

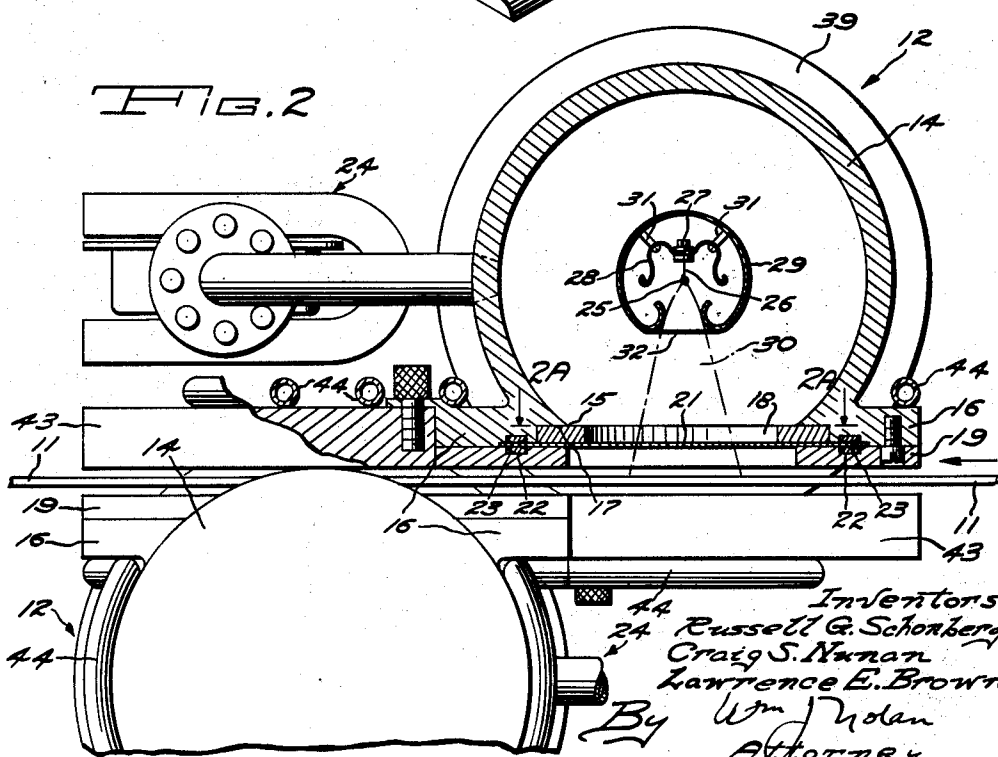
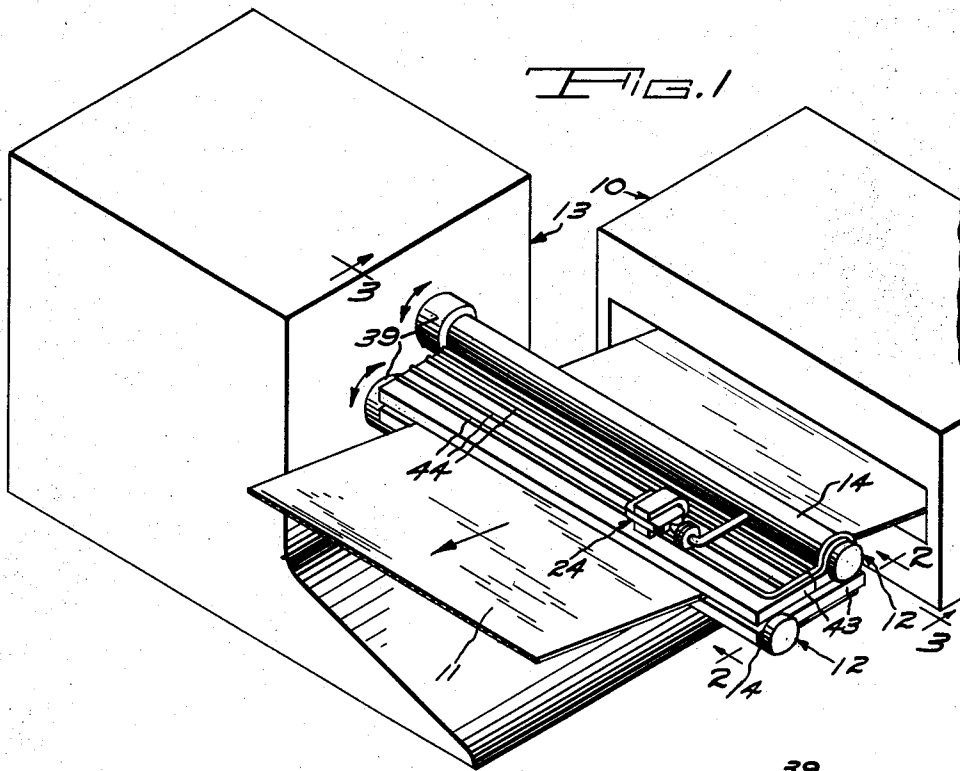
Aug. 11, 1964 **R. G. SCHONBERG ETAL** **3,144,552**
APPARATUS FOR THE IRRADIATION OF MATERIALS WITH A PULSED
STRIP BEAM OF ELECTRONS
Filed Aug. 24, 1960 **4 Sheets-Sheet 1**

