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(54) **Element.**

(57) An element for use as a thermionic cathode and/ or a light emitting device comprising a semiconductor substrate (1) having a recess (3) therein with a bridge structure extending across the recess and comprising a metal layer (9) on a support layer (5). The bridge structure may be in the form of a narrow linear strip or alternatively it may comprise a broad band of support material with a metal layer in the form of a sinuous strip (21) or (91) supported thereon. The element may be enclosed in an envelope and in a preferred construction the metal layer is only about 5 microns wide but the support layer is mechanically stable up to about 1100 K.

Preferably the semiconductor substrate is silicon and the support material is silicon dioxide or silicon nitride (15).

In one construction the element can be used as a thermionic cathode (25) and the element may form part of a thermionic cathode assembly forming part of a display device with a phosphor screen, a grid assembly (27) between the cathode assembly (25) and the screen and an anode for accelerating electrons from the cathode to the screen. Preferably, therefore, cathode ray deflection means are also provided. The elements may be closely packed in matrix form to provide a cathode assembly on a single wafer of semiconductor material (45) to form part of a display device with a screen, accelerating anode, grid assembly 43, etc. The matrix of elements may be addressed by a digital logic circuit and suitable drive circuits and the grid (43) may be provided with an even potential over its surface so that light produced by electrons

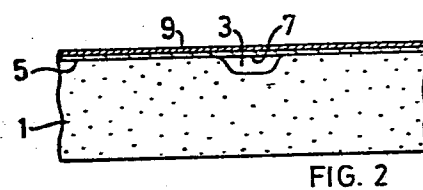
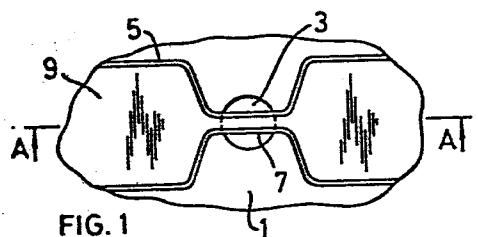
impinging upon the screen (41) will be produced in a matrix of pixels corresponding to the addressed elements. The intensity of each pixel may be controlled by adjusting the current supplied to the relevant cathode element or by adjusting the potential difference between the grid (49) and cathode assembly (39).

As an alternative, the matrix may be addressed by applying equal current flow to each element in a row of the matrix in which case each grid element in a corresponding row of the grid would be addressed separately. Alternatively, equal current may be supplied to each cathode element and the grid assembly may be in the form of a matrix of elements to each of which is applied an independent bias potential.

It is envisaged that the or each element instead of providing a thermionic cathode may each provide a light emitting device and the elements can again be provided in the form of a matrix and the amount of light emitting from each element would be controlled by the current passed to each element.

In some simple cathode structures, the support layer may be etched away so that the bridge across the recess in the substrate is formed just of a metal layer.

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ELEMENT

This invention relates to an element which may be used either as an electron emitting device or as a light emitting device. In particular one or more elements may be used as thermionic cathodes in a thermionic valve such as a cathode ray tube or as light emitting devices in, for example, a display.

The physical phenomenon of thermionic emission is exhibited by a metal heated above a characteristic threshold temperature. When a metal is heated such that the energy of electrons within the metal exceeds the value of the thermionic work function characteristic of the metal, electrons escape from the metal and form a space charge. A thermionic valve utilises the space charge to set up a current flow, in the form of electrons travelling in a vacuum, from a hot metal (a thermionic cathode) to a relatively positively charged anode. The flow of electrons may be altered by means of a control grid interposed in the electron flow.

The advent of semiconductor technology and circuit integration has led to a marked reduction in the general use of thermionic valves. Particular forms of thermionic valve are however much used in special applications.

One such particular form is the cathode ray tube.

The cathode ray tube is an image forming thermionic valve which has commercial application not only in the domestic market as the major component of television receivers but also in research and industry as the major component of oscilloscopes.

In broad terms a cathode ray tube comprises an evacuated glass envelope, one end of which is formed into a screen. At the opposite end of the tube is located an assembly for producing a stream of electrons ("a cathode ray"). This assembly is

commonly known as an electron gun and comprises a thermionic cathode, a control grid and at least one anode. The thermionic cathode produces a space charge of electrons, which electrons are accelerated away from the cathode by the positive charge of the accelerating anode. The speed and therefore the kinetic energy of the electrons may be controlled by a negatively biased control grid. A fine beam of electrons is required and further anodes are usually provided which create an anisotropic electrostatic field tending to focus the electron beam in a manner analogous to the focusing of light rays by a lens. After leaving the electron gun, the beam of electrons is subjected to a deflecting force. This may be an electrostatic force, in which case the beam is caused to pass between two mutually perpendicular pairs of plates. The plates may be charged in order to deflect the beam of electrons in one or both of two perpendicular axes. This method of deflecting the electron beam in a cathode ray tube is commonly used in oscilloscopes.

In an alternative arrangement, the electron beam is caused to pass through the field of electromagnets capable of creating perpendicular electromagnetic fields. The electromagnets are usually located outside the glass envelope of the cathode ray tube. The application of current to the electromagnets allows deflection of the electron beam in one or both of two perpendicular axes. This method of deflection is commonly used in cathode ray tubes where a continuous raster scan is required (as, for example, in a television picture tube).

The electron beam finally impinges upon a phosphor screen where the kinetic energy of the electrons comprising the beam is converted into light.

The conventional miniature thermionic cathode structure is generally a coil of metal wire of high

melting point. The coil is supported at either end by its electrical connection to the electron gun assembly. Typically, such a miniature cathode is constructed from a wire of 20 microns in diameter and 10 millimeters in length. The cathode is commonly made of tungsten which requires to be heated to about 1100 K in order to produce a satisfactory flux of electrons. The operating temperature may be reduced to about 900 K by adding a coating which reduces the effective thermionic work function of the wire. A commonly used coating is a mixture of carbonates.

A miniature thermionic cathode of the type described immediately above consumes a considerable amount of power at its operating temperature. For example, a coated tungsten thermionic cathode of the dimensions given will consume about 50mW at 900 K. Only a fraction of this power goes directly to provide the energy to liberate electrons from the cathode material. The majority of the power taken by the cathode is dissipated as heat by conduction and radiation. An object of the present invention is to reduce the power losses and also to provide a cathode of reduced overall size.

Recent advances in solid state circuitry have provided the technology to produce layer structures of intricate, yet well defined, physical shape. In particular, it is possible to produce complex multi-layered structures, by known miniconductor fabrication techniques (such as material oxidation, deposition and selective etching) which may, for example, operate as complete electronic circuits. This technology has been adapted to produce the element of the present invention.

