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(54) Field emission device.

(57) A device is disclosed which produces high current, low noise, low lateral energy, stochastic electron emission from a multiplicity of insulative particles subjected to a field. The insulative particles are in and of a surface thickness comprised of a random mixture of insulative and conductive particles in ohmic contact. Emission is achieved at applied potentials of about 5 volts which produce a field sufficient to emit electron currents of nanoamperes to milliamperes. Single devices or arrays of devices may be batch fabricated. each device has an integral, implicitly self-aligned electron optic system comprising means for modulating, focusing and deflecting the formed current beam, and means shielding the device from ambient magnetic fields.

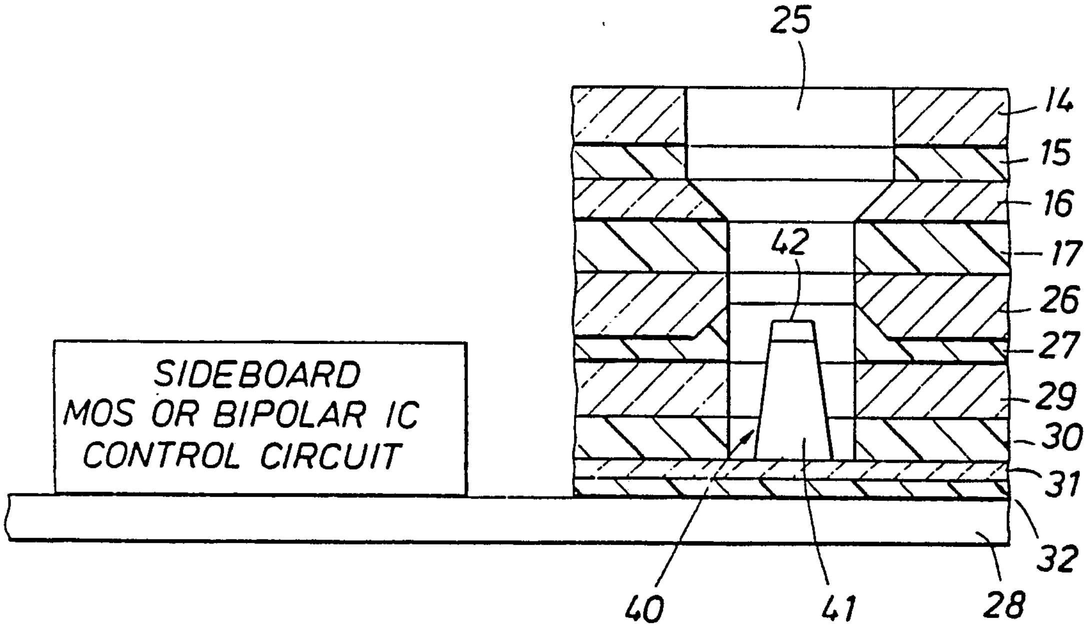


FIG. 2

FIELD EMISSION DEVICE

BACKGROUND OF THE DISCLOSURE

This disclosure sets forth a cold, field emission low noise microampere current from 5 × 10^8 volts/meter field, commonly available at a nominal value of 5 volts. Emission is across the less than 1 ev barrier from the conduction band of a multiplicity of insulator particles in ohmic contact with conductor particle. The insulator particles emit in a stochastic manner, increasing the current-plus-noise to noise ratio by at least 20 decibels over the prior art devices. In a cold field emission device, insulator and conductor particles are randomly deposited to about 200°A thickness to form the a conical tip having a conductive base. The insulator work function is greater than the conductor work function which difference defines ohmic contact between the materials. In the band diagram of ohmic contact, the Fermi levels of the materials must align and the vacuum level must be continuous. In non-ohmic, barrier, contact between materials, the vacuum level has a discontinuity, a barrier where height is the difference in work function. An insulator conduction band is normally empty. In ohmic contact, to maintain charge neutrality and not produce a source of energy because of the work function difference, equilibrium requires the conductive particles to inject electrons into the insulative particles conduction band. The barrier to emission of electrons from the conduction band is the electron affinity (conduction band width) of the insulator material, typically 1 ev or less. Those injected free electrons in the insulator conduction band have a Fermi-Dirac distribution, with most free electrons near the conduction band bottom.

The electrode tip is surrounded by a positive extractor electrode, a ring-like elevated conductive structure. The base of the conical structure is grounded. The extractor electrode field acts on the electrode tip. Since the insulator particles are made protruberances of the surface, the field around each insulator particle is enhanced as in the case of a whisker.

The field is sufficient to cause insulator particles, in and of the surface of the tip, to emit electrons over the 1 ev or less barrier into vacuum. This field is not sufficient to cause growth of other (unwanted) protruberances. Equilibrium requires the conductor particle(s) in ohmic contact to supply replacement electrons. Each insulator particle stochastically randomly emits electrons. Extractor potentials of about 3.5 volts to 8.5 volts produce nanoamperes to milliamperes current depending on scale factors. The energy and velocity of the emitted electrons are low. The structure disclosed includes means to shield the electrons from ambient magnetic fields.

The volume of the structure accessible to the adjacent vacuum space, say, in the range of 10 microtorr vacuum, is such that not more than 3 gas molecules are randomly located in the cavity defined by the structure. The potentials between elements are less than the ionizing potential of residual or diffusing gases. Thus, the gas molecules in the cavity are neither ionized nor create a significant collision scattering of the beam. Random gas molecule location provides minimal beam scattering.

