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Description

This invention relates to a field emission device as described in the first part of claim 1.

Such a field emission device is known from US-A-4.498.952, which will be discussed later.

5 This disclosure sets forth a cold, field emission low noise microampere current from 5×10^8 V/m (volts/meter) field, commonly available at a nominal value of 5 V (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 dB (decibels) over the prior art devices. In a cold field emission device, insulator and
10 conductor particles are randomly deposited up to about 20 nm (nanometer) thickness to form the emission area of a conductive base. The insulator work function is greater than the conductor work function. That potential difference, at contact to insulators of less than 5 nm (nanometers) in thickness, achieves ohmic contact. At insulator thicknesses greater than 5 nm (nanometers), an additive potential barrier due to traps in the insulator prevents barrierless ohmic contact. Ohmic contact is defined herein as barrierless contact
15 between the conductor and insulator. 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
20 particles to inject electrons into the insulative particles conduction band.

A field emission device according to the invention comprises a conductive and supportive substrate, a cermet of insulative and conductive particles defining a pyramidal or conical shape extending to a pointed region centered in a surrounding aperture, a potential being arranged to be applied to act on the pointed
25 region so that electrons are caused to flow from the insulative particles of the pointed region to form an emitted current, and ohmic contact exists between the insulative and conductive particles characterised in that a barrier to emission is the conduction band of the material of the insulative particles from which the conduction band height is less than about 1eV.

The dependent claims describe particular embodiments of the invention.

The barrier to emission of electrons from the conduction band is the electron affinity (conduction band
30 height) of the insulator material, typically 1eV or less. Those injected free electrons in the insulator conduction band have a Fermi-Driac distribution, with most free electrons near the conduction band bottom. The conducting dimension of the insulator material, typically about 3.5 nm (nanometers), is less than the ballistic transport length of electrons therein.

The electrode tip is preferably surrounded by a positive extractor electrode, a ring-like elevated
35 conductive structure. The base of the conical 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)
40 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 V (volts) to 8.5 V (volts) produce nanoamperes to milliampere 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.

45 The volume of the structure accessible to the adjacent vacuum space, say, in the range of $133,3 \cdot 10^{-5}$ Pa (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.

50 A preferred structure according to the invention 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
55 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 US-A-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 vacuum emission work function 2.58 eV, or tantalum nitride of 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 US-A-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 has 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.

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 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 ballistically 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:

$$(1) \quad F_0 = \frac{q N L}{2 \epsilon \epsilon_0} \quad \text{in volts/meters} = 3.2 \times 10^7 \text{ V/m}$$

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
- $\epsilon \epsilon_0$ = 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
- $\epsilon \epsilon_0$ = 9.65×10^{-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 $F_i = F - F_0$, 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.

$$(2) \quad J_s = s V/L + 9/8 (\mu \theta \epsilon \epsilon_0) V^2/L^3$$

where

J_s = current density in A/m² (amperes/square meters);

μ = the electron mobility in the insulative particle = 3×10^5 m²/V sec for silica, and 3×10 m²/V sec for beryllia;

s = the conductivity;

θ = electron diffusion coefficient of 1.4;

$\epsilon \epsilon_0$ = permittivity of the insulative particle = 3.8×10^{-11} F/m for silica, and 5.6×10^{-11} F/m for beryllia;

F_i = 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 nm (nanometers) for L , the maximum source current density for a single silica particle is 2.48×10^{11} A/m², and for beryllia particle 1.89×10^{10} A/m². Current flows from each insulator particle of the tip.

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

$$(3) \quad P = \exp [(-B/F_i) \phi^{1.5} v(y)]$$

where B is a quantum mechanical constant = 6.83×10^9 m e V

ϕ = the barrier to emission, 1 ev for silica, and 0.85 ev for beryllia;

$v(y)$ = the non-dimensional Schottky barrier lowering function, a function of the elliptical function Y ; and

$Y = 1.44 \times 10^{-9} F_i/\phi^2$.