The element of the invention may be used as a thermionic cathode replacing the known cathodes in thermionic devices as described above, or, as we have

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now discovered, by increasing the power supplied to the element, it may be used as an incandescent light source providing a light emitting device of small dimensions for use, for example, in a direct display device.

According to a broad, first, aspect of the present invention, we provide an element for use as a thermionic cathode and/or a light emitting device comprising a semiconductor substrate, a metal layer, and a support layer interposed between the semiconductor substrate and the metal layer, wherein the semiconductor substrate is provided with a recess across which recess extends a bridge structure comprising the support layer and/or the metal layer.

In use, an electrical current is passed through the metal layer, the current resistively heating the metal to a temperature at which thermionic emission and/or light emission occurs.

The recess is formed such that the bridge structure is physically separated from the semiconductor substrate. As examples, the recess may be in the form of a hollow or groove formed in the surface of the semiconductor substrate, or a hole passing through the semiconductor substrate.

The bridge structure may take the form of a narrow linear strip of the metal layer attached to a support layer of similar shape, a broad band of support material to which is attached a metal layer in the form of a sinuous strip or a region of support material having attached thereto a metal layer in the form of a sinuous strip, the region of support material overlying the recess and being supported by three or more support arms.

The bridge structure is preferably formed such that it does not completely occlude the recess in the

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semiconductor material. In this way, when the element of the present invention is used as a thermionic cathode, in an evacuated envelope, a vacuum surrounds the bridge structure reducing conduction of heat from the heated metal layer.

Energy losses due to conduction of heat to the semiconductor substrate are minimised due to the preferred construction of the bridge.

When the element is used as a light-emitting device, it may be enclosed in an evacuated envelope or in an envelope containing a low pressure gas or an inert gas.

The metal layer is preferably nickel or tungsten.

Most preferably when the element is used as a thermionic cathode, the metal layer is provided with a coating capable of reducing the effective thermionic work function of the metal layer.

Preferably, the metal layer of the bridge structure is about 5 microns wide and hence, in order to maintain mechanical stability of the metal layer, the support material must not only be physically strong but must also be capable of remaining mechanically stable at the temperatures required to cause the metal layer to exhibit thermionic emission. Where the metal layer is tungsten, the support layer must remain mechanically stable up to at least 1100 K.

Preferably the semiconductor substrate is silicon. Preferably the support material is silicon dioxide or silicon nitride. These materials may be readily formed in a layer structure using processes known per se in the art. The bridge structure may be formed using the process of anisotropic etching, or chemical milling.

Preferably, the element of the present invention includes integrated circuitry upon the semiconductor substrate. For example when used as a thermionic cathode, the element may have circuit elements for providing cathode drive included on the semiconductor substrate. Similarly, when the element is used as a light emitting device the substrate may include circuitry for providing a current supply to the element.

In a second aspect of the invention, we provide a thermionic valve including a thermionic cathode the thermionic cathode comprising at least one element of the present invention. Most preferably the thermionic valve is a cathode ray tube. The element of the present invention may be made in such a way that its overall size is of the order of 50 microns square and having a very low power consumption. It is therefore of great utility for small size, low power consumption cathode ray tubes.

Preferably, therefore, we provide a display device comprising a thermionic cathode assembly provided with at least one element of the first aspect of the invention a screen coated with a substance capable of converting the kinetic energy of electrons impinging on the screen into light, a grid assembly interposed between the cathode assembly and the screen, and an anode for accelerating electrons from the cathode to the screen.

Preferably the screen is a phosphor screen.

The cathode assembly, grid assembly, screen and anode are enclosed in a vessel at reduced pressure, preferably substantially evacuated.

Preferably the display device is further provided with cathode ray deflection means for deflecting a beam of electrons produced by the

5 cathode to a predetermined point on the phosphor screen. The deflection means may be electromagnetic or electrostatic means, such as those known in the art. In addition one or more focusing anodes may be provided.

10 In this preferred embodiment, the cathode assembly may comprise a single element of the invention, to act as a thermionic cathode in the display device. If required, a number of elements may be closely packed to afford an increased flux density of thermal electrons. Multibeam display devices for use for example in dual beam oscilloscopes and three electron gun colour television tubes may be produced using either two or
15 more cathode assemblies or one cathode assembly provided with suitably spaced elements of the invention.

20 A plurality of elements of the invention may together form a matrix of elements, on a single wafer of semiconductor material. The term "matrix" as used herein refers to a number of elements of the invention arranged in a geometric pattern, preferably as one or more rows and/or columns most preferably linear rows and columns. Such a matrix may be
25 formed using, for example the anisotropic etching process mentioned above.

30 In a third aspect of the invention we provide a display device comprising a thermionic cathode assembly provided with a matrix of elements of the invention, a screen coated with a substance capable of converting the kinetic energy of electrons impinging on the screen into light and an anode for accelerating electrons from the cathode assembly to the screen.

35 Preferably the display device includes a grid

assembly interposed between the screen and the cathode assembly.

Preferably the screen is a phosphor screen.

5 A particular and great advantage of this aspect
of the invention is that a matrix of electron beams
may be produced by a cathode assembly, each element
in the matrix producing thermal electrons which may
be accelerated towards a phosphor screen such that
10 each electron beam thus produced forms a picture
element (pixel) upon the screen. In this way the
need for deflection means is obviated. In
conventional cathode ray tubes the distance from the
cathode to the screen must be sufficiently large for
the deflection applied to the beam to produce a
15 significant displacement of the point at which the
beam impinges upon the screen. This has in the past
limited the reduction in 'front to back' dimensions
of cathode ray tubes. A cathode ray tube of this
embodiment, by negating the need for deflection of
20 the beam provides a tube of greatly reduced 'front to
back' dimension relative to a conventional cathode
ray tube.

Preferably the matrix of elements forming the
cathode assembly is arranged such that each element
25 in the matrix is provided with an independent current
flow. For example, the matrix of elements may be
addressed by a digital logic circuit and suitable
drive circuits. The drive circuits cause a current
to flow through each addressed element thereby
30 heating the element by means of resistance heating.
The hot element, acting as a thermionic cathode, will
then emit thermal electrons which may be accelerated
towards the phosphor screen, past the grid. The grid
is, in this embodiment, preferably provided with an
35 even potential over its surface. Therefore light

produced by electrons impinging upon the phosphor screen will be produced in a matrix of pixels corresponding to the elements which are addressed. An image may therefore be built up by addressing those elements in the cathode assembly which correspond to the pixels it is desired to produce on the phosphor screen. The low thermal mass of the individual elements in the cathode assembly ensures that the individual cathodes heat up and cool down very rapidly thereby allowing a rapid change in the image produced on the phosphor screen. The intensity of each pixel produced on the phosphor screen may be controlled by adjusting the current supplied to the relevant element in the cathode assembly. Preferably however the intensity of each pixel is adjusted by adjusting the potential difference between the grid and the cathode assembly. Colour images may be built up by providing a matrix of different phosphors on the phosphor screen. For example adjacent elements in the cathode assembly may correspond to phosphors producing red, green or blue light in response to energy supplied by impinging electrons.