One typical structure includes: the emitting surface of insulative particles in ohmic contact with conductive particles; a conical base of the conductive material supporting the emitting surface; an apertured permanent magnet surrounding the conical base; an apertured element centered upon and surrounding the emitting surface to provide the field potential and means for modulating the emitted electron current; electrostatic lense elements to focus the electrons into a beam; and, orthogonal elements to deflect the electron beam. The structure is batch manufactured in a semiconductor type process. Several thousand can be formed on a silicon wafer substrate. Accordingly, the term "microgun" is applied to the completed assembly supported on a substrate. One method of fabrication is described in U.S. Patent 4,498,952 dated February 12, 1985.

The preferred insulative particles are beryllia of work function 4.7 ev, or carefully prepared silica of work function 5 ev. The preferred conductive particles are refractory compounds trichromium monosilicide of work function 2.58 ev, or tantalum nitride or work function 2.17 ev. Since the emitting surface is a mixture of refractory conductor particles in ohmic contact with refractory oxide particles, the mixture is a specifically defined cermet. One target for the electron beam is the memory device in U.S. Patent 4,213,192 of the present inventor.

Underlying Physical Principles of Operation of the Disclosed Field Emission Devices

Emission of electrons is produced by imposing a field on randomly mixed insulative particles of the cermet surface of insulative and conductive particles. The cermet pyramid or conic tip is above a lower portion of more conductive material. Accordingly, the pyramid three regions; the lowermost region is the region is adhered to the supportive conductive substrate. The central region is formed of conductive material. The tip insulative and conductive particles are in ohmic contact with adjacent particles. The work function of the insulator exceeds the work function of the conductive particles to define ohmic contact. Since ohmic contact exists, 1) the Fermi and vacuum levels of the two materials align at the contacting surface; 2) electrons are injected from conductor into the conduction band of the insulator and fully accumulate the insulator conduction band; 3) the remaining barrier for emission into the vacuum is at most the width of the conduction band, also called the "electron affinity" of the insulator and is less than 1 ev; 4) the application of a field to the insulative particles causes further injection of electrons and lowers the barrier to emission; 5) the barrier to emission is less than the Heisenberg uncertainty in the position of electrons in the conduction band, thus electrons can leave the conduction band into vacuum.

The geometry comprises an upstanding pointed tip surrounded by a conductive first anode aperture insulated from and spaced above the conductive substrate which supports the pyramid. The substrate may be any insulating surface, or may be N+ doped semiconductor material. Positive potential at the first anode with the substrate at negative or ground forms, a field on the tip insulative particles to initiate electron emission assuming adequate field strength. The bulk electron flow from the substrate through the pyramid tip fills electron traps. Moreover, the electrons flow through the conductive particles and the ohmic contacts with the insulative particles to initiate electron flow in the conduction band of the insulative particles. The field acting upon the conductive particles undergoes Schottky barrier lowering to enable continual and constant tunneling and flow of electrons through the conductive band into vacuum, the process occurring at a high level of probability. The barrier which is lowered by the field strength of sufficient amplitude is the width of the insulative particles conductive band, namely, the electron affinity of the insulative material, typically less than 1.0 ev before Schottky lowering. The field required to fill all traps such that additional field thereabove initiates electron flow in the insulative particles (in the conduction band thereof) is given by Simmons, Journal of Physics, vol. 4, 1971, p. 641, which states:

$$(1) \qquad F_0 = \frac{q\ N\ L}{2\ ee_o} \text{ in volts/meters} = 3.2 \text{ x } 10^7 \text{ V/M}$$

where

F_0 = field required to fill all traps;
q = the electron charge;
N = the number of traps per cubic meter;
L = the average conductive dimension of insulative particles; and
ee_0 = is the permittivity of the insulative particles.

Typical values for these parameters are:

N = 1×10^{25} traps per cubic meter;
L = 35×10^{-10} m; and
$ee_0 = 9.65 \times 10^{-11}$ F/m.

Once the field is exceeded, electron flow is in the conduction band of the insulative particles. The current density of the electron flow for an applied field F which exceeds the trap filled field F_0 by an amount $Fi = Fa - F_0$, is calculated for one insulative particle having a conductive dimension L according to O'Reilly, Solid State Electronics, vol. 18, 1975, p. 965, which equation has both an ohmic term and a space-charge limited term.

(2) $Js = s\,V/L + 9/8\,(ee_0)\,V^2/L^3$

where

Js = current density in amperes/square meters;
Js = the electron mobility in the insulative particle = 3×10^5 m²/v sec for silica, and 3×10^4 m²/v sec for beryllia;
s = the conductivity;
s = electron diffusion coefficient of 1.4;

ee_0 = permittivity of the insulative particle = 3.8×10^{-11} F/m for silica, and 5.6×10^{-11} F/m for beryllia;
Fi = the effective field strength in volts per meter = 5×10^8 V/m;
V = voltage acting on an insulative particle; and
L = the average conductive dimension of the insulative particle.

The ohmic first term of equation (2) is much smaller than the second or conduction term, and therefore the first term may be neglected. Using the values represented above and 3.5 nanometer for L, the maximum source current density for a single silica particle is 2.48×10^{11} amperes/m^2, and for beryllia particle 1.89×10^{10} amperes/m^2.

