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Farrell et al.

[11] **3,925,670**

[45] **Dec. 9, 1975**

[54] **ELECTRON BEAM IRRADIATION OF MATERIALS USING RAPIDLY PULSED COLD CATHODES**

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[22] Filed: **Jan. 16, 1974**

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[52] **U.S. Cl.** ..... **250/400;** 250/492 B

[51] **Int. Cl.²** **H01J 37/00**

[58] **Field of Search** ..... 250/453, 454, 455, 492, 250/493, 396, 400, 492 A, 398, 399; 219/121 EB

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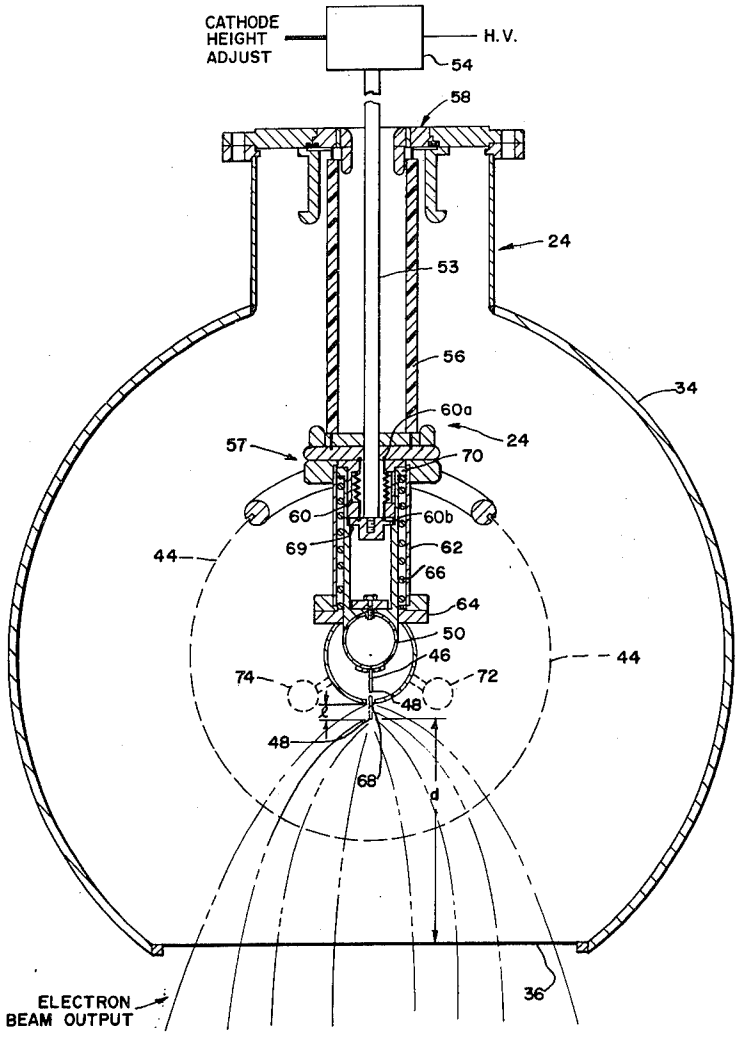
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[57] **ABSTRACT**

A cold cathode electron gun rapidly driven with high voltage pulses in an electric field configuration such that the emitted electrons are splayed over and directed into a target to be irradiated.