Preferably the matrix of elements is addressed such that each element in a row of the matrix is supplied with an equal current flow and the grid assembly comprises a number of independent grid elements each corresponding to a column of the elements forming the cathode assembly. Each grid element may be addressed separately such that the combined effect of addressing the elements in rows of the cathode assembly and the grid elements in columns of the grid assembly provides a method of selecting, for example, the intensity of each point produced by the matrix of elements. The terms row and column are of course interchangeable in respect of the cathode assembly drive and the grid assembly drive.

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5 In a further preferred embodiment, each element in the cathode assembly is provided with substantially equal current flow, the grid assembly forming a matrix of grid elements, to each element of which may be applied an independent bias potential. Each grid element corresponds to a thermionic cathode in the cathode assembly, whereby by addressing the grid, e.g. using digital circuitry and, if necessary, drive circuits, the kinetic energy of electrons produced by each cathode in the cathode assembly may be individually adjusted thereby adjusting the intensity of light produced on the phosphor screen.

10 The display devices may be used in for example so called flat screen televisions or alphanumeric displays.

15 In a fourth aspect of the invention we provide a display device comprising one or more light emitting devices the or each light emitting device consisting of an element of the first aspect of the invention. Preferably the display device comprises a plurality of light emitting devices most preferably arranged to provide a matrix of light emitting devices. Preferably the light emitting devices are enclosed in a suitable envelope. A suitable envelope may include for example an evacuated envelope or an envelope having an inert atmosphere.

20 Individual light emitting devices in the matrix may be addressed using, for example, digital circuitry and drive circuitry. The light emission from each light emitting device may be controlled by the current passed to each device. Each device has a low thermal mass which allows modulation of the emitted light intensity at a relatively high frequency. The display device may be provided with a screen of colour filters thereby allowing a coloured

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image to be produced. A matrix may be used for example to produce a flat screen television or an alphanumeric display.

5 The various aspects of this invention are now described, by way of example, with reference to the accompanying drawings, in which:-

Figure 1 is a plan view of one embodiment of a single element of the invention,

10 Figure 2 is a section on the line A-A of Figure 1,

Figure 3 is a plan view of a second embodiment of a single element of the invention,

Figure 4 is a section on the line B-B of Figure 3,

15 Figure 5 is a plan view of a third embodiment of a single element of the invention,

Figure 6 is a side elevation of a thermionic cathode in combination with a control grid assembly,

20 Figure 7 is a schematic isometric view of a display device of the third aspect of the invention,

Figure 8 is a schematic isometric view of a further embodiment of a display device of the third aspect of the invention, and

25 Figure 9 is a schematic isometric view of yet a further embodiment of a display device of the third aspect of the invention.

30 Referring to the simple embodiment of the invention shown in Figures 1 and 2, a silicon substrate 1 provides mechanical support for the element, which may be a cathode or a light emitting device. The substrate is of a type now well known in the electronics industry as a semiconductor substrate upon which integrated circuits are constructed. The
35 silicon substrate 1 is provided with a recess 3 in

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the form of a depression etched into the surface of the substrate by anisotropic etching. A layer of silicon dioxide (or silicon nitride) 5 overlies the surface of the silicon and is so shaped as to form a narrow bridge 7 over the recess 3. A layer of tungsten metal 9 lies over the silicon dioxide layer such that the cross sectional area of the layer is at its lowest in that part of the layer overlying the silicon dioxide layer forming the bridge 7. This ensures that the maximum resistive heating of the metal layer is concentrated in the bridge region.

The layer of silicon dioxide (or silicon nitride) 5 shown in Figure 1 is shaped to correspond to the shape of the layer of tungsten metal 9. In practice the silicon dioxide layer may cover the surface of the silicon substrate 1 except for regions adjacent the bridge structure, which allow communication between the recess 3 and the surroundings.

In use, the element, if it is to be a thermionic cathode, is placed within an evacuated envelope and a current is passed through the metal layer 9. Resistive heating of the metal layer in the bridge area occurs and the metal is heated to a temperature sufficient to cause thermionic emission. This will typically be 1100 K for a tungsten conductor or 900 K for a carbonate coated tungsten conductor. The recess 3 reduces the loss of energy by conduction into the substrate and the low cross sectional area made possible by the supported conductor, reduces conduction and consequent heat loss through the conductor itself.

Figures 3 and 4 show a second embodiment of the first aspect of the invention in which the techniques of anisotropic etching have been used to form a

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silicon substrate 11, provided with a recess 13. A layer of silicon dioxide (or silicon nitride) 15 overlies the silicon substrate forming a bridge 17 over the recess 13 such that the recess is not completely enclosed. A conductor 19 of tungsten has been deposited upon the silicon dioxide (or silicon nitride) layer and has been etched to provide a narrow sinuous conductor portion 21 on the bridge 17. In this embodiment, the recess is square in plan with an edge measuring about 50 microns. The narrow conductor portion has a width of about 5 microns. The advantage of an etched conductor pattern of this type is that the operating voltage of the element can be tailored to a convenient value.

Figure 5 shows a third embodiment of the first aspect of the invention. The third embodiment comprises a silicon substrate provided with a recess (these being substantially as described above). The silicon substrate is overlain with a support layer 75 of silicon dioxide or silicon nitride. The support layer 75 is provided with apertures 77 communicating with the recess formed in the silicon substrate, such that a suspended region 79 of the support layer 75 is formed. The region 79 is suspended above the recess by four arms 81, 83, 85 and 87 formed of the support layer 75. A conductor 89 has been deposited upon the support layer 75 and has been etched to provide a relatively narrow, sinuous conductor portion 91 on the suspended region 79 of the support layer 75. Electrical connection to the conductor portion 91 is made by way of connector portions 93 and 95 passing over arms 81 and 83 respectively. Connector portions 93 and 95 pass over opposed arms 81 and 83 in order to reduce mechanical distortion which may otherwise occur during resistive heating of conductor portion 91. Arms 85 and 87 may be provided with dummy strips

97 and 99 (shown in broken line outline) of the same material as the connector portions 93 and 95 in order further to reduce possible mechanical distortion. It will be appreciated that connector portions 93 and 95 could pass over different arms from those shown, and that the number of arms may be different, although at least three should be provided for adequate support.