Field emission is expressed as the product of the source current density Js, equation (2), and the probability of emission P. The expression for P in the literature is:

(3) $P = \exp [(-B/Fi)\ Ø^{1.5}\ Vy]$

where

B is a quantum mechanical constant = 6.83×10^9m ev
Ø = the barrier to emission, 1 ev for silica, and 0.85 ev for beryllia;
Vy = the non-dimensional Schottky barrier lowering function, a function of the elliptical function Y; and
$Y = 1.44 \times 10^{-9}\ Fi/Ø^2$.

In cold field emission, the maximum value of Y is 1.0, and at Y = 1.0, one has Vy = 0.0 and P = 1.0. Significant cold field emission is obtained when Y is greater than 0.6. In the present case, the total emitted current density is:

(4) $Je = N * Js * P$ in a/m^2

where N is the number of emitting insulator particles. Each emitting particle yields a current approximately that of one whisker of the prior art.

With representative 250 insulator particles emitting with average L = 3.5 nanometer, present and prior art emitters at the same geometry and an equal emitted current density are compared in the Table below. The emitted current density used for comparison, 7.41×10^{10} amperes/m^2, is very near the maximum for cold emission for lanthanum hexaboride (LaB_6).

TABLE - COMPARISON OF PRESENT AND PRIOR ART EMISSION

Material	Barrier	N	Field v/m	Y	Vy	P	Source a/m^2
Mo	4.35 ev	1	9.83×10^9	.8651	.2151	.258	2.87×10^{11}
LaB_6	2.31 ev	1	3.70×10^9	.9998	.0003	.998	7.42×10^{10}
Silica	1.0 ev	250	4.17×10^8	.7746	.3481	.003	2.23×10^{13}
Beryllia	0.85 ev	250	3.63×10^8	.8501	.2377	.029	2.48×10^{12}

Comparing molybdenum (Mo) to silica and beryllia particles, molybdenum whiskers require 23.6 or 27 times the field, respectively, to obtain 7.41×10^{10} amperes/m^2 emission. Or stated another way, molybdenum requires 23.6 or 27 times the applied voltage. Comparing lanthanum hexaboride to silica or beryllia particles, lanthanum hexaboride requires 8.9 or 10.2 times the field or applied voltage, respectively, to obtain 7.41×10^{10} amperes/m^2 of emission.

In the case above of 250 emitting silica or beryllia particles, the emitted current is about 0.3 milliamperes, as compared to about 1 microamperes from the molybdenum whisker.

The field applied is dependent upon a geometric factor which converts the field from that between parallel plates to that about the surface of the cermet. The field Fi from an applied voltage V is:

(5) $Fi = V$

where

V is the applied voltage.

The geometric field factor for the worst case of the preferred embodiment is obtained from empirical data. An exemplary tip has an apex angle of 60 degrees and tip radius between 50 and 90 nanometers. Smaller apex angles increase the geometric field factor. The geometric field factor is empirically:

(6) $= 7.26 \times 10^7 (1.6 - 1.84x)a^{(-0.569)}$
where x = the distance in micrometers between the top of the cermet and the plane of the bottom of the extractor anode, being positive if the tip is above, and negative if the tip is below that plane and; a = the diameter of the aperture in the extractor anode in micrometers. Preferred typical values are x = +0.15 micrometers and a = 1.3 micrometers.

With the preferred values, the geometric field factor is about 8.87×10^7 m^{-1} and the extractor anode potential required to produce the field of 4.17×10^8 v/m for silica particles (see the above Table), is 4.7 volts. For the 3.63×10^8 v/m field required for beryllia particles (see the Table), the anode voltage is 4.1 volts. In both cases the field is significantly in excess of the field F_0 of equation (1) at 3.2×10^7, such that all traps are filled. Extractor anode potentials are about one-third that required to ionize stray gas molecules and hence gas molecules in the near space are not ionized and not electrostatically attracted to the tip.

Noise Occurring in Emission

In the prior art, four main types of noise in emitted current occur: Johnson noise, flicker noise, shot noise and burst noise. All are stochastic in nature, and follow different descriptive equations. In the prior art, the burst noise arising from created ions, adsorbing or ablating the emitting whisker, is the largest noise factor. In the present disclosure, no ions are created that can adsorb onto or ablate emitting insulator particles. Therefore, burst noise is eliminated as a noise source in the present device.

While 250 emitting insulator particles were assumed, many more (e.g., 1,000) particles can be made emitting. The 250 stochastically emitting particles reduce the current plus noise to noise ratio by the factor:
(7) $R = 1/(N)^{.5}$ where N is the number of emitting particles.
As an example, 250 stochastically emitting particles reduce the current plus noise to noise ratio by:
(8) $R = 20 \log (N^{.5}) = 24$ decibels when N = 250 emitting insulator particles.
The 24 db noise reduction over the prior art of the example is in addition to the reduced noise in the present device due to the elimination of ion produced burst noise. The remaining noise factors are sufficiently small that evaluation is trivial; the present emitter is significantly improved in noise immunity.