11 Claims, 8 Drawing Figures



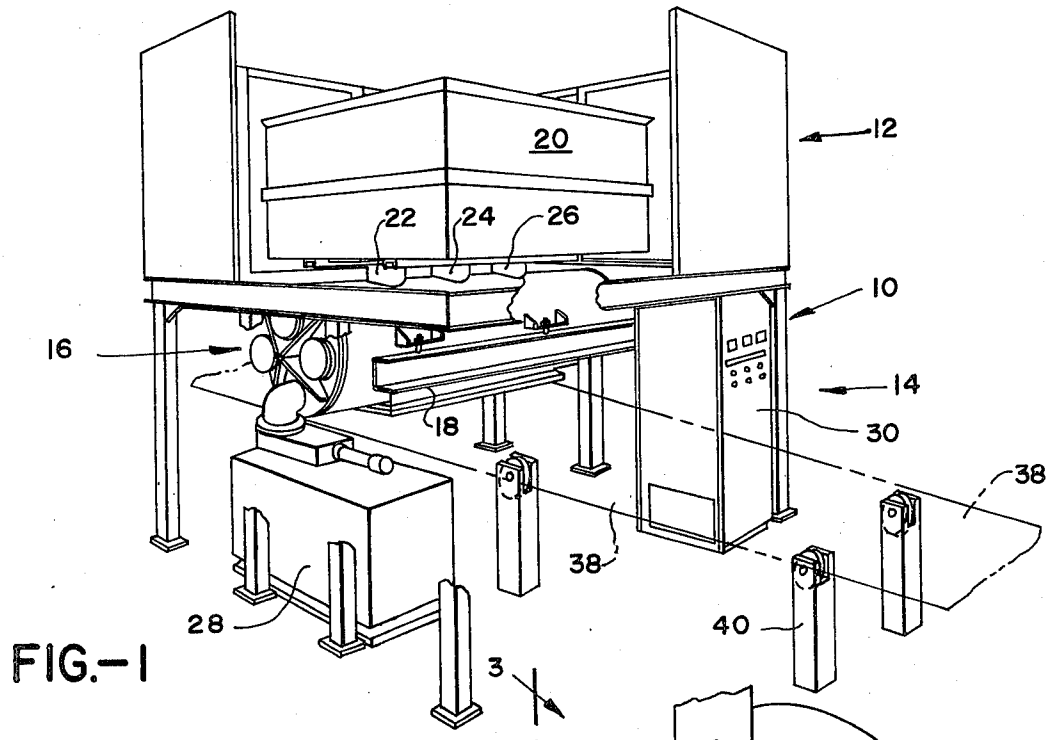

20
12
22
24
26
10
16
14
18
30
38
38
28
40

FIG.-1

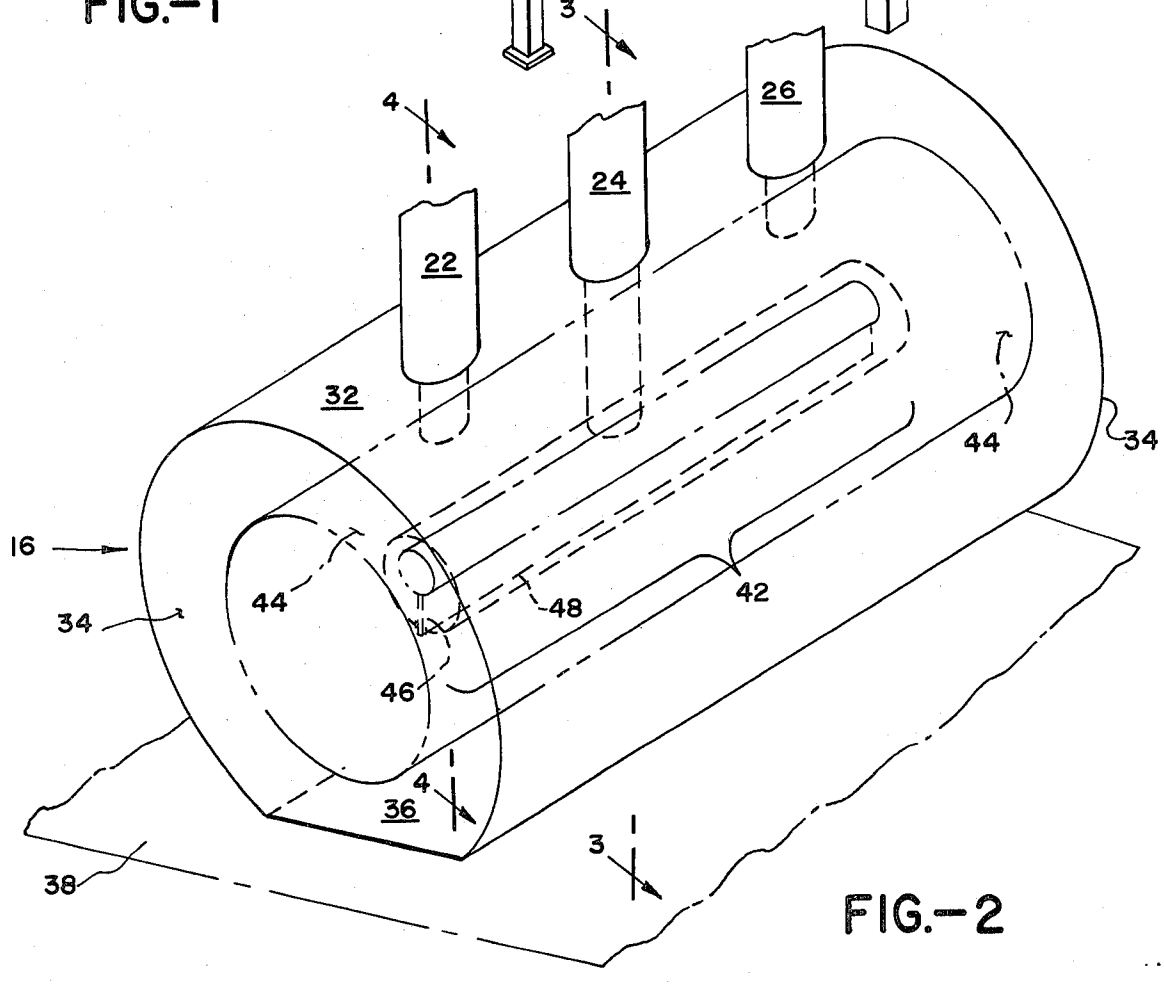

3
4
26
24
22
32
44
34
16
44
34