Figure 6 shows a thermionic cathode of the present invention (shown generally at 25) in combination with a control grid assembly (shown generally at 27) and exemplifies a possible mounting technique for the thermionic cathode of the present invention. The control grid assembly 27 comprises a ceramic plate 29 having a metal coating on its front and rear faces. The ceramic plate 29 is provided with an aperture 31 passing through both the plate and metal coatings, perpendicular to the general plane of the plate. The thermionic cathode 25 is provided with electrically conductive protusions 33, e.g. of solder or conductive paste, which can be used to connect the thermionic cathode 25 to the grid assembly 27 and which make electrical contact between the metal layer of the thermionic cathode 35 and the rear metal coated face 37 of the grid assembly 27. The rear metal coated face 37 of the grid assembly 27 therefore is at the same potential as the thermionic cathode in use. The thermionic cathode 25 is aligned such that, in use, electrons emitted by the thermionic cathode pass through the aperture 31 under the influence of a positive potential provided by an anode (not shown). The front metal coated face 39 of the grid assembly 27 forms a control grid which may be used to alter the flow of electrons from the cathode. In use, the front metal coated face 39 would normally be negatively biased with respect to

the cathode. The advantage of this mounting system is that the cathode and grid are maintained at a fixed spacing and alignment. This has attendant advantages not only in terms of the mechanical strength of the arrangement but also in terms of ease of manufacture.

Referring to Figure 7 there is depicted a display device of the invention. The display device comprises a cathode assembly 39, a phosphor screen 41, and a grid assembly 43 interposed between the cathode assembly 39 and the phosphor screen 41.

The cathode assembly 39 comprises a silicon substrate 45 upon which is formed a plurality of elements of the invention (for example 47). Each element of the invention acts as a thermionic cathode. The thermionic cathodes 47 are arranged in an array or matrix. The matrix depicted in Figure 7 has only nine rows and twelve columns for the purpose of ready illustration. In practice the matrix may possess a large number of rows and columns limited only by physical constraints of manufacture.

The grid assembly 43 comprises a perforate plate. The construction of the grid assembly is as shown in Figure 6, an insulating plate being provided with a metal coating (not shown) on its front and rear faces. The grid assembly is provided with a plurality of grid apertures (for example 49) capable of allowing passage of electrons. Each aperture 49 in the grid assembly 43 corresponds spatially with a thermionic cathode 47 in an equivalent row and column in the cathode assembly 39.

The phosphor screen 41 comprises a transparent support material, to the side facing the grid assembly of which is affixed a coating of a phosphor material capable of converting electron kinetic energy into

visible light. The phosphor coating is either of one type, capable of generating the same colour of visible light over the surface of the phosphor screen 41 or is comprised of regions of a number of different phosphors each different phosphor being capable of generating a different colour of visible light. Such phosphor screens are well known in the art and are therefore not further described.

The cathode assembly 39, the grid assembly 43 and the phosphor screen 41 are enclosed in an evacuated envelope (not shown). The envelope also encloses an accelerating anode (not shown) disposed between the grid assembly 43 and the phosphor screen 41. The phosphor screen 41 may form part of the envelope. The transparent support material of the phosphor screen may comprise a transparent electrically conducting material and may form the accelerating anode. A suitable material is, for example, a coating of tin oxide.

In use, the accelerating anode is maintained at high positive potential relative to the cathode assembly 39. Each thermionic cathode 47 in the cathode assembly 39 is capable of being separately supplied with an electrical current by means of address logic and drive circuitry which may be located outside the envelope or may be included within the envelope, for example, upon the silicon substrate 45 of the cathode assembly. When a current is passed through the thermionic cathodes 47, they are heated to a temperature at which thermionic emission of electrons occurs. The electrons are accelerated away from the cathode assembly 39 by the high positive potential of the accelerating anode. Electrons produced by each thermionic cathode 47 pass through the corresponding aperture 49 in the grid

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assembly 43 and onwards to the phosphor screen 41 where their kinetic energy is converted into visible light by the phosphor. In this way each thermionic cathode 47 when supplied with current produces a point of light on the phosphor screen 41, each point of light forming a picture element or pixel of an image to be formed on the phosphor screen 41. An image may therefore be produced on the phosphor screen 41 by selectively addressing and supplying current to those thermionic cathodes in the cathode assembly 39 corresponding to the desired pixels of the image. The intensity of each pixel may be individually altered by varying the voltage between the grid 43 and the selected thermionic cathode. For example the thermionic cathodes may be sequentially addressed and a synchronous video signal may be applied to the grid to produce a picture. The thermionic cathodes are about 5 microns across and may be spaced as little as 10 microns apart. In this way a high definition image may be produced on the phosphor screen 41. Suitably the display device of the invention may be used to display a rapidly changing, high definition image, for example a television picture.

In the schematic arrangement depicted in Figure 7 considerable spacing of the cathode assembly 39, the grid assembly 43 and the phosphor screen 41 is shown. In practice the cathode assembly 39 and the grid assembly 43 are in close proximity and may be in actual physical contact as depicted for one thermionic cathode and one grid assembly in Figure 6. The grid assembly 43 and the phosphor screen 41 are separated. However in order to minimise the cross sectional area of the pixels formed upon the phosphor screen 41 it is desirable to reduce the

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distance between the cathode assembly 39 and the phosphor screen 41 as much as possible. The electron beam produced by each thermionic cathode will tend to spread as it passes from the cathode assembly 39 to the phosphor screen 41 and it is desirable to obviate the need for separate focussing anodes if possible although they may be included if necessary. The grid assembly 43 tends to reduce the cross sectional area of each electron beam. If however the cathode assembly and the phosphor screen are close together the requirement for a grid assembly may be obviated. Such a construction may be preferred for alphanumeric displays.

Referring now to Figure 8 there is depicted a further embodiment of the display device of the invention. In general arrangement this embodiment resembles the display device described above with reference to Figure 7. The display device again comprises a cathode assembly 51, a phosphor screen 53 and a grid assembly 55 interposed between the cathode assembly 51 and the phosphor screen 53. Differences arise however in the addressing of the thermionic cathodes 57 of the cathode assembly 51 and in the construction of the grid assembly 55. The remaining common features are as described above with reference to Figure 7. In the embodiment of Figure 8 each row of thermionic cathodes 57 is linked such that in use the same current flows in each thermionic cathode of a row. The grid assembly 55 comprises a number of electrically separate grid elements 59 each grid element 59 being common for a column of grid apertures 61. Each row of thermionic cathodes in use is separately supplied with an electrical current by means of address logic and drive circuitry. Each grid element 59 may be separately supplied with an

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electrical potential. By supplying current successively to each row of thermionic cathodes 57 and appropriate bias to each grid element 59 a scanned image may be formed upon the phosphor screen 53. The intensity of each pixel forming the image may be adjusted by varying either the current passing through each row of thermionic cathodes 57 or preferably by varying the negative potential applied to each grid element 59. In a particular embodiment the display device is used to produce a television picture, the grid elements 59 being scanned at line scan speed, the rows of thermionic cathodes being scanned at frame scan speed, pixel intensity being varied by the value of negative potential applied to each grid element 59.