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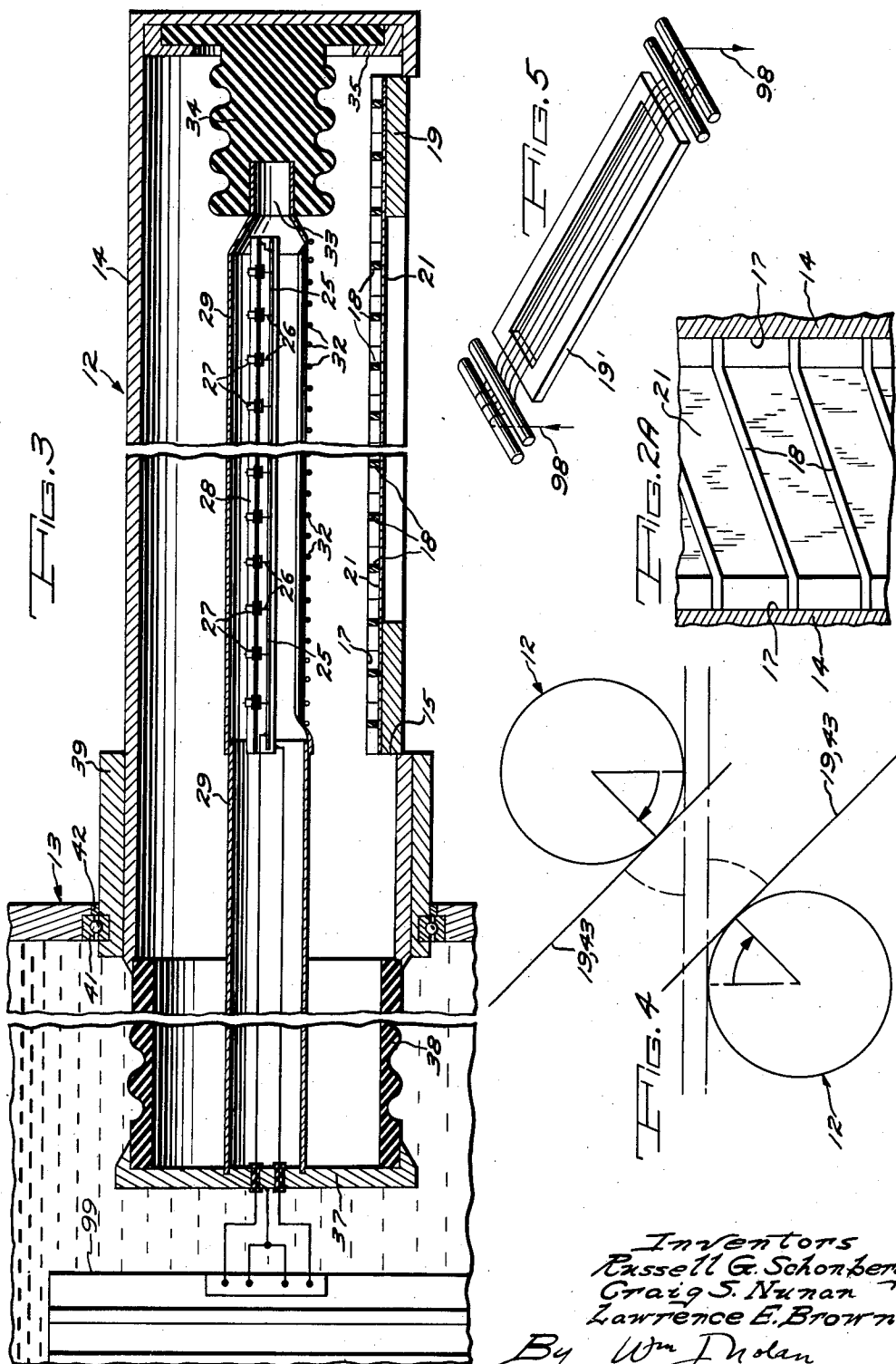
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4 Sheets-Sheet 2