48
42
46
4
36
3
38

FIG.-2

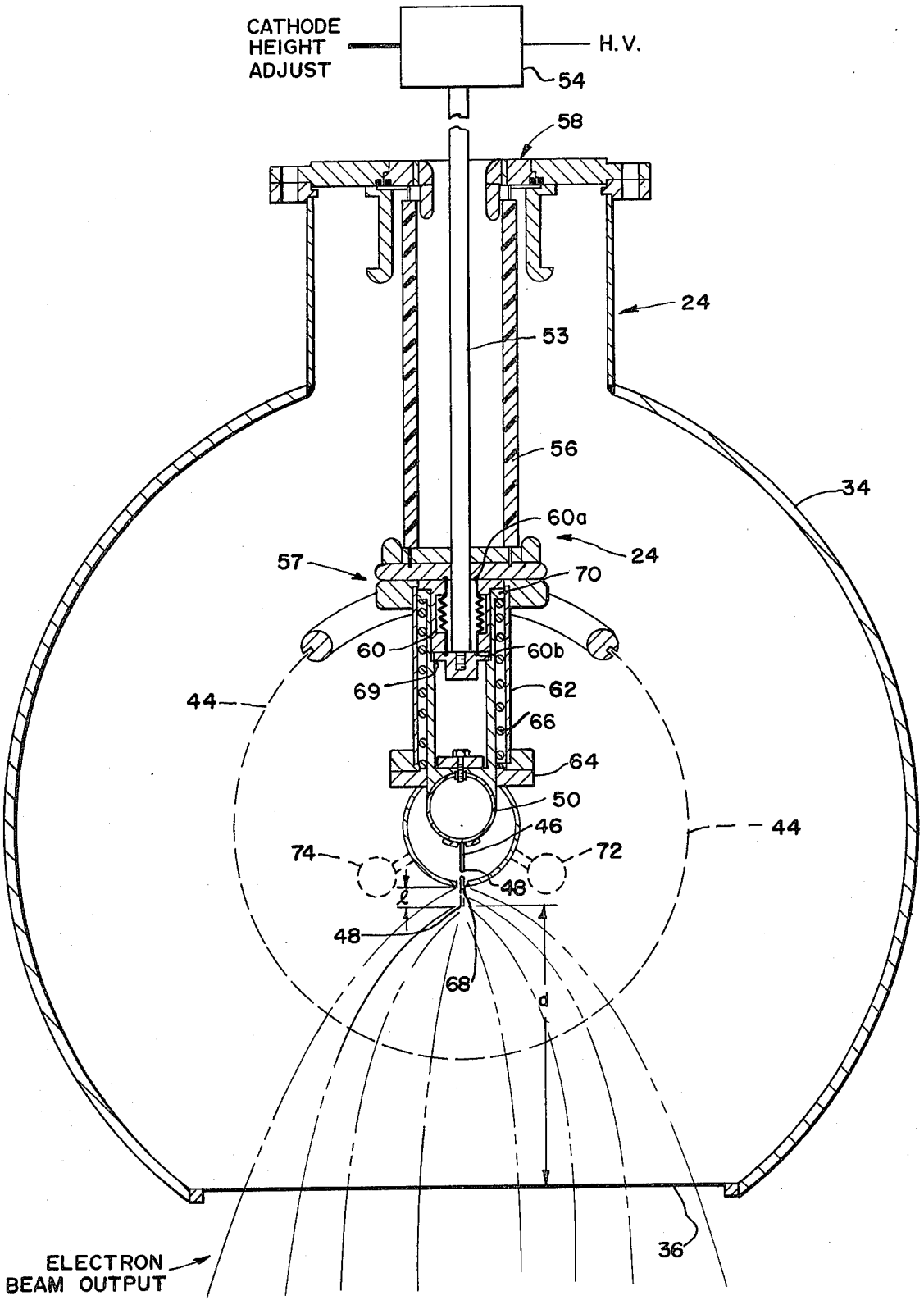

CATHODE
HEIGHT
ADJUST
H.V.
54
58
24
53
56
34
60a
24
57
70
60
60b
69
62
66
44
64
50
46
44
74
72
48
48
68
d
ELECTRON
BEAM OUTPUT
36