Energy of the Emitted Electrons

The distribution of the energy of the emitted electrons can be compared with prior art devices. The energy distribution is important because it is not reducible by the focus means. A large energy spread yields a larger resulting beam spot size. Because of the larger energy distribution of prior art emitters, a small aperture is usually inserted in the beam path to eliminate all but essentially on-axis electrons. That severely reduces available current. The width of the energy spread at half the maximum of the peak (FWHM) for cold field emission is given in the literature as:
(9) $FWHM = {}'9.76 \times 10^{-11} Fi\varnothing^{.5} / Ty$ in ev
where Ty is a tabulated and calculable function of Y; and
$/2 = 0.693$ at 0^0 K.
If comparison is made at maximum field Fmax (Y = 1, and Ty = 1.1107), then
(10) $Fi = Fmax = 6.94 \times 10^8 Y^2\varnothing^2$ v/m

TABLE - FWHM ENERGY SPREAD OF FIELD EMITTERS BY MATERIALS

Material	Barrier	Fmax v/m	FWHM ev
Tungsten	4.5 ev	1.406×10^{10}	3.634
Molybdenum	4.35 ev	1.314×10^{10}	3.337
Lanthanum hexaboride	2.31 ev	3.706×10^{9}	0.685
Silica particles	1.0 ev	6.944×10^{8}	0.085
Beryllia particles	0.85 ev	5.017×10^{8}	0.056

At lesser fields, the FWHM is also less; at greater fields, the FWHM is greater. The advantage of the present device emitting particles can be readily seen in the comparison Table.

The energy of emitted electrons is low, less than the applied extractor potential. Thus, the velocity of the electrons is also low, about that of 4 ev electrons. Such low energy makes the emitted electrons susceptible in some measure to ambient magnetic fields, and the earth's magnetic field. For that reason, an initial part of the structure of the device includes a grain-oriented permanent magnet, deposited with an aperture implicitly aligned to the vertical axis of the cermet tip. The magnet has very low induction, such that ambient magnetic fields negligibly change the permanent magnet field. The flux lines parallel the vertical axis of the cermet tip. Thus, electrons emitted off axis, or veering off axis due to lateral energy of emission, are steered onto the vertical axis. If it were not for the magnet field, most emitted electrons would be collected by the extractor electrode to reduce the target current density. The magnet field extends beyond the height of the structure to have the opposite effect on ions. That is, unwanted ions created in acceleration space beyond the structure are steered off axis, away from the exit aperture of emitted electrons.

An advantage of the low velocity electrons is that they may be easily managed in micrometer distances by small beam control potentials. A potential of 5 volts across a micrometer space is an electrostatic field of 5 million volts per meter. Such small potentials at focus and deflection elements form a focused beam of electrons. Normally, it is difficult to achieve a focus crossover from a field emission source. The source size of a typical cold field emitter is in the range of a few angstroms, decreasing with increasing field. In prior art field emitters, the emitted electron beam continues to spread. A type of focus is achieved by electromagnetic field confinement, and by apertures limiting the usable electrons to those emitted on axis. In the present device, the emitting area is N times that of the prior art yielding a a true crossover focus. The lense structure employed is based on the principles published by K. Schlesinger, Proceedings or the I.R.E., Transactions on Electron Devices, "Focus Reflex Modulation of Electron Guns", May, 1961. The same type of lense structure is also known as a "saddle field" lense. That type of lense has much higher transmission efficiency, approaching 96% as compared to other lense types.

Materials Comprising the Device

Insulators and conductors that fulfill the requirement for ohmic contact are not common in nature. The requirement for ohmic contact is that the work function of the insulator exceed the work function of the conductor. When an additional requirement, that the insulator conduction band width be less than 1 ev is imposed, the choices of materials are more severely restricted. Very acceptable work functions given below are at room temperature. The preferred materials for the particles in ohmic contact are trichromium silicide (Cr_3Si having a work function of 2.58 ev), and silica (SiO_2 having a work function 5 ev, barrier 1 ev) or beryllia (BeO with a work function 4.7 ev, barrier 0.85 ev) for the insulator particles. Where very high currents are desired, silica is to preferred to beryllia. Where high currents with reduced beam spot size are desired, beryllia is preferred over silica. Cr_3Si is also used in the process of making the device for an additional reason. Cr_3Si has very high free surface energy and forms a strong bond with insulators, such as the polyimide (Hitachi brand PIQ or equivalent) used as an insulator layer in the device structure. Usual metals, such as aluminum, used as conductors, do not adhere to polyimide, which retains flexibility after deposition. The Cr_3Si is used as an adherence layer, deposited a few nanometers in thickness onto polyimide. Then, a conductor thickness of aluminum, typically for low ohmic conduction, is deposited and sticks to Cr_3Si. Other conductor particles such as tantalum nitride (TaN having a work function 2.17 ev), or lanthanum hexaboride (LaB_6 having a crystalline work function 2.31 ev) can be used. The choice is a matter of economics. Since Cr_3Si has other uses in the structure fabrication, it is economical to use fewer materials rather than many. Other insulator particles may be used such as magnesia, calcium oxide and some rare earth oxides. But each of those choices has some auxiliary problem such as porosity (high trapping density) or sublimation in vacuum, or tendency toward phase problems in deposition of the insulator/conductor particles, not readily forming a random mixture. A final step in the structure fabrication procedure is sputter etching to insure that the insulator particles protrude from the surface. To accomplish that, the conductor particles must have a higher etching rate than the insulator particles. The intended result is that the emitting area is mostly insulating particles protruding from the surface; beneath the surface, current flow is through the conductor particles.