Referring now to Figure 9 there is depicted a further embodiment of the display device of the invention. In general arrangement this embodiment resembles the display device described above with reference to Figure 7. The display device again comprises a cathode assembly 63, a phosphor screen 65 and a grid assembly 67 interposed between the cathode assembly 63 and the phosphor screen 65. Differences arise however in the addressing of the thermionic cathodes 69 of the cathode assembly 63 and in the construction of the grid assembly 67. The remaining common features are as described above with reference to Figure 7. In the embodiment of Figure 9 in use each thermionic cathode 69 is provided with the same current flow such that each thermionic cathode produces substantially the same flux of thermal electrons. The grid assembly 67 comprises a number of electrically separate grid elements 71 each grid element 71 being associated with a single grid aperture 73. Each grid element 71 may be separately

supplied with an electrical potential by means of address logic and if necessary suitable drive circuitry. In this way the intensity of each pixel formed on the phosphor screen 65 may be independently varied by varying the negative potential applied to each grid element 71.

In a final embodiment, the elements of the invention are employed as individual light emitting devices. A direct display device of the fourth aspect of the invention comprises a matrix of elements of the invention resembling for example the structure shown generally at 39 in Figure 7. The matrix of light emitting devices is enclosed in a suitable envelope filled with a low pressure inert gas and provided with a transparent window in front of the matrix. The individual light emitting devices comprising the matrix may be separately supplied with an electrical current by suitable address logic and drive circuits. The intensity of light produced by each light emitting device may thereby be independently varied such that an image may be produced by the composite light emitting devices forming the matrix. The preferred method of forming each light emitting device is anisotropic etching as described above. This advantageously provides a mirror surface behind each light emitting device reflecting most of the light produced by the incandescent element in a forward direction. The low thermal mass of light emitting devices of the invention allows for a rapid modulation of the light intensity of the devices. This enables a rapidly changing image to be produced by the direct display device. Line and frame storage techniques may also be used to reduce the number of and/or speed of switching cycles for the light emitting devices.

The direct display device may therefore be useful as a display for a television picture. A coloured display may be produced by providing colour filters in or on the window of the direct display device.

- 5 In all of the above described aspects and embodiments of this invention, the bridge structure over the recess etched in the silicon substrate has comprised a support layer (e.g. of silicon dioxide or silicon nitride) which supports the metal layer. In a modified
- 10 construction, it is possible to dispense with the support layer by completely etching it away in the area of the recess. Such a modified construction could be used for simple cathode structures, especially if they are used to produce incandescent devices.

CLAIMS:

1. An element for use as a thermionic cathode and/or a light emitting device comprising a semiconductor substrate (1), a metal layer (9) and a support layer (5) interposed between the semiconductor substrate (1) and the metal layer (9), wherein the semiconductor substrate (1) is provided with a recess (3) across which recess extends a bridge structure (7) comprising the support layer (5) and/or the metal layer (9).
2. An element according to claim 1 wherein the bridge structure (7) is in the form of a narrow linear strip of the metal layer (9) attached to a support layer of similar shape.
3. An element according to claim 1 wherein the bridge structure comprises a broad band (17) of support material to which is attached a metal layer in the form of a sinuous strip (21).
4. An element according to claim 1 wherein the bridge structure comprises a region of support material (79) having attached thereto a metal layer (19) in the form of a sinuous strip (91), the region of support material overlying the recess (77) and being supported by three or more support arms (81, 83, 85 or 87).
5. An element according to any one of claims 1-4 wherein the bridge structure (7) is formed such that it does not completely occlude the recess (3) in the semiconductor material (1).
6. An element according to any one of claims 1-5, said element being enclosed in an evacuated envelope.
7. An element according to any one of claims 1-5, said element being enclosed in an envelope containing a low pressure gas or an inert gas.
8. An element according to any one of the preceding claims, wherein the metal layer is nickel or tungsten.
9. An element according to any one of the

preceding claims wherein the metal layer is provided with a coating capable of reducing the effective thermionic work function of the metal layer.

10. An element according to any one of the preceding claims wherein the metal layer of the bridge structure is about 5 microns wide.

11. An element according to any one of the preceding claims wherein the support layer is such as to remain mechanically stable up to at least 1100 K.

12. An element according to any one of the preceding claims wherein the semiconductor substrate (1) is silicon.

13. An element according to any one of the preceding claims wherein the support material is silicon dioxide or silicon nitride (15).

14. An element according to any one of the preceding claims and including integrated circuitry upon the semiconductor substrate.

15. A thermionic valve including a thermionic cathode (25) which comprises at least one element as claimed in any one of claims 1-14.

16. A thermionic valve as claimed in claim 15 and which comprises a cathode ray tube.

17. A display device comprising a thermionic cathode assembly (25) provided with at least one element as claimed in any one of claims 1-14, a screen (not shown) coated with a substance capable of converting the kinetic energy of electrons impinging on the screen into light, a grid assembly (27) interposed between the cathode assembly (25) and the screen, and an anode (not shown) for accelerating electrons from the cathode to the screen.

18. A display device according to claim 17 wherein the screen is a phosphor screen.

19. A display device according to claim 17 or 18 wherein the cathode assembly, grid assembly, screen and anode are enclosed in a vessel at reduced

pressure.

20. A display device according to claim 17, 18 or 19 which is further provided with cathode ray deflection means for deflecting a beam of electrons produced by the cathode to a predetermined point on the phosphor screen.

21. A display device according to claim 20 wherein the deflection means comprises electro-magnetic or electrostatic means.

22. A display device according to any one of claims 17-21 wherein one or more focusing anodes is/are provided.

23. A display device according to any one of claims 17-22 wherein the cathode assembly has a number of elements (47) as claimed in any one of claims 1-14 which are closely packed to afford an increased flux density of thermal electrons.

24. A display device comprising a thermionic cathode assembly (39) provided with a matrix of elements (47) as claimed in any one of claims 1-14 formed on a single wafer of semiconductor material (45), a screen (41) coated with a substance capable of converting the kinetic energy of electrons impinging on the screen into light and an anode (not shown) for accelerating electrons from the cathode assembly (39) to the screen (41).

25. A display device according to claim 24 which further includes a grid assembly (43) interposed between the screen (41) and the cathode assembly (39).