FIG.—3

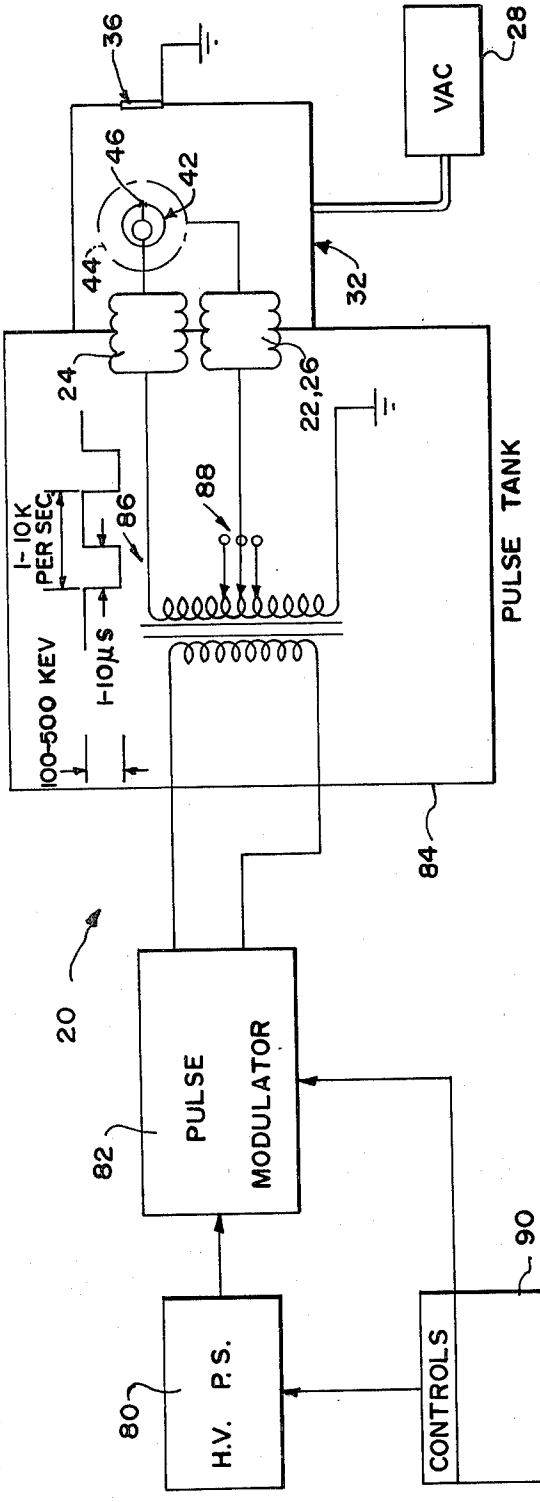


FIG.-5

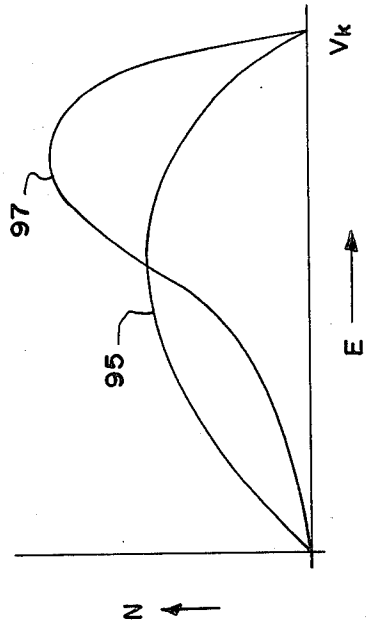


FIG.-6

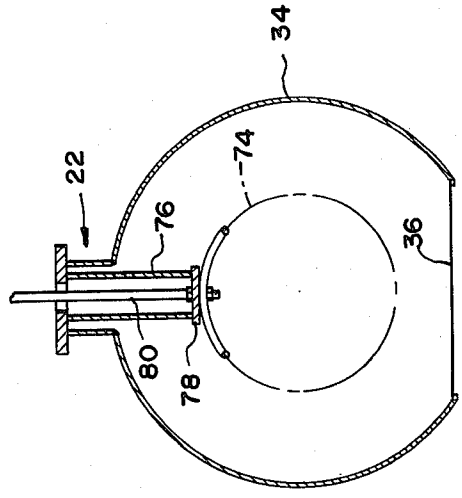


FIG.-4

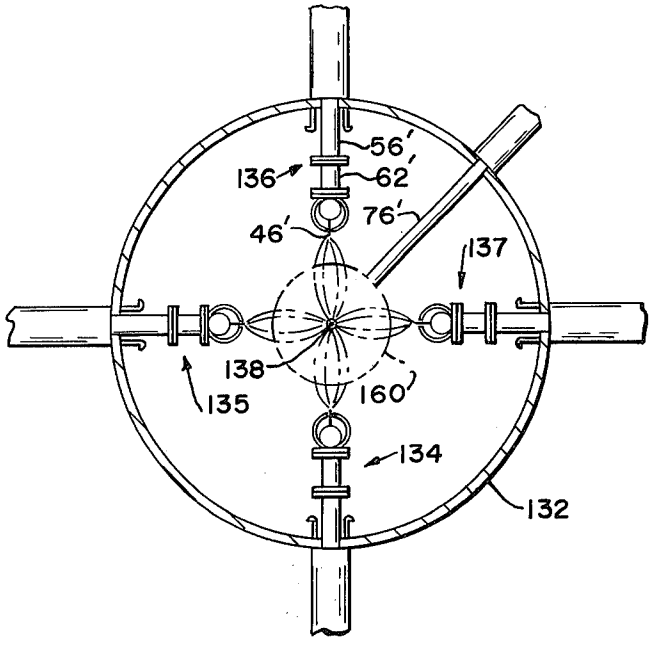

56'
136
62
76'
46'
137
138
135
160
134
132

FIG.—7

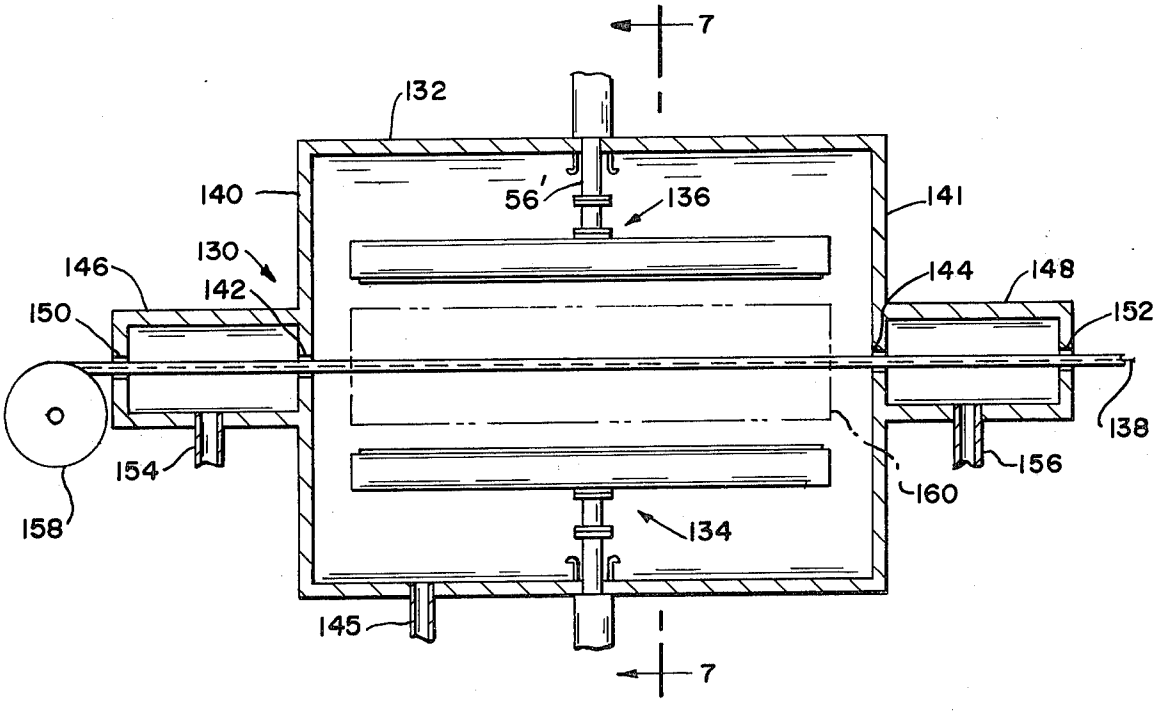

7
132
140
56'
136
141
130
146
142
144
148
150
152
138
154
156
158
160
134
145
7

FIG.—8

ELECTRON BEAM IRRADIATION OF MATERIALS USING RAPIDLY PULSED COLD CATHODES

BACKGROUND OF THE INVENTION

This invention relates to electron beam systems and particularly to a radiation method and apparatus useful for the curing of polymeric products and other radiation processing.

Ionizing radiation is used in numerous commercial applications, including the curing of coatings, processing of materials such as wood pulp, and processing of foods. Electron beams in particular have proven to be effective and various systems have been devised for obtaining electron beams capable of covering the area of the material or object being processed. For example, U.S. Pat. No. 3,588,565, dated June 1971, for "Low Dose Rate High Output Electron Beam Tube" by John G. Trump, describes a particular type of electron beam tube, which it is claimed, can produce a large cross-sectional area electron beam with properties useful for radiation processing. U.S. Pat. No. 3,588,565 also contains background information regarding the prior art and general considerations regarding radiation processing of materials with electron beams.