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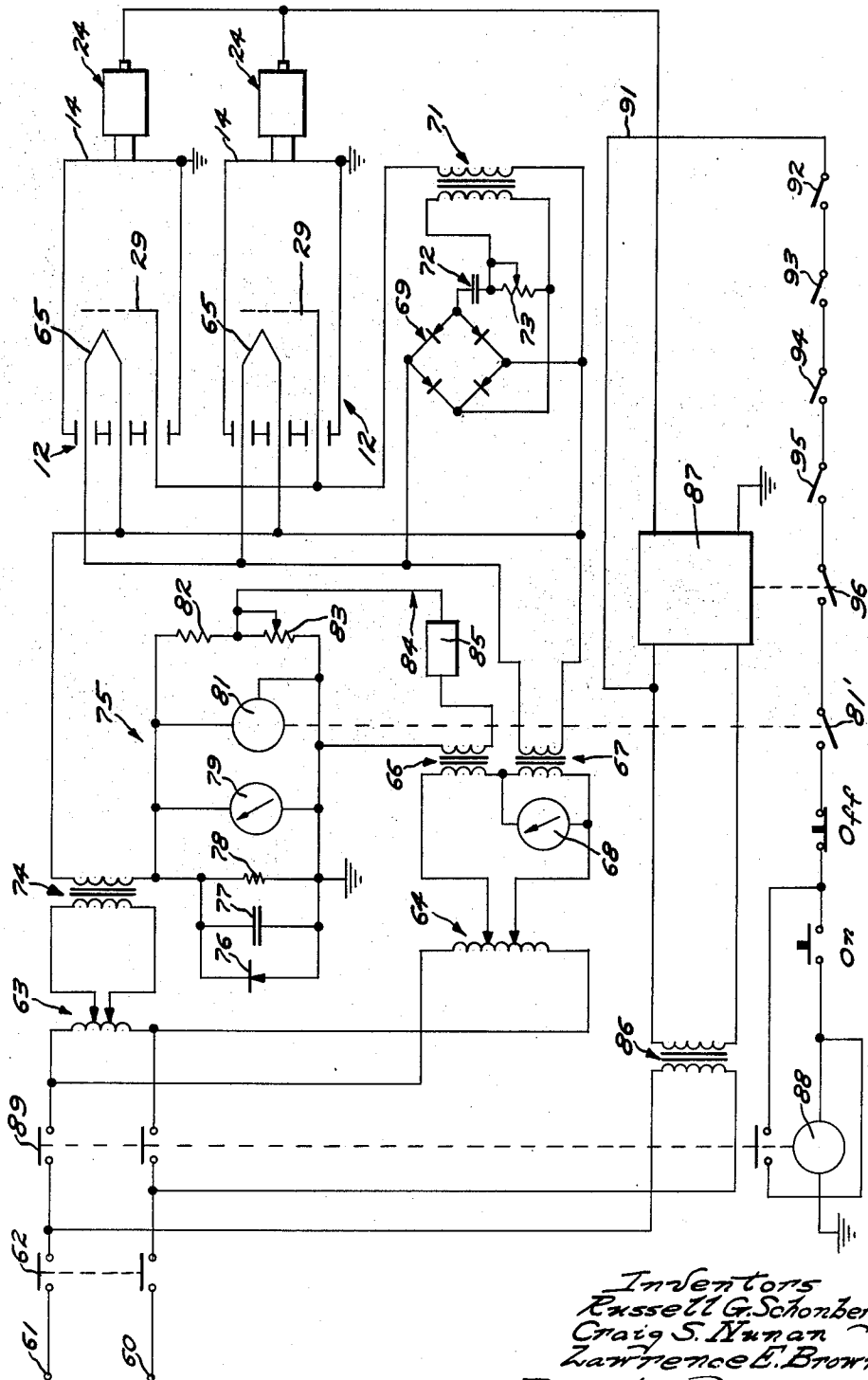
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FIG. 6