26. A display device according to claim 25 wherein the screen is a phosphor screen.

27. A display device according to claim 24, 25 or 26 wherein the matrix of elements (47) forming the cathode assembly (39) is arranged such that each element in the matrix is provided with an independent current flow.

28. A display device according to claim 27 wherein the matrix of elements (47) is addressed

by a digital logic circuit and suitable drive circuits, whereby the drive circuits cause a current to flow through each addressed element thereby heating the element by means of resistance heating, so that each hot element acts as a thermionic cathode and emits thermal electrons which may be accelerated towards the phosphor screen (41) past the grid (43).

29. A display device according to claim 28 wherein the grid (43) is provided with an even potential over its surface so that light produced by electrons impinging upon the phosphor screen (41) will be produced in a matrix of pixels corresponding to the elements which are addressed.

30. A display device according to claim 29 wherein the intensity of each pixel produced on the phosphor screen (41) is controlled by adjusting the current supplied to the relevant element (47) in the cathode assembly (39).

31. A display device according to claim 29 wherein the intensity of each pixel is adjusted by adjusting the potential difference between the grid (49) and the cathode assembly (39).

32. A display device according to any one of claims 24-31 wherein colour images may be built up by providing a matrix of different phosphors on the screen.

33. A display device according to claim 24, 25, 26 or 27 wherein the matrix (51) of elements (57) is addressed such that each element (57) in a row of the matrix is supplied with an equal current flow and the grid assembly comprises a number of independent grid elements (59) each corresponding to a column of the elements forming the cathode assembly (51).

34. A display device according to claim 33 wherein each grid element (59) is addressed separately such that the combined effect of addressing the elements (57) in rows of the cathode assembly (51) and the grid elements (59) in columns of the grid assembly

(55) provides a method of selecting, for example, the intensity of each point produced by the matrix (51) of elements (57).

35. A display device according to claim 24,25,26 or 27
5 wherein each element (69) in the cathode assembly (63) is provided with substantially equal current flow, the grid assembly (67) forming a matrix of grid elements (71), to each element of which is applied an independent bias potential, the arrangement being
10 such that each grid element corresponds to a thermionic cathode in the cathode assembly, whereby by addressing the grid (67) the kinetic energy of electrons produced by each cathode in the cathode assembly may be individually adjusted thereby adjusting the intensity of light
15 produced on the phosphor screen (65).

36. A display device comprising one or more light emitting devices, the or each light emitting device consisting of an element as claimed in any one of claims 1-14.

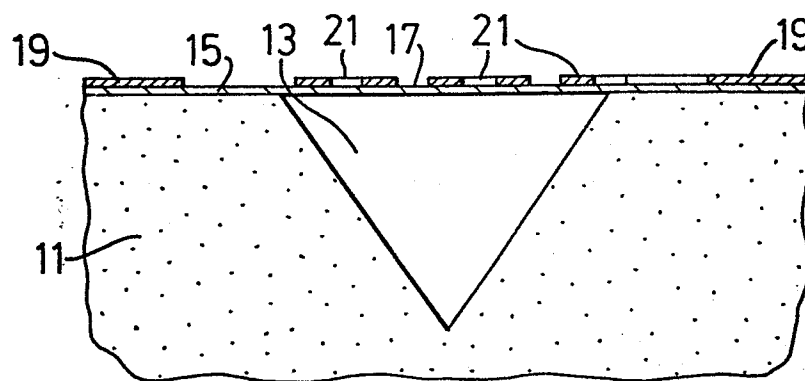
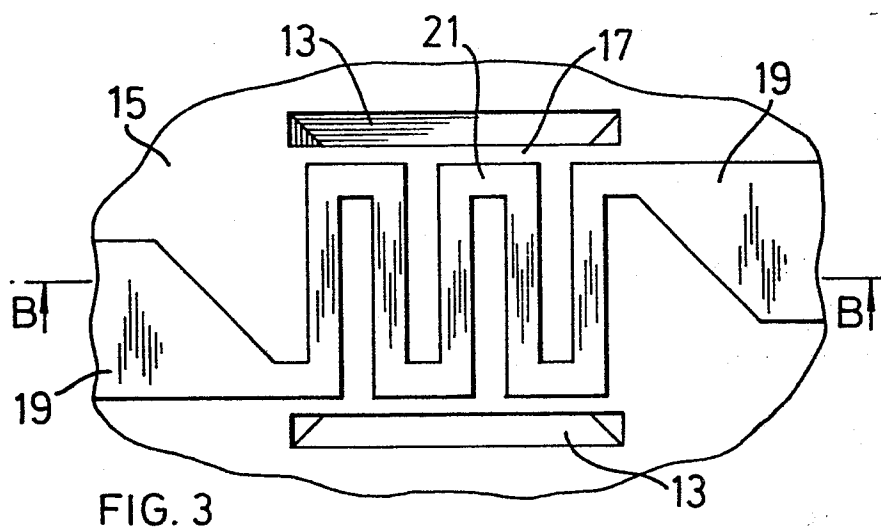
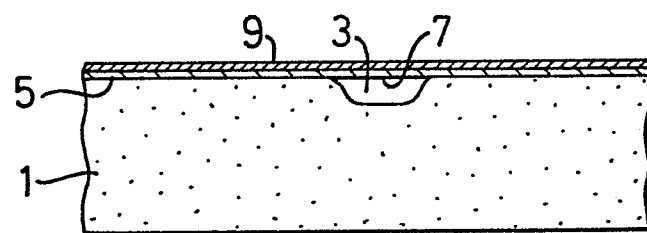
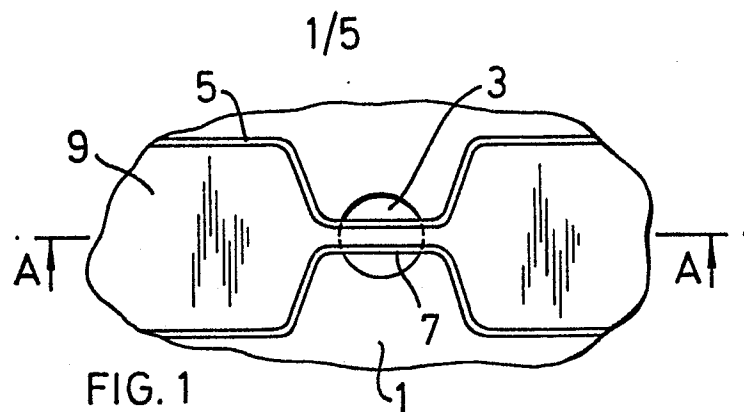
20 37. A display device according to claim 36 which further comprises a plurality of light emitting devices arranged to provide a matrix.