Heretofore, the general approach to obtaining suitable beams has been to create electrons in an evacuated or gas filled tube and accelerate them to energies of 100keV or more. The accelerated electrons are passed through a thin metallic foil such as for example 0.001 inch thick aluminum which separates the interior region of the electron beam tube from the atmosphere, or in some cases, a special environment inside a chamber. The materials to be processed are exposed to the electron beam either in the atmosphere or in the special environmental chamber.

System presently in commercial operation use either a large area electron beam or a small diamter "pencil" beam which is scanned across the materials being processed. These beams have been produced by cathodes heated to a state of thermionic emission. The maximum average current density, and hence maximum dose rate at the sample, is determined by the upper limit on allowable temperature rise to the foil window. Foil heating is caused by the combination of radiant energy emitted by the hot cathodes and energy deposition into the foil by the electron beam. The latter effect results from energy transferance from the electrons as the electrons pass through the foil. The actual temperature rise is determined by the energy and rate of energy input, specific heat and thermal conductivity of the window foil, and the efficiency of heat transfer out of the foil by all available radiative, conductive and convective methods. Such foil heating from causes other than beam energy is undesired.

Foil failure defining the maximum allowable temperature usually occurs when high temperature reduces the mechanical strength to the point where the high pressure outside the electron gun ruptures the foil. In extreme cases of heating it is also possible to melt the foil.

Because of the limitation described above, it has been necessary to operate at relatively low average current densities, typically less than about 100 microamperes/cm^2 after the foil.

Where beam scanning devices are utilized, nonuniform dosing rates result in terms of energy profile since lower energy electrons are scanned over a wider distance. This results in uneven dosage of the material being processed.

Another disadvantage of known systems in addition to the foil problem is the fact that thermionic cathodes, particularly large area ones, consume considerable power. Furthermore, continuous (CW) operation requires that the high voltage be continuously applied to the cathode, with increased probability of window or cathode damage due to sparking.

Another disadvantage of hot cathodes is their need for high vacuum (10^{-6} torr) environments and their susceptibility to contamination, whereas plasma cathodes operated in the 10^{-4} torr region are not susceptible to contamination.

A cold cathode electron gun has been developed to produce electron beams for use in electron beam lasers. This gun uses a "cold" cathode or perhaps more properly a "plasma" cathode. The publication of G. Loda and T. DeHart entitled "Investigation of Pulsed Cold Cathode Electron Guns for Use as a Laser Discharge Sustainer", DNA 2777F, May 1972, describes the development of this cathode and the physical principles of its operation. A typical cathode configuration consists of strips of a metal foil such as tantalum mounted with their edges facing the window foil. The foil, support structure, or a screen inside the support structure is used as an anode. Other materials can be used for cathodes, for example stainless steel razor blades, steel needles, etc. A high voltage pulse, typically 100 keV to 300 keV, is applied between the cathode and anode. Microscopiec surface structure, sometimes referred to as needles, on the cathode explode because of the high current density which they start to emit, and the plasma resulting from the explosion rapidly spreads and forms a large area cathode region in space, adjacent to the physical cathode. When this occurs, electrons are drawn from the plasma region and flow toward the anode, the magnitude of the current density being determined by the law of space-charge limited current flow, i.e., the current density is proportional to the three halves power of the voltage and inversely proportional to the second power of the anode-cathode spacing. The electron beam is then extracted from the gun through the thin foil window as previously described.

This type of electron gun has the advantages that, because thermionic cathodes are not employed, no filament power supply is required; no provision for scanning the beam is required; the radiant energy emitted from the cathodes is negligible as it affects the window foil; and high voltage is applied to the gun only during the time of the current pulse.

A limitation discussed in the Loda and DeHart article is that the maximum pulse duration which can be achieved is limited by the anode-cathode spacing employed and is, therefore, also dependent upon the current density at a given voltage. Typical maximum pulse lengths are on the order of 6 microseconds for the one-shot single pulse electron guns which have been used for electron beam lasers. Such guns are operated at about 1 pulse per minute or slower. Such one-shot or single pulse operation would not in general be useful for materials processing applications because of the long time which would be required for completion of the processing at slow repetition rates. Furthermore, most processes are dose rate dependent and single pulse, massive dose operation is not an effective radiation technique.

SUMMARY OF THE INVENTION AND OBJECTS

It is the general object of the present invention to provide an electron beam irradiation system which will overcome the above limitations and disadvantages.

Another object of the invention is to provide a rapidly pulsed versatile cold cathode electron irradiation system which retains the advantages of cold cathode operation particularly in eliminating the need for filament power to drive hot cathodes or electron beam scanning devices.

Another object of the invention is to provide an electron irradiation system of the above character in which the energy distribution as a function of edge-to-edge radiation pattern is substantially uniform.

Another object of the invention is to provide an electron irradiation system of the above character in which the population distribution of energies of the beam are controllable and contain an appreciably larger number of lower energy electrons than prior art devices.

Another object of the invention is to provide a system of the above character which is compact and reasonable to construct.

It has now been found that by rapidly pulsing such cold or plasma cathode type electron gun, that the same can be successfully adapted to material irradiation applications when constructed and operated in accordance with the present invention. More specifically, it has been found that the rapid pulsing of the cold-cathode structure at voltages of approximately 100 keV to 300 keV and for pulse length periods of greater than 1 microsecond, at 1 to 10 kHz repetition rate produces a very effective irradiation tool, the output of which can be formed of an expanded wide area electron beam capable of useful irradiation of materials conveyed past the output of the gun at useful processing speeds. The results produced are substantially equivalent to that obtained with continuous (CW) operation of prior art hot cathode systems. In one form of the invention the cold cathode structure is formed in cylindrical geometry using a grounded conductive elongate outer shell forming a vacuum chamber and having an electron permeable window at one side which serves also as an anode for the structure. Means forming a sharp-edged cathode are disposed approximately centrally within the outer shell and is aligned with its major axis. The cathode structure's edge is directed towards the electron permeable window so as to emit electrons toward the same when suitably pulsed. Preferably, a screen is disposed between the cathode, but at a reduced voltage. The cathode and screen configurations are arranged to produce splaying of the electrons emitted so as to spread the resultant beam over a significant area and hence to provide a wide area of coverage of approximately uniform distribution over the window. A high voltage pulse forming network is disclosed for producing pulses of the voltage range, duration and repetition rates set forth herein. In another form of the invention, multiple guns surround the material to be treated such as plastic coated electrical cable, the conductor of the cable or other means serving as an anode. In this form, the device may or may not have a foil window, depending upon the vapor pressure of the material being irradiated.