In cold field emission, the maximum value of Y is 1.0, and at $Y = 1.0$, one has $v(y) = 0.0$ 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:

$$(4) \quad J_e = N * J_s * P \text{ in a/m}^2$$

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 $L = 3.5$ nm (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} A/m², is very near the maximum for cold emission for lanthanum hexaboride (LaB₆).

TABLE

COMPARISON OF PRESENT AND PRIOR ART EMISSION							
Material	Barrier	N	Field V/m	Y	v(y)	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} A/m² 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} A/m² of emission.

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

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

$$(5) \quad F_i = \beta V$$

where βV is the average field enhancement factor (1/m) about the isolated emitting oxide particles and V is the applied voltage.

The geometric field factor β 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 nm (nanometers). Smaller apex angles increase the geometric field factor. The geometric field factor is empirically:

$$(6) \quad \beta = 7.26 \times 10^7 (1.6 - 1.84x)a^{(-0.569)}$$

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 $x = +0.15 \mu\text{m}$ (micrometers) and $a = 1.3 \mu\text{m}$ (micrometers).

With the preferred values, the geometric field factor is about $8.87 \times 10^7 \text{ m}^{-1}$ and the extractor anode potential required to produce the field of $4.17 \times 10^8 \text{ V/m}$ for silica particles (see the above Table), is 4.7 V (volts). For the $3.63 \times 10^8 \text{ V/m}$ field required for beryllia particles (see the Table), the anode voltage is 4.1 V (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:

$$(7) \quad R = 1/(N)^5$$

where N is the number of emitting particles.

As an example, 250 stochastically emitting particles reduce the current plus noise to noise ratio by:

$$(8) \quad R = 20 \log (N^5) = 24 \text{ dB (decibels)}$$

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. Since the electrons traverse the insulator conduction band into vacuum ballistically, no spread in energy due to phonon collision occurs. Thus only the quantum mechanical uncertainties affect energy spread, as expressed by equation (9) below. The width of the energy spread at half the maximum of the peak (FWHM) for cold field emission is given in the literature as:

$$(9) \quad \text{FWHM} = \Delta^* 9.76 \times 10^{-11} \text{ Fi} \cdot \Delta/2 \text{ Ty in eV}$$

where Ty is a tabulated and calculable function of Y; and

$$\Delta/2 = 0.693 \text{ at OK.}$$

If comparison is made at maximum field Fmax (Y = 1, and Ty = 1.1107), then

$$(10) \quad \text{Fi} = \text{Fmax} = 6.94 \times 10^8 \text{ Y}^2 \cdot \Delta^2 \text{ V/m}$$

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	0.9 eV	5.62×10^8	0.069
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 true crossover focus. The lense structure employed is based on the principles published by K. Schlesinger, Proceedings of 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. When an additional requirement, that the insulator conduction band width be less than 0.9 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 vacuum emission 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. US-A-4,213,192.

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.