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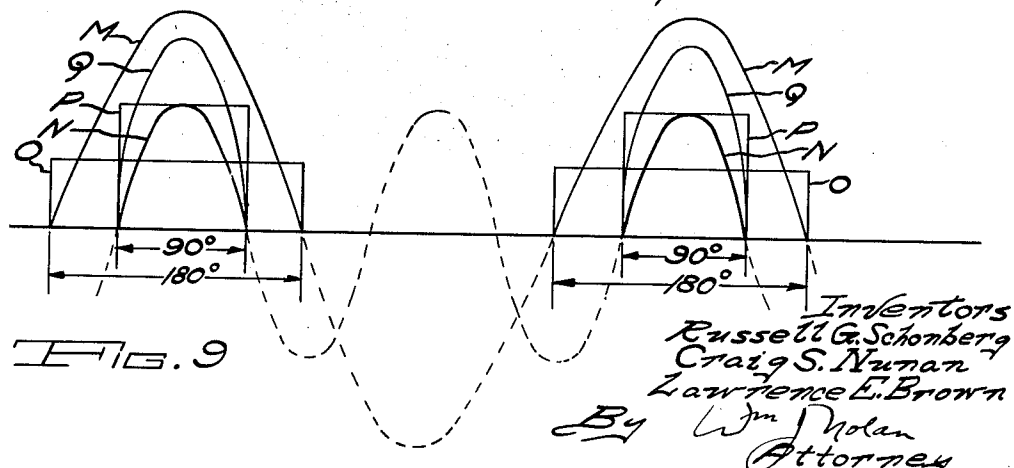
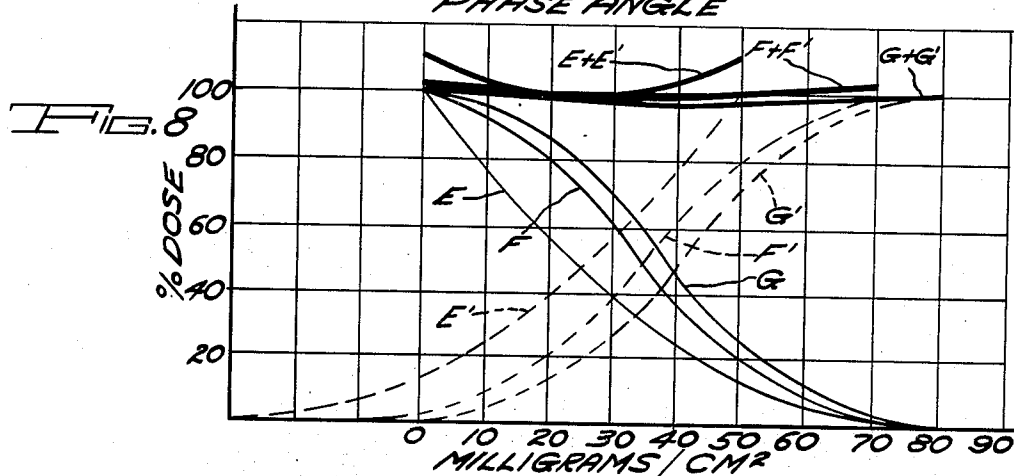
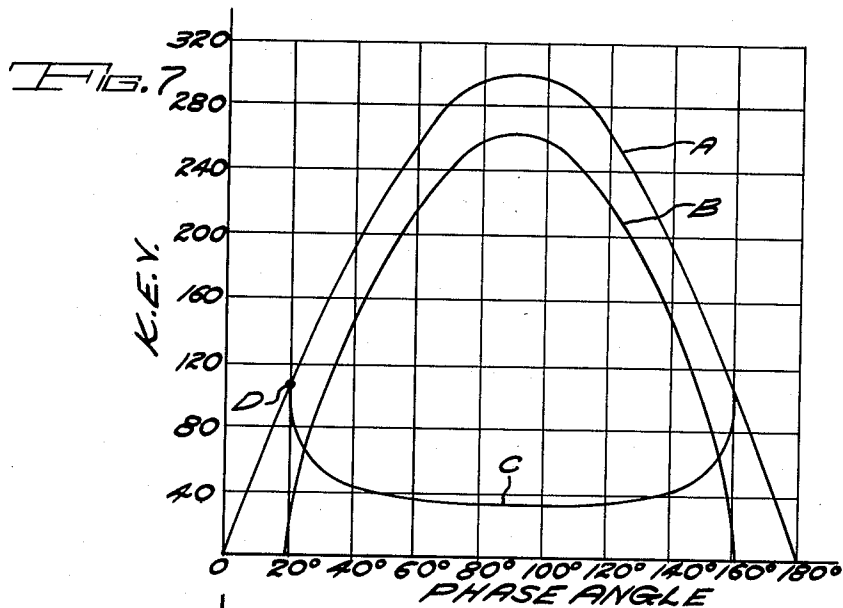
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APPARATUS FOR THE IRRADIATION OF MATERIALS WITH A PULSED STRIP BEAM OF ELECTRONS

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Filed Aug. 24, 1960, Ser. No. 51,599
13 Claims. (Cl. 250—49.5)

The present invention relates in general to particle irradiation devices and more particularly to methods and apparatus for irradiation of relatively thin layers of material.

It is known that irradiation of polymers by high speed electron beams causes polymerization, polymerization grafting, cross linking of certain polymer chains, and scission of certain molecular chains. This can create materials which are stronger, have a greater melting point or greater elasticity. Also, irradiation of certain semiconductors serves to increase their efficiency.

In the past, irradiation to achieve the mechanisms stated above have been performed by means of scanning the high energy pencil beam from electron beam machines such as Van de Graff generators, resonant transformers, linear accelerators, and the like. The pencil beam itself has a circular cross section which is typically on the order of one centimeter in diameter. An individual molecule is in the pencil beam for only a brief instant during each scan and the dose rate during this brief instant is many times higher than the average dose rate. It has been observed that the efficiency of polymerization grafting decreases as the dose rate increases. There is evidence to indicate that the same degree of polymerization grafting can be achieved by a given average power of unscanned continuous irradiation as can be achieved with many times this power using a scanned pencil beam. Hence, a device which produces a broad area unscanned beam can radiation process certain chemical systems far more economically than is possible with present systems employing high energy scanned pencil beams.

The object of the present invention is to provide novel methods and apparatus for applying a large dose of relatively low energy particles uniformly to a relatively thin layer of material without scanning the particles beam across the material.