The material for the permanent magnet deposition is chosen for a high Curie temperature, so that the magnet recovers from vacuum baking at a temperature of 150°C. The vacuum bakeout removes moisture from the structure that otherwise would hinder operation. The magnet deposition process is molecular, by sputtering the magnetic material from a high coercive force permanent magnet. The magnetic material is sputtered onto the substrate temporarily backed by a similar permanent magnet with opposite pole facing the magnetic material source to initiate field alignment. Thus, sputtering off a non-aligned magnet produces a grain oriented, aligned magnet on the substrate. Ferrous oxide or alnico varieties are suitable materials.

Advantages of the Disclosed Device

In summary of the above description, the device and structure of the present disclosure has the following advantages over the prior art:

A. orders of magnitude higher current;

B. orders of magnitude higher brightness because of higher current at orders of magnitude narrower electron energy distribution;

C. smaller achievable beam spot size resulting from narrower electron energy distribution;

D. much higher current-plus-noise to noise ratio, because of the multiplicity of stochastically emitting sources;

E. improvement in current-plus-noise to noise ratio because the burst noise due to ions has been eliminated;

F. potentials obtainable from common integrated circuits are suitable for all device control signals;

G. freedom from ambient magnetic fields; and

H. operation at and economies of 10 microtorr vacuum levels, as compared to nanotorr vacuum levels.

Deflection Elements and Focus Anodes

The beam emitted from the conic or pyramid tip is shaped and deflected by elements arranged above the supportive substrate. Elements are shaped into focus elements and deflector bars around the emitting tip. Deflection is obtained by two pair of orthogonal coplanar deflector anodes arranged as opposing pairs adjacent to the aperture. All elements are electrically insulated from each other. The deflection plates jointly deflect the beam within a specified sweep, and with applied offset voltages can function as an aperture lense.

The first anode is an encircling ring centered around the emitter tip. A voltage applied to the first anode creates a field to initiate electron emission. The magnet may be biased relative to the anode to alter the shape of the anode field. The exit element of the saddle lense is polarized to provide lense action by providing a radical restricting force and focusing the electron beam. The microgun structure thus includes the supportive substrate, the pyramid tip, and the various elements described above. All of this apparatus will be termed a microgun. It finds use as a miniature scanning electron microscope in single quantity. It can be used in multiple arrays with a suitable target, one such arrangement being U.S. Patent No. 4,213,192.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a partial sectional view of a portion of the emitting surface and subsurface of the field emission device of the present disclosure;

Fig. 2 is a sectional view of the field emission device including substrate and various deflector elements and anodes;

Fig. 3 is a spatial arrangement of components acting on the emitted electron beam; and

Fig. 4 is a chart of potentials applied to the various components of the field emission device.

DETAILED DESCRIPTION OF THE PREFERRED AND ILLUSTRATED EMBODIMENT

Fig. 1 discloses an emitting tip, greatly enlarged, formed of a plurality of particles up to about 5.0 nanometers or less in maximum diameter. The microgun device 40 has a bottom conductor layer 41 made of the same material as particles 43 commingled in the cermet 42. The cermet is a mixture of conductive and insulative randomly distributed particles. The insulative particles are about 3.5 nanometer. The tip is preferably about 80 nanometers or less in radius and has a solid angle of 60° or less. Insulative and conductive particles are deposited by an ionic molecular process at cold temperature to produce the particle dimensions desired, about 3.5 nanometers. The conductive particles 43 are in ohmic contact with the insulative particles 44. The cermet 42 is biased in favor of conductive particles in ohmic contact with the support layer 41 and connects to a potential source through a conductor layer. The layer 41 is preferably formed of the same or a similar conducting material as the particles 43. The deposition builds up the tip with particles by dual vacuum particle emission with particle ballistics electrostatically directed and the surface is thereafter sputter etched to enhance insulator particle exposure. The conductive material has a higher sputter etching rate so it is partially removed to expose mostly insulative particles. The insulative particles 44 initiate the electron flow into space from the conic member.

Going now to Figs. 1 and 2 jointly, it will be recalled that numeral 40 identifies the field emission device which has the upper cermet portion 42 above the conductive base portion 41. The base is an ohmic contact with a conductor 31 insulated from and upon an insulator (bottom) substrate 28. The emission device 40 is centered in an aperture 25. Proceeding upwardly from the bottom substrate 28, the next layer is an insulator layer 32. In turn, that supports the layer 31 of conductive material connected with the emitting microgun 40. Normally, the layer 28 is grounded while the layer 31 is connected to an acceleration voltage source in Fig. 4. The insulator layer 30 is preferably polyimide.

Over an oxide layer 30, the next layer 29 is the magnet layer deposition. It is placed just below the tip 42 to direct electrons away from the tip to initiate beam definition. The layer 29 is conductive material (discussed above) and also is part of the components forming a saddle field. The first anode 26 is a circle around the aperture 25. The circular conductive ring is sandwiched between adjacent insulative layers 27 and 17 typically of polyimides. The first anode layer 26 is typically between about 0.15 and 0.6 microns thick. The layer 27 is typically about 0.3 to about 1.0 microns thick. Thickness is a function of the electron optical characteristics desired. The layers 26, 27 and 29 extend to MOS or bipolar control circuitry formed simultaneously with the microgun.