These and other objects and features of the invention will become apparent when taken with reference to the accompanying detailed description, claims and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of a complete system for electron beam irradiation of materials constructed in accordance with the present invention.

FIG. **2** is an isometric view, partially cut away and partially shown in phantom, illustrating the electron beam cold cathode gun constructed in accordance with the present invention.

FIG. **3** is a cross-sectional view of the cathode support portion of the apparatus of FIG. **2** taken along the lines **3—3** thereof.

FIG. **4** is a cross-sectional view of the screen support portion of the apparatus of FIG. **2** taken along the lines **4—4** thereof.

FIG. **5** is an electrical diagram illustrating the pulse forming circuit utilized in the present invention for driving the electron gun.

FIG. **6** is a graph showing the energy distribution of the electron gun of the present invention and illustrates the same in comparison with the typical energy distribution of hot cathode prior art devices.

FIG. **7** is a cross-sectional view of another embodiment of an electron gun constructed in accordance with the present invention and particularly adapted for irradiation of elongate materials such as plastic cable or the like.

FIG. **8** is a side elevational view in cross-section of the apparatus of FIG. **7.**

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now more particularly to the system set forth in FIG. **1,** there is shown an electron beam irradiation system constructed in accordance with the present invention generally consisting of an elevated support structure **10** having upper and lower levels **12, 14,** from the upper of which a cold cathode electron gun **16** is suspended on rails **18.** The upper level **12** of the support structure houses a high voltage pulse modulator **20** to be hereinafter described and which is connected downwardly through high voltage bushings **22, 24** and **26** to the electron gun **16.** On the lower level **14** there is provided a vacuum system **28** which is connected through one side and wall of the electron gun. At another side of the lower level of the structure there is provided a control panel **30** and associated circuits for establishing the various pulsing parameters to be used by the system, including the strength of the applied pulse, its shape, duration and repetition rate as well as other adjustments to prevent ringing and to provide a proper match between the high voltage pulsing network and the impedance presented by the electron gun.

Referring now to FIGS. **2–4,** the electron gun is shown in detail and consists of an outer cylindrical conductive member **32** forming an outer shell together with suitable end walls **34** forming a cylindrical vacuum tight chamber terminating in a generally planar lower face incorporating an electron window **36** which may, if desired, be water cooled. Means partially shown with portions broken away in FIG. **1** and indicated in FIG. **2** are provided for carrying material to be irradiated on a belt **38** below the window and running on roller support means **40** generally in a continuous manner through the lower level of the apparatus as shown.

High voltage bushing **24** serves to support a cathode assembly **42** and to conductively connect the same to high voltage pulse source **20,** while high voltage bush-

ings **22, 26** support a control grid screen **44** and conductively connect it to a somewhat lower voltage tap also provided by high voltage pulse source **20.**

Referring now more particularly to FIG. **3,** the detailed configuration of the cathode and its support structure bushing **24** will now be set forth. The cathode comprises an elongate strip **46** of conductive metal, such as tantalum or stainless steel, terminating in a downwardly projecting edge **48.** Since the cathode is expected to require replacement from time to time due to material loss from electron emission, it is set in a replaceable cathode holder **50** having a cylindrical shape and mounted to a vertically extending cathode carrying conductive sleeve **52.** Push rod means **53** are provided for conductively connecting the cathode to the output of the high voltage supply and also serves as part of means for adjusting the height of the cathode relative to other elements of the structure. This arrangement permits adjustment of cathode position throughout operation to compensate for cathode erosion during life. The push rod **53** is, therefore, slideably adjustable within a suitable mounting **54** at generally indicated at **54** located within the high voltage pulse forming supply.

A high voltage insulative bushing **56** is mounted to the upper support structure and carries at its lower end a cathode housing support flange **57.** Thus, bushing **56** is rigidly affixed at its upper end in sealing relation to an upper mounting flange **58** forming a vacuum tight wall which prevents leakage of insulative oil **59** from within the bushing into the chamber in cooperation with bellows seal **60** to be described. A cathode assembly adjusting sleeve **62** depends from flange **57** and is a replaceable member having a length which may be changed so as to vary the overall position of the cathode housing within the chamber. The lower end of the sleeve **62** terminates in a cathode housing holder and flange **64** upon which an upstanding helical spring **66** rests, its upper end engaging flange **68** on an inner sleeve member **70** to which the cathode **46** and cathode holder **48** are attached. Bellows seal **60** surrounds the lower end of the push rod **53** and is sealed at its ends **60*a*, 60*b*** to flange **57** to provide the vacuum oil barrier between the oil filled bushing and the chamber. The flange **64** at the lower end of the cathode assembly supports a cathode encircling housing **65** which is a cylindrical member surrounding the cathode and having a slit **68** at its lower side for permitting the cathode to project downwardly. The cathode housing **66,** the cathode holder **50,** and the cathode **46** together with the inner sleeve and supporting block and push rod are electrically connected and, therefore, assume the same voltage whenever a high voltage pulse is impressed upon the push rod. Adjustment of the overall position of the assembly is accomplished by substitution of the adjusting sleeve **62** while the amount of projection of the cathode blade from the lower end of the cathode housing **65** is controlled by the push rod itself acting downwardly against bonds **69** provided in the inner sleeve, which in turn carries the upper, flanged portion **70** of the sleeve in compression against the spring.