One feature of the present invention is the provision of a novel method of irradiating a material with a strip beam whereby a cumulative irradiation dose is applied to the material without scanning the strip beam.

Another feature of the present invention is the provision of a novel method for irradiating a thin layer of material by generating oppositely directed strip beams and passing the material to be irradiated transverse to these beams whereby a cumulative irradiation dose is applied to opposite sides of the material without scanning the strip beam or turning the material over.

Another feature of the present invention is the provision of a novel strip particle beam generator including a particle emitter, focusing means for focusing particles emitted from the filament into a strip beam extending the entire length of the filament and accelerating means for accelerating the strip beam in the direction of a material to be irradiated.

Another feature of the present invention is the provision of a novel strip particle beam generator including means for generating a first strip beam, means for generating a second strip beam, and means for passing the material to be irradiated transverse to said beams whereby opposite sides of the material are continuously exposed to a strip beam for applying a cumulative irradiation dose thereto.

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Another feature of the present invention is the provision of a novel strip beam generator of the last aforementioned feature including a particle permeable window for passing the strip beam from vacuum onto the material to be irradiated in atmosphere and metallic support members positioned transversely of said window to support and carry heat away from said window.

Another feature of the present invention is the provision of a novel strip beam generator including means for generating a first strip beam and means for generating a second strip beam and wherein the axes of the means for generating the two beams are separated by both a horizontal and a vertical distance and said beam generating means are rotatable about their axes whereby the space to accommodate the material to be irradiated can be changed so that materials of different thicknesses can be passed therethrough.

Still another feature of the present invention is the provision of a novel method for generating a pulsating high voltage strip beam including the steps of providing a first pulsating voltage between a filament and an anode, providing a second pulsating voltage between said filament and an intermediate electrode located between said filament and said anode and wherein said second pulsating voltage is a second harmonic of said first pulsating voltage and the phase relation between said voltages is adjusted such that a positive half cycle of said second pulsating voltage occurs during the mid-portion of the positive cycle of said first pulsating voltage.

Other features and advantages of the present invention will become more apparent upon a perusal of the specification taken in conjunction with the accompanying drawings, wherein:

FIG. 1 is an isometric view of a low energy electron discharge device embodying features of the present invention.

FIG. 2 is an end view partially in section of the irradiation heads of FIG. 1 taken along line 2—2 in the direction of the arrows.

FIG. 2A is a plan view of the window structure taken along line 2A—2A in FIG. 2.

FIG. 3 is a cross sectional view of a portion of the structure shown in FIG. 1 taken along line 3—3 in the direction of the arrows.

FIG. 4 is a schematic view showing the manner in which the irradiation heads shown in FIGS. 1—3 can be rotated to change the width of the space therebetween.

FIG. 5 is an alternative embodiment of the present invention.

FIG. 6 is a circuit diagram for a strip beam generator embodying features of the present invention.

FIG. 7 is a graph of electron energy in k.e.v. plotted for the positive half of an alternating voltage cycle with curves representing electron energy arriving at an output window, electron energy outside the window, and electron energy lost in the window.

FIG. 8 is a graph of percentage of dose plotted versus depth for a number of different current wave forms for a material irradiated from both sides, and

FIG. 9 is a schematic representation of possible voltage and current wave forms for a strip electron beam generated by an irradiation machine embodying features of the present invention.

The particular irradiation machines depicted in the drawings and described in the following specification are especially designed for directing a strip beam of electrons onto the object to be irradiated. However, features of the present invention are equally applicable to irradiating machines for irradiating objects with other particles such as, for example, protons, neutrons and deuterons.

Referring now to FIGS. 1—3 a thin layer of material to be irradiated is passed by means of a roller mechanism

generally indicated as 10 between two identical evacuated irradiation heads 12 positioned so as to irradiate opposite sides of the material 11. The irradiation heads 12 are rotatably supported from one side of an enclosure 13 housing a large voltage transformer 99 in an insulating oil bath for providing energy to the electrons for irradiation of the material 11.

Each irradiation head 12 includes a long hollow tube 14 serving as an anode, accelerating electrode and provided with a slot opening 15 longitudinally thereof which is surrounded by a flange member 16 spaced from the edge of the slot opening 15 to provide a recess 17 around the perimeter of the opening 15. Positioned within the recess 17 transversely of the opening 15 are a plurality of rib supporting members 18, as of aluminum, these rib supporting members 18 being positioned at a slight angle with respect to a perpendicular drawn between the long sides of the opening 15 (see FIG. 2A). The ribs 18 are bent at their ends as shown to provide lateral stability to the ribs. A window frame 19 is fixedly secured to the flange 16 around the opening 15 to support a particle permeable window 21 as of aluminum, between the window frame 19 and the flange 16 for covering the opening 15. Both the window frame 19 and the flange 16 are provided with mating grooves which completely surround the recess 17, and a deformable gasket 23 as of lead is positioned in each of these grooves 22 whereby the window 21 is vacuum sealed between opposing gaskets 23 to maintain the volume within the irradiation head 13 at a very low pressure.