Typically, the cermet 42 extends about 0.15 micrometer above the bottom plane of the first anode 26. The cermet emitter ideally terminates approximately within the thickness of the anode 26. The anode 26 is undercut as shown in Fig. 2 because there is no compelling need to make this layer thicker.

The structure of Fig. 2 is a sandwich of several deposited layers. The top layer 14 forms deflection bars above a polyimide insulator. Four bars deflect the beam where the bars are pairs of spaced, parallel bars. The deflection bars are above an insulative layer 15. The deflection bars (two pair) are parallel edges spaced about 1.7 micrometer apart to define X and Y deflection bars at right angles. The two pair in the layer 14 are identified in Fig. 4 as the deflection bars 20 and 21. The conductive layer 16 (sandwiched above and below by insulators) is a lense or focus layer for the emitted beam.

Going now to Fig. 3, wave forms of the various components are shown. Fig. 4 further shows in exploded view the various anodes with the insulative material omitted. Also, the target is shown but the evacuated housing has been omitted for sake of clarity. The beam shaping layers are represented by rings or bars with conductor paths 51 to 58.

The terminal 51 connects to the emitter 40. The magnet layer 29 connects to a selected voltage source. The anode 26 connects to the terminal 52. The anode 26 is positive, slightly less than 5 volts to initiate current emission. The wave form 51 is switched to ground while the wave form 52 is switched to approximately 5 volts positive to initiate emission. The potentials applied to the opposing deflection bars 20. The other deflection plates 21 receive the potentials 53 and 58 stepped up by a bias and switched to opposite steps. The step up in the wave forms 53, 54, 55 and 58 forms an aperture lense focusing voltage, narrowing the beam. The various wave forms applied to the opposing focus electrodes are mirror images; this jointly deflects the beam in a controlled fashion and also narrows the beam.

Focus , shaping and deflection are obtained by the step biases 60 applied to the wave forms 53, 54, 55 and 58. Beam modulation can be obtained by driving the anode 26 to cutoff, or to intermediate values to control the beam intensity. Beam focus or spot size is adjusted by the voltage applied to the layer 16. All the voltage wave forms shown in Fig. 3 can be obtained through MOS or bipolar integrated circuits fabricated on a sideboard location. The control voltages applied to the deflector bars are in the millivolt range obtained by sideboard located integrated circuits.

The foregoing is directed to the preferred embodiment. It has been described as a single device. It can be fabricated and used in single fashion, or it can be deployed in multiple arrays typically in rows and columns. The foregoing is directed to the preferred embodiment but the scope is determined by the claims which follow.

Claims

1. A field emission device wherein emission is obtained from particles of insulative material under the influence of a field, and wherein a barrier to emission is the conduction band width and is less than about 1 ev, and wherein the insulative particles are a component of a cermet of randomly arranged conductive and insulative particles, and ohmic contact exists between the particles.

2. The device of Claim 1 wherein electrons in the insulative particles have at least the energy of the Fermi level of the conductive material, and energy imparted by an applied field to the electrons initiates emission.

3. The device of Claim 2 wherein said field is sufficient to cause electron traps in said insulative particles to be overfilled, and all electrons flow in the insulative material conduction band.

4. The field emission device of Claim 3 including a pointed structure is centered in an aperture of a conductive electrode, and said cermet is formed upon and conductively connected at a base of said pointed structure to a conductive substrate and a potential applied between said substrate and conductive electrode operates on said point and said cermet to emit electron flow from said point.

5. The field emission device of Claim 1 wherein the conductive material is refractory metal, nickel, silver, aluminum, rare earth borides, highly doped silicon or a silicide of refractory metal and having a lesser work function than that of said insulative material.

6. The field emission device of Claim 1 wherein the conductive particles are trichromium silicide, and the insulative material is Al_2O_3, BeO, B_2O_3, BN, CaO, MgO, SiO_2 or Si_3N_4.

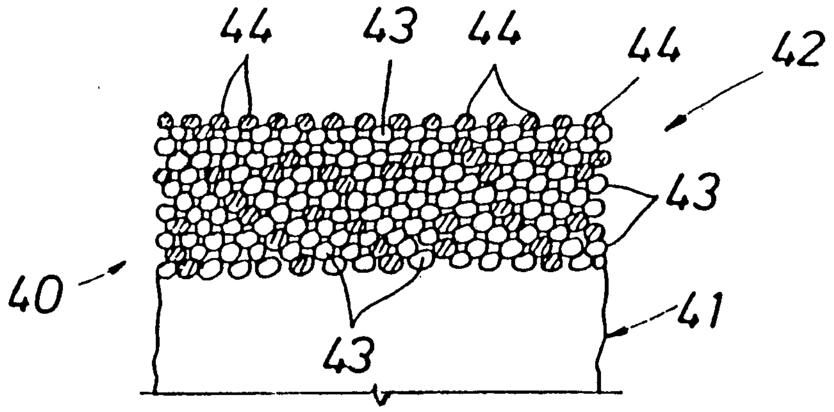
7. A field emission device comprising a conductive substrate conductively connected to cermet of insulative and conductive particles of pyramidal or conical shape with a point centered in an aperture of a first conductor, and a potential is applied between said substrate and said first conductor forming a field causing electrons to flow through the cermet in the conduction band of the insulative particles with a barrier to emission of less than about 1 ev, the electron flow to the point of the cermet into vacuum being from insulative particles of the surface of the point, the potential producing the field for emission being less than the ionization potential of gasses or vapors residual within or diffusing within the field to preserve the integrity of the emitting insulative particles, reduce noise and emitted current degradation, and allow operation in the presence of vapors or gasses in the field.