Fig. 1 discloses an emitting tip, greatly enlarged, formed of a plurality of particles up to about 5.0 nm (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 nm (nanometers), less than the loss-free, ballistic transport length of electrons therein, and insufficient in thickness to support insulator traps which would otherwise cause a non-ohmic, barrier contact. The tip is preferably about 80 nm (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 nm (nanometers), less than the loss-free, ballistic transport length of electrons therein, and insufficient in thickness to support insulator traps which would otherwise cause a non-ohmic, barrier contact. The conductive particles 43 are in ohmic contact with the insulative particles 44 which are electrically isolated from one another producing an added field enhancement about each emitting particle 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 μm (microns) thick. The layer 27 is typically about 0.3 to about 1.0 μm (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 μm (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 μm (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 V (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 comprising a conductive and supportive substrate (31), a cermet of insulative (44) and conductive (43) particles defining a pyramidal or conical shape extending to a pointed region (42) centered in a surrounding aperture (25), a potential (52) being arranged to be applied to act on the pointed region so that electrons are caused to flow from the insulative particles (44) of the pointed region (42) to form an emitted current, and ohmic contact exists between the insulative and conductive particles characterised in that a barrier to emission is the conduction band of the material of the insulative particles from which material the conduction band height is less than about 1eV.
2. A device according to claim 1 wherein electrons in the insulative particles (44) have at least the energy of the Fermi level of the conductive material.
3. A device according to claim 1 or 2 wherein the emission field is sufficient to cause electron traps in said insulative particles (44) to be overfilled, and all electrons flow in the insulative material conduction band.
4. A field emission device according to any one of claims 1 to 3 wherein said cermet (43,44) is formed upon and conductively connected at a base (41) of said pointed structure to the conductive substrate (31).
5. A device according to any one of claims 1 to 4 wherein the conductive material of the particles (43) is refractory metal, nickel, silver, aluminum, rare earth borides, highly doped silicon or a silicide of refractory metal having a lesser work function than that of said insulative material.
6. A device according to any one of claims 1 to 5 wherein the conductive particles (43) 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 device according to any one of claims 1 to 6 wherein the potential producing the field for emission is 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. A device according to any one of claims 1 to 7 including two pairs of deflection bars (20,21) orthogonal to and insulated from each other, and said bars are centered relative to the emitting point (42); 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 according to any one of claims 1 to 7 sharing a common substrate (28) 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. A device according to any one of claims 1 to 8 formed of trichromium silicide particles in ohmic contact

with silica or beryllia particles.

Patentansprüche

- 5 1. Feldemissionsvorrichtung, umfassend ein leitendes und tragendes Substrat (31), ein Cermet aus isolierenden (44) und leitenden (43) Teilchen, die eine pyramidenförmige oder kegelförmige Gestalt bilden, die sich zu einem spitzen in einer umgebenden Öffnung zentrierten Bereich erstreckt, ein Potential (52) ist angeordnet, um auf den spitzen Bereich so einzuwirken, daß Elektronen veranlaßt werden, von isolierenden Teilchen (44) des spitzen Bereichs (42) zu fließen, um einen Emissionsstrom
10 zu bilden, und ohmscher Kontakt besteht zwischen den isolierenden und leitenden Teilchen, dadurch gekennzeichnet, daß eine Barriere gegen Emission des Leitungsband des Materials der isolierenden Teilchen ist, von welchem Material die Leitungsbandhöhe geringer als etwa 1eV ist.
- 15 2. Vorrichtung nach Anspruch 1, in der Elektronen in den isolierenden Teilchen (44) mindestens die Energie der Fermikante des leitenden Materials besitzen.
3. Vorrichtung nach Anspruch 1 oder 2, in der das Emissionsfeld ausreichend ist um zu veranlassen, daß Elektronenhaftstellen in den isolierenden Teilchen (44) überfüllt sind, und alle Elektronen in dem Leitungsband aus isolierendem Material fließen.
20
4. Feldemissionsvorrichtung nach einem der Ansprüche 1 bis 3, in der das Cermet (43, 44) gebildet ist auf und leitend verbunden ist an einem Sockel (41) der spitzen Struktur mit dem leitenden Substrat (31).
- 25 5. Vorrichtung nach einem der Ansprüche 1 bis 4, in der das leitende Material der Teilchen (43) feuerfestes Metall, Nickel, Silber, Aluminium, Boride seltener Erden, hochdotiertes Silizium oder eine Siliziumverbindung feuerfesten Metalls mit einer geringeren Arbeitsfunktion als die den isolierenden Materials ist.
- 30 6. Vorrichtung nach einem der Ansprüche 1 bis 5, in der die leitenden Teilchen (43) aus Trichromsilicid sind und das isolierende Material Al_2O_3 , BeO , B_2O_3 , BN , CaO , MgO , SiO_2 oder Si_3N_4 ist.
- 35 7. Vorrichtung nach einem der Ansprüche 1 bis 6, in der das das Feld für die Emission erzeugende Potential geringer ist als das Ionisationspotential von Restgasen oder -dämpfen innerhalb oder diffundierend innerhalb des Feldes, um die Integrität der emittierenden isolierenden Teilchen zu erhalten, Geräusch und Herabsetzung emittierten Stroms zu verringern und den Betrieb in Gegenwart von Dämpfen und Gasen in dem Feld zu ermöglichen.
- 40 8. Vorrichtung nach einem der Ansprüche 1 bis 7, enthaltend zwei Paar von Deflektionsstäben (20, 21), die rechtwinklig zueinander und isoliert voneinander sind, wobei die Stäbe relativ zu dem Emissionspunkt (42) zentriert sind; Spannungsmittel, angeschlossen an ein Deflektionspaar; getrennte Spannungsmittel, angeschlossen an das andere Deflektionspaar; und worin die Deflektionsstäbe zur Ablenkung der emittierten Elektronen und zur Fokussierung der emittierten Elektronen wirksam sind.
- 45 9. Eine Mehrzahl von Feldemissionsvorrichtungen nach einem der Ansprüche 1 bis 7, die sich ein gemeinsamen Substrat (28) teilen, jede auf einen zugeordneten Bereich eines entsprechenden Ziels gerichtet, und integrierte Schaltungssteuerungsmittel einschließend, die integrierend durch das gemeinsame Substrat getragen sind für die Mehrzahl der Feldemissionsvorrichtungen.
- 50 10. Vorrichtung nach einem der Ansprüche 1 bis 8, gebildet aus Trichromsilicid-Teilchen in ohmschem Kontakt mit Silika- oder Beryllerde-Teilchen.