In some applications it may be desired to modify the electric field configuration for which purpose additional outboard beam forming electrodes **72, 74** of various shapes may be supported and electrically connected to the cathode housing to control spread of the beam. In general, the foregoing elements together form a multiply adjustable cathode positioning assembly capable of transmitting high voltage pulses therethrough and also permitting relative adjustment of the cathode blade projection from and elevation of the housing with respect to the screen grid and the window.

Cylindrical screen grid **44** surrounds the cathode structure and is carried by high voltage bushings **22, 26** having fixed height adjustment and positioned, for example at locations spaced from and on each side of the cathode carrying assembly **24,** as shown in FIG. **2.** FIG. **4** illustrates one form of suitable construction in which an insulative bushing **76** supports a sealing and support oil filled flange **78** at its lower end to which the cylindrical screen grid is attached. A rod **80** carries the high voltage pulse to the grid.

Referring now to FIG. **5,** the pulse forming circuit and connections thereof are schematically shown. Thus, a high voltage power supply **80** is connected to drive a pulse modulator **82** which feeds a pulse transformer tank **84** and together producing a negative going pulse in the range of from 100 to 300 keV at the output. This pulse is shown at the secondary **86** of the transformer tank and is connected through the high voltage cathode bushing **24** to the cathode structure. The housing and window of the electron gun are grounded as the other one end of the transformer tank secondary. Adjustable taps **88** are provided for supplying a somewhat lower voltage pulse to the screen grid **44** through high voltage bushings **22, 26.** The screen serves to control the radiation pattern geometry and is found to permit the cathode to window spacing to be much smaller, and therefore, the entire structure to be more compact, simpler and more inexpensive to build.

By changing the cathode-to-grid voltage difference and/or the grid-to-cathode spacing, a range of useful values of current density (J) can be obtained.

Adjustment of pulse shape, as by modification of the rise time or actual shaping to non-square configurations also affects the energy distribution of the resultant beam. For electron beam radiation processing, a wide range of energies, containing a large fraction of lower energy radiation is desirable. As shown in FIG. **6,** curve **95** represents an approximated energy distribution of the beam of the present invention. Whereas curve **97** illustrates the output of a typical DC type device, curve **95** indicated an increased and much improved lower energy profile.

A control circuit **90** is connected to the high voltage pulse supply **80** and modulator **82** to provide adjustment of the output pulse strength, duration and repetition rate.

Thus, the current density and beam spread produced by the present invention is controllable by adjustment of cathode to anode distance d and cathode projection **1** as well as by adjustment of cathode grid voltage, pulse strength, duration and repetition rate. The following ranges of values will permit a satisfactory dosage to be obtained for a wide variety of materials to be processed:

Voltage strength	100–500 keV
Pulse length	0.1–10 microseconds
Repetition rate	1 pps – 10 k pps
Rise time	Approximately .1 microsecond
Cathode to screen potential	1–200 keV
Average power consumption	25–250 kilowatts

Examples of construction sized for the above electrical parameters are as follows:

Chamber 34 diameter	24 inches
Screen 44 diameter	12 inches
l	from 0 to ½ inch
d	from 2½ to 4½ inches

Referring now to FIGS. **7** and **8**, there is shown a modified form of the invention, especially adapted to the irradiation processing of elongate materials, either generally circular or ribbon-like in cross-sectional shape, such as plastic coated wire and cable and such material embodying a conductor or having a conductor associated therewith to serve as an anode. In the following description, parts which are the same in structure and function as those of the apparatus of FIGS. **1** through **5** have been given like numbers with the addition of a prime so that the detailed description given heretofore of the electron gun structure will be immediately applicable and further detailed description unnecessary.

A chamber **130** having an outer cylindrical wall **132** supports a plurality (i.e., four) of cold cathode electron guns **134, 135, 136, 137** arranged about an axis **138** from which the guns are equidistant and towards which they are directed. Each of the guns is identical in structure to that described in connection with FIGS. **1** through **5.** The ends of the chamber are closed by suitable walls **140, 141** for establishing a vacuum tight enclosure having end ports **142, 144** aligned on the axis **138.** Piping **145** serves to connect the chamber to a suitable vacuum supply. Inlet and outlet chambers **146, 148** of similar construction are provided and consist of elongate small enclosures having end openings **150, 152** aligned on the axis **138** of chamber **130** and opening into the chamber through ports **142, 144.**

Each of the inlet and outlet chambers are connected to a vacuum supply through piping **154, 156.** However, openings **142, 144** and **150, 152** are of sufficient size that the product passing therethrough does not frictionally engage the openings, the vacuum in chamber **130** being roughly maintained by differential pumping effect provided by the inlet and outlet chambers notwithstanding the evident leakage.

Means such as rollers **158** or guides are provided for passing the product to be irradiated through openings **150, 142, 144, 152** and along the axis of chamber **130** and for taking up the product from the outlet chamber **148** at the other end of the apparatus. Such means in the case of wire cable which can be easily tensioned merely consists of guide rollers to establish the proper orientation of the material as it passes through treatment. In the case of material requiring additional support, such means could take other forms such as belting and the like.

A cylindrical screen grid **160** surrounds the axis of the chamber and is, accordingly, geometrically relocated from that shown in FIGS. **2** through **5.** However, the support structure **76'** for the screen grid is identical to that previously described.