The volume within each of the irradiation heads 12 is maintained at a very low pressure by means of an electrical vacuum pump 24 of the type described in U.S. Patent No. 2,993,638 to Hall et al. With the low pressure within the irradiation head 12 the thin window 21 is held tightly against and supported by the rib support members 18 positioned across the opening 15. Also, since the rib support members 18 are in intimate contact with the window 21 they conduct heat which has been generated by high energy particles away from the window.

Electron producing elements within each of the tubes 14 include a filament 25 such as tantalum positioned on the axis of the tube 14 and extending substantially the entire length thereof. The filament 25 is supported at short intervals by short support wires 26 which are held within insulating members 27 spaced along the length of a focus electrode 28. The focus electrode 28 is shaped so as to focus particles emitted from the filament 25 into a strip beam 30 directed through the window 21 onto the material 11 passing between the two opposing irradiation heads 12. By way of definition "strip beam" is used to describe a particle beam with a cross section which has one transverse dimension more than twice the other transverse dimension. A typical strip beam is 2½" wide and 3 feet long. An intermediate electrode 29 is supported from the focus electrode 28 by means of a plurality of insulating stubs 31 and surrounds the focus electrode 28 except in the region where the sheet beam 30 is focused toward the window 21. A grid comprising, for example, a plurality of wires 32 can be placed across the opening in the intermediate electrode 29 the length thereof through which the sheet beam 30 passes to improve the modulating efficiency.

One end of the intermediate electrode 29 is tapered to a hollow cylinder 33 and supported in a recess in the end of an insulator member 34 captured against the closed free end of the tube 14 by an annular flange 35. The other end of the intermediate electrode 29 is supported from a metallic end cap 37 which is supported from an insulating cylinder 38, the other end of which is carried on a flange on the end of the tube 14 adjacent the position where the tube 14 is supported by the wall of the enclosure 13.

The tube 14 is rotatably mounted in an aperture in the wall of the enclosure 13 by means of a sleeve 39

fixedly secured about the circumference of the tube 14 and provided with a ball bearing race which cooperates with a series of ball bearings and a similar race secured in the aperture through the wall of the enclosure 13. A sealing gasket 42 provides a seal between the wall of the enclosure 13 and the sleeve 39 to prevent leakage of oil from the enclosure while irradiation heads are free to rotate on a longitudinal axis.

An extension plate 43 is removably attached to the flange 16 on each of the irradiation heads 12 and is positioned in the region in front of the window 21 of the opposing irradiation head 12 to shield the area surrounding the irradiation machine from extraneous radiation which might pass through or around the material 11, or in case particles are emitted from the irradiation head when no material is in front of its window 21. These extension plates 43 can be removed to monitor the output from the opposing irradiation head 12. Both of the irradiation heads 12 are provided with a series of water cooling tubes 44 which serve to cool the irradiation heads. Heat which is usually generated in the window 21 is conducted by means of the support ribs 18 to the tube 14 and flange 16 and thence to the water cooling tubes 44.

The horizontal axes of the two irradiation heads 12 are separated from one another by both a horizontal and a vertical distance whereby the spacing between the opposing irradiation heads can be varied to accommodate different material thicknesses.

The vertical distance between these axes will determine the space between the irradiation heads 12 when the window frames 19 and the extensions 43 lie in horizontal planes. In practice, the vertical distance between opposing irradiation heads 12 is chosen to provide a spacing between the irradiation heads which will accommodate the thickness of material for which the irradiation machine is largely expected to be used. The space is chosen as small as possible to limit the production of ozone by the strip beam in the air gap to a minimum. With the predetermined vertical distance between opposing irradiation heads 12 initially established, the horizontal distance separating the two horizontal axes will determine the maximum separation which can be achieved by rotating the irradiation heads, maximum separation occurring when radii perpendicular to the window of each of the irradiation heads are colinear, as schematically shown in FIG. 4.

The material 11 being irradiated is passed through irradiation heads 12 somewhat askew so that the strip beam 30 makes a slight angle such as 5° with a line running perpendicularly between the edges of the material 11. This prevents any slight irregularities in the uniformity of the irradiation dose across the material 11 due to the fact that the support wires 26 surround the filament 25 and prevent perfectly uniform emission the entire length thereof. Similarly, the support ribs 18 are positioned at an angle with respect to a line straight across the opening 15 to prevent irregularities in irradiation uniformity across material 11 due to absorption of energy by the support rods 18. By changing the angle of feed of the material slightly, the shadowing effect of the bars or ribs 18 can be regulated.

Referring now to FIG. 5, there is shown an alternative embodiment of the present invention wherein materials such as single strand cords 98, insulated wire, etc., can be run lengthwise of the strip beam irradiator head represented by the window frame 19'. The cord or wire 98 twists as it runs back and forth over the irradiator for uniform irradiation.

