array pattern in which the light valves are arranged.

6. The system specified in claim **5** when the planar portion of the light valve is substantially square and the slits extend from the edges of each wing to the central core portion.

7. The system specified in claim **1**, wherein a light reflective coating is provided on the top surface of the central core portion and the wing portions.

8. The system specified in claim **3**, in combination with a light source, an optical system for directing light through the transmissive substrate to the surface of the reflective light valves, said optical system including an opaque stop disposed in the optical path between the array of light valves and a display screen, so that when the wing portions of the light valves are nondeflected the light reflected is substantially totally reflected off or blocked by the stop and no light reaches the display screen, while when the wing portions are deflected a portion of the light reflected therefrom passes around the central stop and produces a large, displayed image.

9. A light reflective element adapted for use as an electrostatically deflectable light valve which element comprises;

- a central core portion supported by a post member which extends from one side of the core portion, and
- a plurality of generally planar, symmetrically spaced and shaped independently deformable reflective wing portions extending outwardly from the central core portion, which wing portions are defined by an equal plurality of thin slits provided between said wing portions which slits extend from the central core portion to the outer edge of the wing portions.

10. The light reflective element specified in claim **9**, with four generally square wing portions provided, with thin slits separating the wing portions.

11. An electrostatically deflectable light valve system comprising an array of spaced apart, deformable light reflective elements supported upon a substrate, the elements being arrayed along X and Y orthogonal axes, each of said reflective elements comprising a central core portion supported by a centrally located post member which extends from one side of the reflective elements to the supporting substrate, and four spaced apart, generally planar, symmetrically spaced and shaped deformable and reflective wing portions extending outwardly from a common central core portion, which four wing portions are spaced apart by slits extending in the direction of the X and Y axes of the array pattern.

* * * * *