38. A display device according to claim 37 wherein the light emitting devices are enclosed
25 in a suitable envelope which is evacuated or has an inert atmosphere.

39. A display device according to claim 37 or 38 wherein individual light emitting devices in the matrix are addressed using digital circuitry
30 and drive circuitry.

40. A display device according to claim 37, 38 or 39 wherein the light emission from each light emitting device is controlled by the current passed to each device.

35 41. A display device according to any one of claims 37-40 which is provided with a screen of colour filters thereby allowing a coloured image to be produced.



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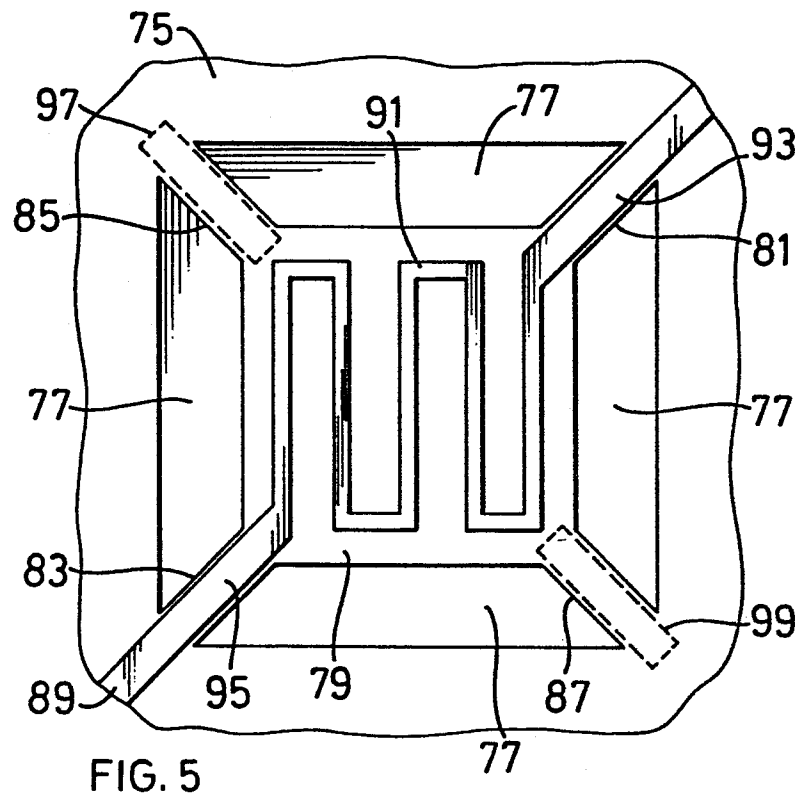