Referring now to FIG. 6 there is shown a circuit diagram for a typical irradiation machine incorporating the features of the present invention. Two leads 60 and 61 are connected to an external source as, for example, a 440-volt, 60-cycle line and are connected through a switch 62 to a high voltage and a low voltage variable

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transformer 63 and 64, respectively, connected in parallel for supplying high voltage between the filament focus electrode combination 65 and the tube or anode electrode 14 which is at ground potential and a low voltage across the filament-focus electrode combination 65. The secondary circuit of the low voltage variable transformer 64 includes the primary winding of a saturable reactor transformer 66, described in detail below, series connected with the primary of a low voltage transformer 67 for supplying the operating voltage and current to the filament-focus electrode combination 65 in each of the irradiation heads 12. A voltage meter 68 is connected across the primary winding of the low voltage transformer 66 to measure the voltage of the filament-focus electrode combination 65 and thereby give an indication of the power consumed in the filament. The filament-focus electrode combinations 65 for both irradiation heads 12 are connected in parallel across the secondary of the low voltage transformer 67. Also connected in parallel with these filament-focus electrode combinations 65 is a frequency doubler circuit 69 the output of which is connected to the primary of a step-up transformer 71 for providing a high voltage to the electrode 29. A capacitor 72 is connected in series with the primary of the step-up transformer 71 and a variable resistance 73 is provided in shunt with the primary of step-up transformer 71 whereby the phase of the voltage applied to the electrode 29 is properly synchronized with the voltage between the filament-focus electrode combination 65 and ground as described in detail below.

High voltage variable transformer 63 is connected to the primary of the high voltage transformer 74 for providing a high voltage between the filament-focus electrode combination 65 and ground. One side of the secondary of the high voltage transformer 74 is connected to the two filament-focus electrode combinations 65 and the other side of this secondary is connected through circuit controlling means 75 to ground. The circuit controlling means 75 includes in parallel a Zener diode 76 which operates as a voltage limiter, a capacitor 77 which eliminates transients in the line, a resistor 78, a meter 79 for measuring the average beam current, an over-current relay 81 which will turn off the high voltage if the voltage becomes excessive, and fixed and variable resistors 82 and 83, respectively, connected in series for use with a filament current regulator circuit 84 described in detail below.

Filament current regulator circuit 84 includes a line connected between the resistors 82 and 83, connected through a current inverter and amplifier 85 which monitors the average current drawn by the irradiation machine and through the secondary of the saturable reactor transformer 66 to ground. The current passing through the filament current limiting circuit 84 will vary so as to hold the filament current constant by changing the reactance of the saturable reactor transformer 66.

Also, connected in parallel with the primaries of the transformers 63 and 64 is the primary of a control power transformer 86 for providing proper voltage and current to an electrical vacuum pump power supply 87 which supplies power to the electrical vacuum pumps 24 connected to each of the irradiation heads 12.

Circuitry for cutting off the the voltage producing the strip beam is provided in the event that difficulties occur in the operation of the irradiation machine. A line 91 connected from the secondary of the control power transformer 86 to ground is provided with a series of contact switches, and when any one or more of these switches opens, a relay 88 opens a switch 89 cutting off the power to the two transformers 63 and 64 but not the power to the control power transformer 86. The following circuit breaking contacts are provided in the line 91; beam overload contact 92, a cooling water flow contact 93, an overheating contact 94, a door contact 95 triggered when personnel open an access door leading to the immediate

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vicinity of the irradiation machine, contact 96 to indicate a pressure rise in the irradiation heads 12 and operated by power supply 87, and an over-current contact 81' operated by the over-current relay 81 described above.

Referring now to FIGS. 7-9 for the manner in which the voltages are selected to generate the strip beam, FIG. 7 is a plot of electron energy in thousands of electron volts for the positive half cycle of the pulsating voltage applied between the filament and the anode with 300 k.e.v taken in this example as a maximum potential between the filament and the anode. The curve A is a plot of the energy of electrons arriving at the window 21 over this half cycle. Curve B is a plot of the energy of electrons emerging from the window over this first half cycle and the curve C is a plot of the electron energy lost in the window during this first half cycle. It is to be noted that until the electron energy arriving at the window reaches a certain value D such as 100 k.e.v. in this example all electrons will be stopped by the window, and that as the electron energy arriving at the window increases past this point D the energy lost in the window decreases and asymptotically approaches a minimum amount of energy lost in the window during the mid-portion of this half cycle. It is obvious from the above that if current flows in the form of a strip beam during the full half cycle of this pulsating voltage, the efficiency of operation will be low due to the large amount of energy lost in the window. However, if current is only allowed to flow over the quarter cycle positioned midway of the positive half cycle of the voltage wave form, greater efficiency can be obtained.