8. The field emission device of Claim 7 including two pairs of deflection bars orthogonal to and insulated from each other and from said first conductor, and said bars are centered relative to the emitting point; voltage means applied to one deflection pair; separate voltage means connected to the other deflection pair; and wherein said deflection bars are operative to deflect the emitted electrons and to focus the emitted electrons.

9. A multiplicity of the field emission devices of Claim 7 sharing a common substrate each directed to an assigned area of respective targets, and including integrated circuit control means integrally supported by said common substrate for the multiplicity of field emission devices.

10. The field emission device of Claim 7 formed of trichromium silicide particles in ohmic contact with silica or beryllia particles.

FIG.1.


44
43
44
44
42
43
40
41
43

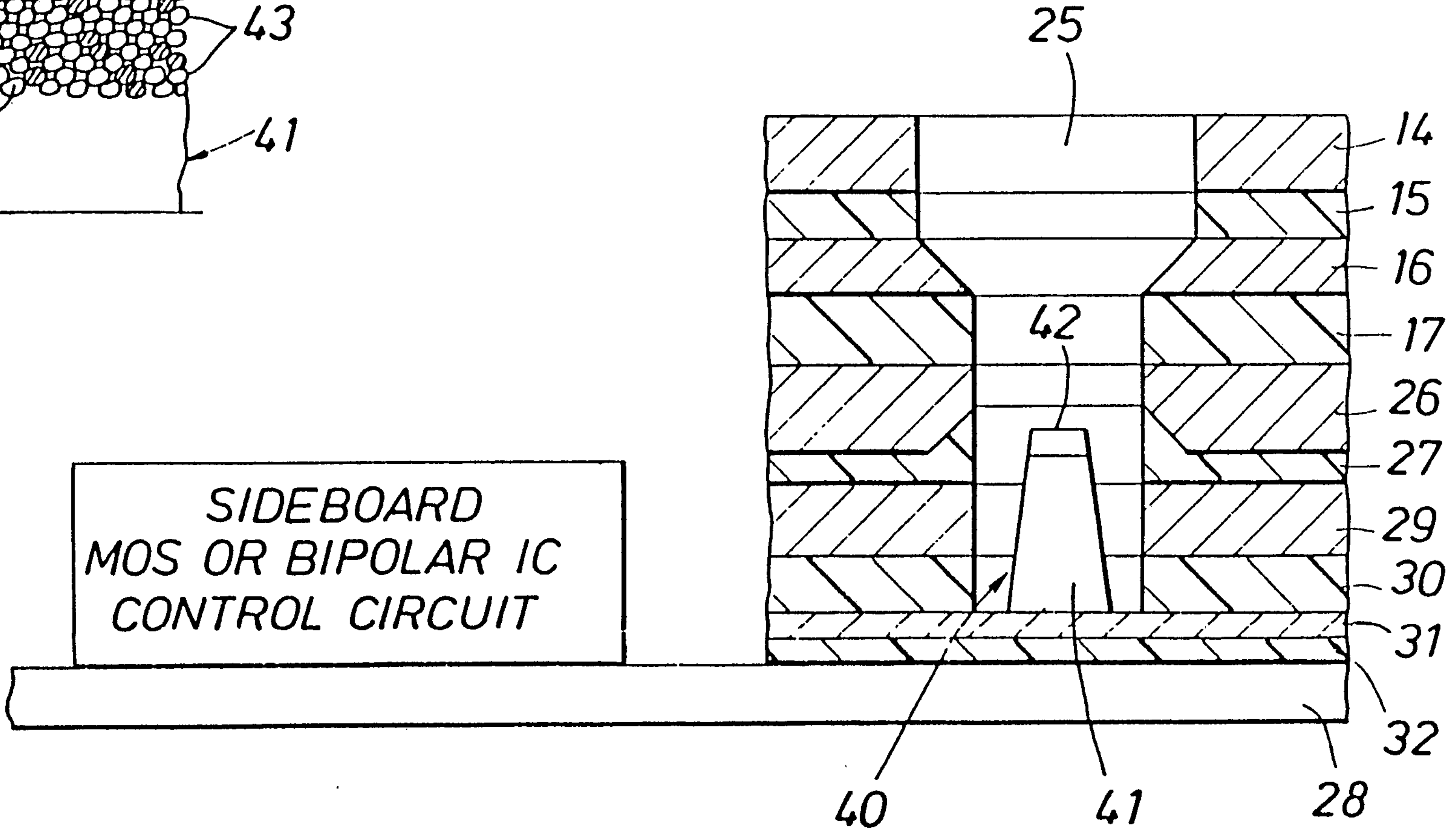

25
14
15
16
17
42
26
27
SIDEBOARD
MOS OR BIPOLAR IC
CONTROL CIRCUIT