Revendications

- 55 1. Dispositif d'émission de champ comportant un substrat conducteur et de support (31), un composé métallo-céramique fait de particules isolantes (44) et conductrices (43) définissant une configuration pyramidale ou conique qui s'étend jusqu'à une zone pointue (42) centrée dans un orifice périphérique (25), un potentiel (52) étant conçu pour être appliqué afin d'agir sur la zone pointue de telle façon que

des électrons sont contraints à circuler à partir des particules isolantes (44) de la zone pointue (42) pour former un courant émis, tandis qu'il existe un contact ohmique entre les particules isolantes et conductrices, caractérisé en ce qu'une barrière à une émission est constituée par la bande de conduction du matériau des particules isolantes, matériau à partir duquel la hauteur de bande de conduction est inférieure à environ 1 eV.

2. Dispositif selon la revendication 1, dans lequel des électrons présents dans les particules isolantes (44) possèdent au moins l'énergie du niveau de Fermi du matériau conducteur.

3. Dispositif selon la revendication 1 ou 2, dans lequel le champ d'émission est suffisant pour provoquer une sursaturation des pièges à électrons présents dans lesdites particules isolantes (44), et tous les électrons se déplacent dans la bande de conduction du matériau isolant.

4. Dispositif d'émission de champ selon l'une quelconque des revendications 1 à 3, dans lequel ledit composé métallo-céramique (43, 44) est formé sur le substrat conducteur (31) en étant relié d'une manière conductrice à celui-ci au niveau d'une base (41) de ladite structure pointue.

5. Dispositif selon l'une quelconque des revendications 1 à 4, dans lequel le matériau conducteur des particules (43) consiste en métal réfractaire, en nickel, en argent, en aluminium, en borures de terres rares, en silicium fortement dopé ou en un siliciure de métal réfractaire ayant un travail de sortie inférieur à celui dudit matériau isolant.

6. Dispositif selon l'une quelconque des revendications 1 à 5, dans lequel les particules conductrices (43) consistent en siliciure de chrome (à trois atomes de chrome), tandis que le matériau isolant consiste en Al_2O_3 , BeO , B_2O_3 , BN , CaO , MgO , SiO_2 ou en Si_3N_4 .