Means are provided for obtaining an anode structure disposed along the axis of the chamber **130.** In the case of irradiation of cable containing conductive wire, the conductive wire may be grouned at either end and, therefore, can serve as an anode for the device. If the material is non-conductive, a cylindrical shell of conductive material, such as titanium foil, can be mounted to surround the axis and, therefore, serve as an anode. If the material has a vapor pressure too high for treatment in vacuum, a cylindrical foil window can be installed and the material passed through the center thereof. A third voltage level can be applied to the conductive wire of the cable to act as the final anode for the electron. The operation of the device is otherwise the same as that previously set forth in connection with the operation of the apparatus of FIGS. **1** through **5.**

It will be seen from the above description that a highly effective and comparatively simple method and apparatus have been provided for the irradiation treatment of materials. While the invention has been disclosed by setting forth particular examples of structures, it should be understood that many modifications and changes will occur without departing from the spirit and scope of the invention set forth herein. For example, while a single elongate blade is illustrated as forming a cathode in the device as illustrated, it should be understood that a plurality of elongate blades aligned end-to-end or side-by-side or a plurality of projections such as steel needles and the like could be substituted for the single blade disclosed with suitable mounting modifications and without departing from the present invention. Accordingly, the invention set forth herein should be taken in a general sense and limited only by the scope of the accompanying claims.

We claim:

1. In an electron irradiation processing apparatus, means forming a vacuum chamber, means forming an electron discharge device disposed in said chamber, a high voltage power supply including means for pulsing said electron discharge device at a rate greater than about 1 pulse per second, a cold cathode capable of plasma emission of electrons disposed within said electron discharge device, means forming a high voltage bushing connecting said power supply to said cathode, said cathode including means forming a cathode housing having a generally elongate cylindrical configuration said housing having an elongate slit therein, means forming an elongate electron emissive edge projecting through said slit and directed toward a predetermined location, and means for adjusting the position of said edge relative to said housing; means forming an anode along the area at said location, means connecting said anode to said power supply, whereby electrons are caused to be emitted from said cathode as extended streams along the length of said cathode and splayed over the area of said anode without scanning, means for adjusting the distance of said cathode toward and away from said location, and means for passing a material to be treated through said predetermined location.

2. An apparatus as in claim **1** further including means of forming a screen grid interposed between said cathode and said location, and means connecting said screen grid to said high voltage source for being pulsed therewith at a voltage lower than said cathode.

3. Apparatus as in claim **1** in which said high voltage power supply includes control means adapted to operate said supply to deliver an output having the following ranges, 100 to 500 kiloelectron volts, repetition rate 1 pulse per second to 10,000 pulses per second, pulse length 0.1 microsecond to 10 microseconds.

4. Apparatus as in claim **1** further including an electron transmissive window disposed between said location and said cathode, said window being electrically conductive and connected as an anode for electrons emitted from said cathode.

5. Apparatus as in claim 1 further including means for adjusting the distance of said cathode toward and away from said location.

6. A method for the electron irradiation of material utilizing a cold cathode electron gun disposed in electron irradiation processing apparatus of the type including means forming a vacuum chamber, means forming an electron discharge device disposed in said chamber, a high voltage power supply including means for pulsing said electron discharge device, a cold cathode capable of plasma emission of electrons disposed within said electron discharge device, means for forming a high voltage bushing connecting said power supply to said cathode, and further in which said cathode includes a cathode housing having a generally elongate cylindrical configuration in which is disposed means forming an elongate electron emissive edge projecting through a slit within said cylindrical housing and directed toward a predetermined location and means for adjusting the position of said edge relative to said housing comprising the steps of pulsing said cathode with pulses having the following characteristics, voltage strength 100 to 500 keV, pulse length greater than 0.1 microsecond, repetition rate 1 to 10^4 pulses per second, and passing a material to be treated by radiation through said predetermined location.

7. The method as in claim 6 in which said apparatus further includes a screen grid disposed between said cathode and said location and including the step of pulsing said screen grid in synchronism with said cathode at a potential 1 to 2 keV less than said cathode.

8. In electron irradiation processing apparatus for treatment of elongate material, means forming a vacuum chamber, means for passing material to be treated through said chamber and along a predetermined path therein, means forming a plurality of electron discharge devices disposed in said chamber, a high voltage power supply including means for pulsing said electron discharge devices at a rate greater than about 1 pulse per second, each said electron discharge device including a cold cathode capable of plasma emission of electrons, means forming a cathode housing having a generally elongate cylindrical configuration and including means forming an elongate slit therein, means forming an elongate electron emissive edge projecting through said slit and directed towards said predetermined path, means for adjusting the position of said housing relative to said edge, and means forming a high voltage bushing connecting each of said housing forming means and said edge forming means to said power supply.

9. An apparatus as in claim 8 further including means of forming a screen grid surrounding said path, and means connecting said screen grid to said high voltage source for being pulsed therewith at a voltage lower than said cathode.

10. In an electron irradiation processing apparatus, means forming a vacuum chamber, means forming an electron discharge device disposed in said chamber, a high voltage power supply including means for pulsing said electron discharge device at a rate greater than about 1 pulse per second, a cold cathode capable of plasma emission of electrons disposed within said electron discharge device, means forming a high voltage bushing connecting said power supply to said cathode, said cathode including means forming a cathode housing having a generally elongate cylindrical configuration said housing having an elongate slit therein, means forming an elongate electron emissive edge projecting through said slit and directed toward a predetermined location, and means for adjusting the position of said edge relative to said housing; means forming an anode along the area at said location, means connecting said anode to said power supply, whereby electrons are caused to be emitted from said cathode as extended streams along the length of said cathode and splayed over the area of said anode without scanning, and means for passing a material to be treated through said predetermined location.

11. A method for the electron irradiation of material utilizing a cold cathode electron gun disposed in electron irradiation processing apparatus of the type including means forming a vacuum chamber, means forming an electron discharge device disposed in said chamber, a high voltage power supply including means for pulsing said electron discharge device, a cold cathode capable of plasma emission of electrons disposed within said electron discharge device, means for forming a high voltage bushing connecting said power supply to said cathode, and further in which said cathode includes a cathode housing having a generally elongate cylindrical configuration in which is disposed means forming an elongate electron emissive edge projecting through a slit within said cylindrical housing and directed toward a predetermined location, comprising the steps of pulsing said cathode with pulses having the following characteristics, voltage strength 100 to 500 keV, pulse length greater than 0.1 microsecond, repetition rate 1 to 10^4 pulses per second, and passing a material to be treated by radiation through said predetermined location.

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