29
30
31
32
40
41
28

FIG. 2

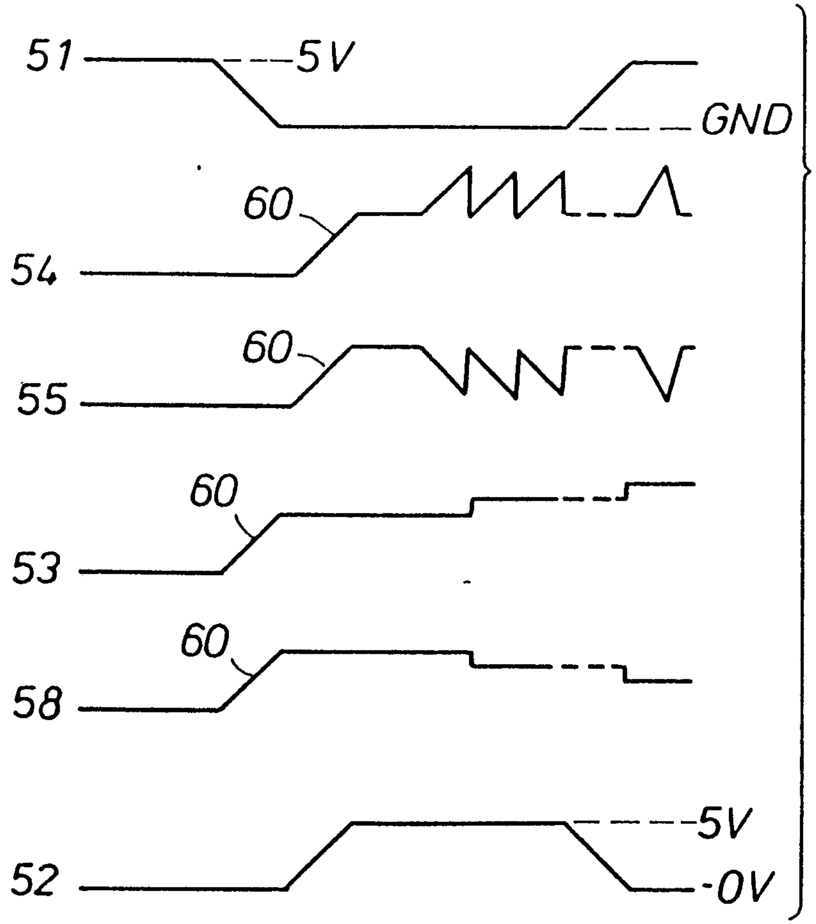

51
5V
GND
54
60
55
60
53
60
58
60
52
5V
-0V

FIG. 3

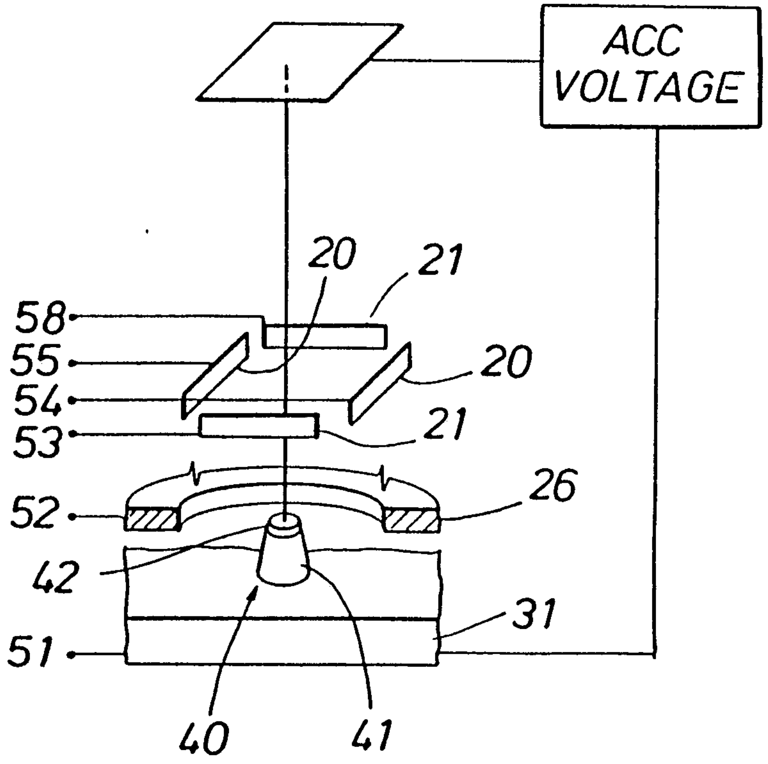

ACC VOLTAGE
20
21
58
55
54
53
20
21
52
26
42
31
51
40
41

FIG. 4

European Patent
Office

EUROPEAN SEARCH REPORT

Application Number

EP 87 30 3550

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.4)
A	US-A-4 498 952 (CHRISTENSEN) * column 2, lines 6-34; column 9, line 62 - column 10, line 11; figure 18 * ---	1,7	H 01 J 1/30
A	GB-A-1 226 627 (SYLVANIA ELECTRIC) * Page 1, lines 24-50,82-92; figure 2 * ---	1,7	
A	US-A-4 008 412 (YUITO et al.) ---	1,7	
E	US-A-4 663 559 (CHRISTENSEN) * Whole document * -----	1-10	

TECHNICAL FIELDS SEARCHED (Int. Cl.4)

H 01 J 1/00

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	17-12-1987	JANSSON P.E.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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A : technological background
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