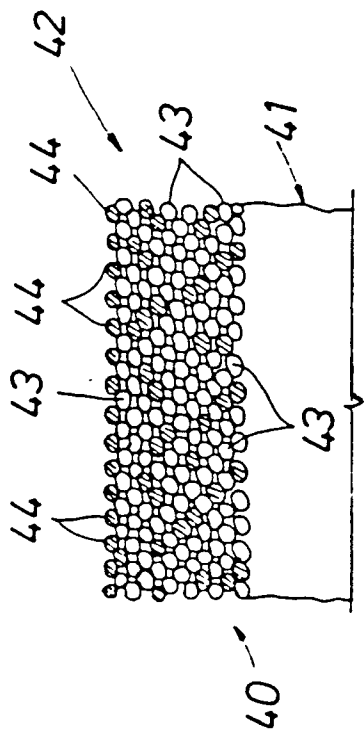
7. Dispositif selon l'une quelconque des revendications 1 à 6, dans lequel le potentiel produisant le champ à émettre est inférieur au potentiel d'ionisation de gaz ou de vapeurs restant ou se diffusant à l'intérieur du champ pour préserver l'intégrité des particules isolantes émettrices, pour réduire un bruit et une dégradation du courant émis, et pour permettre un fonctionnement en présence de vapeurs ou de gaz dans le champ.

8. Dispositif selon l'une quelconque des revendications 1 à 7, comportant deux paires de barres de déviation (20, 21) perpendiculaires entre elles et isolées les unes par rapport aux autres, lesdites barres étant centrées par rapport au point d'émission (42); des moyens de tension appliqués à l'une des paires de déviation; des moyens de tension séparés reliés à l'autre paire de déviation; et dans lequel lesdites barres de déviation agissent pour dévier les électrons émis et pour focaliser les électrons émis.

9. Multiplicité de dispositifs d'émission de champ selon l'une quelconque des revendications 1 à 7, partageant un substrat commun (28), respectivement dirigés vers une zone assignée de cibles respectives, et comprenant des moyens de commande à circuits intégrés, supportés solidairement par ledit substrat commun prévu pour la multiplicité de dispositifs d'émission de champ.

10. Dispositif selon l'une quelconque des revendications 1 à 8, formé de particules de siliciure de chrome (à trois atomes de chrome) en contact ohmique avec des particules de silice ou d'oxyde de béryllium.

FIG.1.



SIDEBOARD
MOS OR BIPOLAR IC
CONTROL CIRCUIT

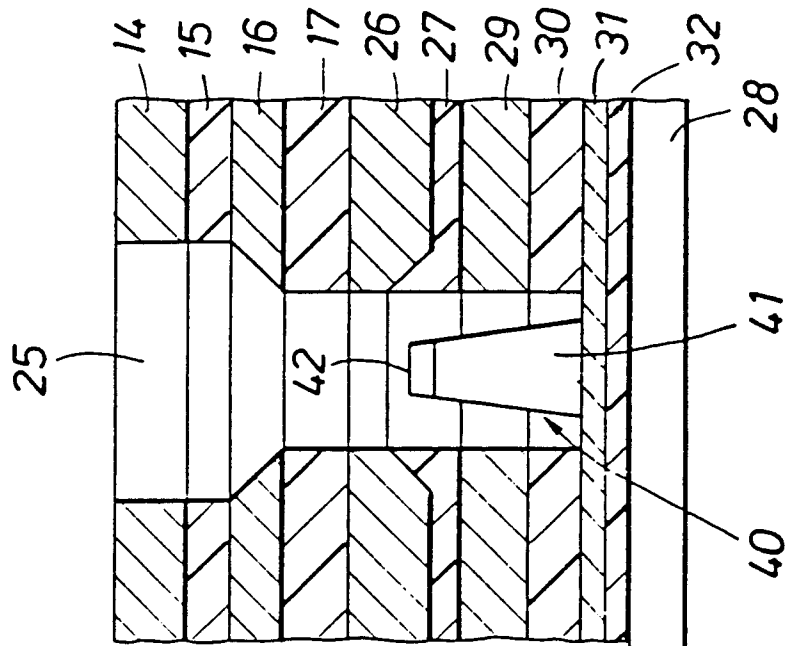


FIG.2