FIG. 5

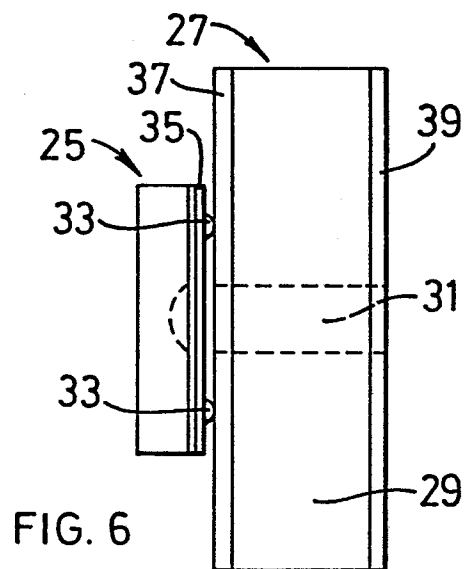


FIG. 6

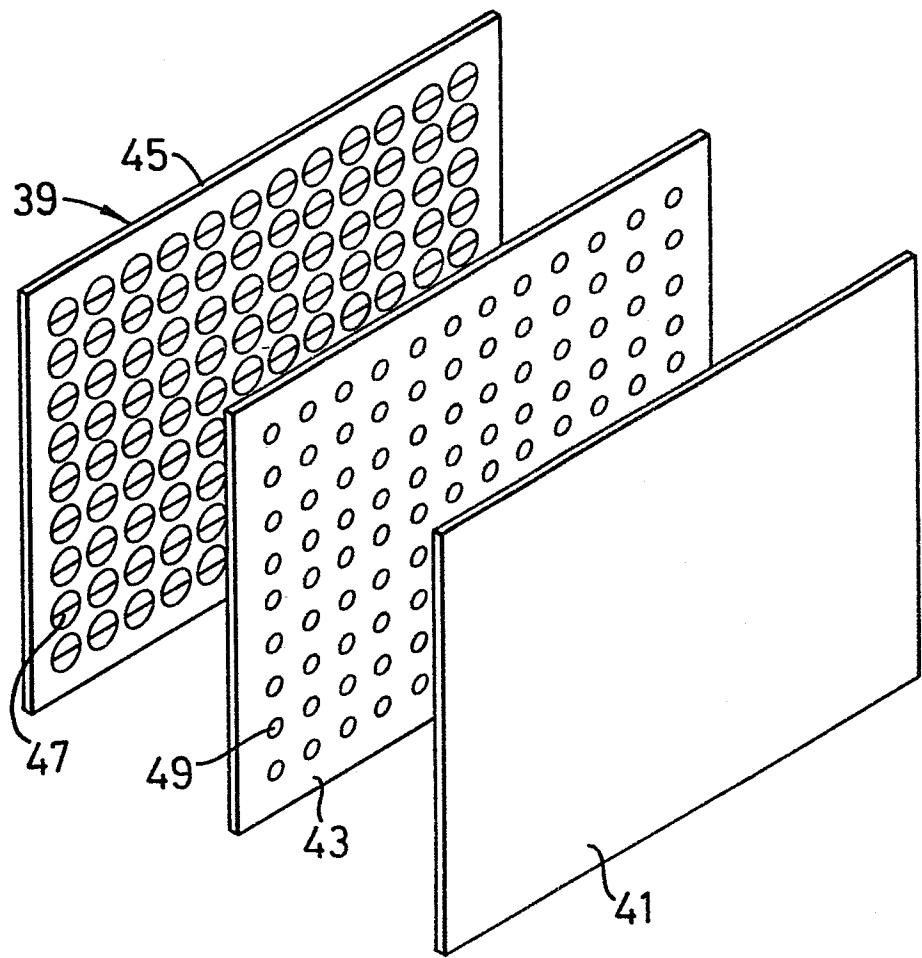


FIG. 7

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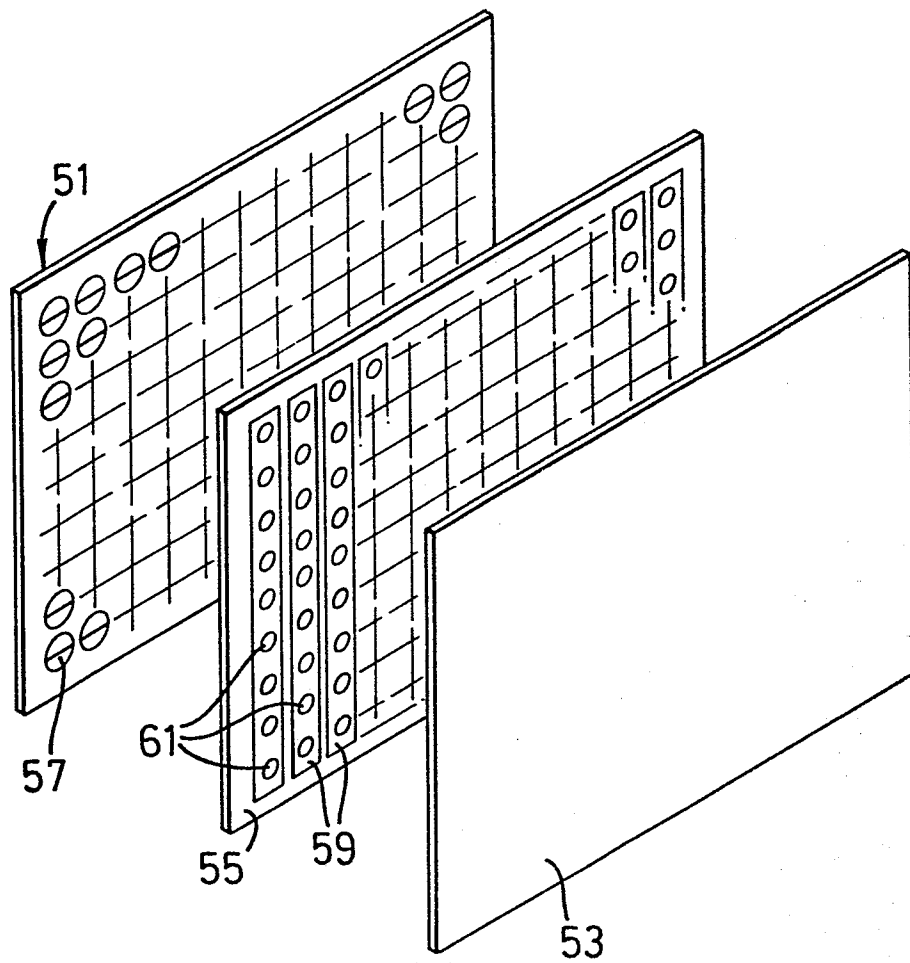


FIG. 8

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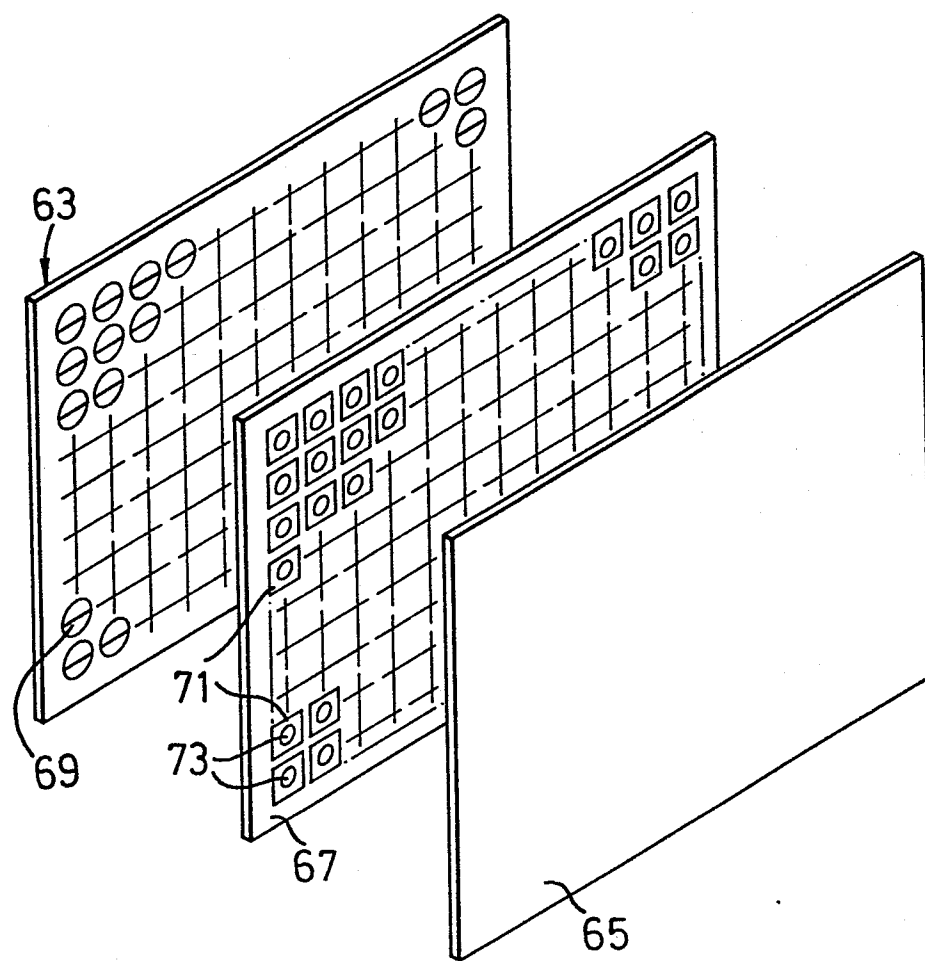


FIG. 9



European Patent
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EUROPEAN SEARCH REPORT

0125859

Application number

EP 84 30 3057

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. ³)
A	PATENTS ABSTRACTS OF JAPAN, vol. 7, no. 72 (E-166)[1217], 25th March 1983; & JP - A - 58 1956 (TOKYO SHIBAURA DENKI K.K.) 07-01-1983	1-3, 5, 8	H 01 J 1/14 H 01 J 29/04 H 01 K 7/00 H 01 K 1/02
A	EP-A-0 025 221 (TOKYO SHIBAURA)	1	
A	US-A-4 020 381 (OESS et al.)	1	
A	FR-A-2 134 361 (IBM) * Page 1, lines 1-10; page 2, line 37 - page 3, line 16; page 4, line 1 - page 6, line 10; figures *	1, 36-39	
			TECHNICAL FIELDS SEARCHED (Int. Cl. ³)
			H 01 J 1 H 01 J 29 H 01 J 31 H 01 K 1 H 01 K 3 H 01 K 7 H 01 K 9
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 08-08-1984	Examiner SCHAUB G.G.
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			