FIG. 8 is a plot of percentage of dose versus depth of the material being irradiated showing a plot E for the dose versus depth relation when constant intensity current flows during the entire half cycle of the voltage wave form, F is a plot of the dose versus depth relation when constant intensity current flows from a temperature limited filament during a quarter cycle in the middle of the first half cycle of the voltage wave form and curve G is a plot of the dose versus depth relation when current flows from a space charge limited filament during a quarter cycle in the middle of the first half cycle of the voltage wave form. The curves E', F' and G' are plots for irradiation of the material from the opposite side and curves E+E', F+F', and G+G' are plots for the cumulative irradiation when the material is irradiated from both sides. It is evident that the dose versus depth relations for plots F and G are much more desirable than that for E.

In the present irradiation machine a second harmonic voltage is applied to the intermediate electrode 29 by means of circuitry described in FIG. 6 so that the strip beam is generated by this machine only during a quarter cycle and the phase of the second harmonic voltage applied to the intermediate electrode is adjusted such that the quarter cycle on which the beam is generated occurs midway of the positive half cycle of the voltage wave form applied between the filament-focus electrode combination and the anode. This is illustrated in FIG. 9 wherein M is a plot of the pulsating voltage applied between the filament-focus electrode combination and the anode, N is a plot of the second harmonic pulsating voltage applied between the filament-focus electrode combination and the intermediate electrode, O is the square wave current that would be conducted from a current limited filament if the intermediate electrode voltage were not applied, P is the plot of the square wave current which flows from a current limited filament when the intermediate electrode voltage is applied, and Q is the sinusoidal current wave form which flows from a space charge limited filament when the intermediate electrode voltage is applied. Thus, by applying the second harmonic voltage to the intermediate electrode a much more efficient irradiation machine is provided to produce a strip beam for relatively low energy irradiation of materials.

In a typical operation of the present invention, the voltage applied by the high voltage transformer 74 between

the filament-focus electrode 65 and the anode 14 is on the order of 300 k.e.v., the voltage applied across the filament-focus electrode on the order of 200 v. and the voltage applied between the filament and the intermediate electrode on the order of 6,000 v. with 10 milliamperes total emission from each irradiator. The total beam power from two irradiators would be 20 ma. $\times$ 250 k.e.v. = 5,000 watts. A strip electron beam produced with these potentials can irradiate films on the order of 72 milligrams per square centimeter thickness at the rate of 60" per second and threads or wires of approximately 36 milligrams per square centimeter thickness run lengthwise of the strip beams at a rate of 240" per second.

To prevent high voltage gradients from existing between the intermediate electrode and the anode structure, additional intermediate electrode shells successively outwardly increasing in potential could be utilized between the electrode 29 and the anode 14 and still provide a long strip beam for uniform dose irradiation of thin materials.

Such a machine can have many uses for polymerization, polymerization grafting, cross linking and scission. It can be used to fix the twist in cellulose acetate or other polymer fibers, to strengthen and raise the melting point of insulation surrounding electrical wire, to irradiate semiconductors for efficiency improvement, to irradiate resins in Fiberglas matrices and to irradiate many other thin layers of material such as wheat flour, grains, and paint on metal surfaces, etc. Also, liquids and gases may be passed in front of the windows for processing. Also, instead of directing the strip beam through a permeable window it could be directed onto an X-ray target or the like to generate a beam of X-rays for similar uses.

For X-ray use, the window 21 may be made of an X-ray producing material such as, for example, 2 mil thick high strength tantalum or a portion of the tube 14 can be made of X-ray producing material with the tube 14 rotatable with respect to the axis of the filament 25. In the latter case rotation of the tube 14 with respect to the strip beam could change the machine from an electron to an X-ray machine.

It should be noted that a multiplicity of emitters may be utilized in an array and they may be in separate envelopes (as in FIG. 1) or they may be many irradiators in one envelope. In this way the dose rate may be reduced.

Since many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. Apparatus for generating a pulsating strip particle beam for the purpose of irradiating matter comprising a longitudinal particle emitter adapted and arranged to emit particles along the longitudinal extent thereof, focusing means for focusing the particles emitted from said emitter into a strip beam extending the entire length of said emitter and accelerating means for intermittently accelerating particles emitted from said emitter, said accelerating means including an anode, a high voltage alternating current source, and means for coupling said high voltage source between said anode and emitter so that particles are accelerated from said emitter towards said anode only during the half cycle of said source when the anode voltage is greater than the emitter voltage, whereby particles from said emitter are intermittently accelerated to a high velocity for irradiation of matter the acceleration of said particles being limited to the region of said apparatus between said particle emitter and said anode.

2. The apparatus of claim 1 wherein said anode substantially surrounds said particle emitter and is adapted to pass said pulsating strip beam through a longitudinal opening therein and including a particle permeable mem-

ber closing the opening in said anode and a housing surrounding said means for producing high voltage; said emitter, said focusing means and said anode being supported from said housing surrounding said means for producing high voltage.

3. Apparatus for generating a strip particle beam comprising, in combination, a longitudinal particle emitter, focusing means for focusing the particles emitted from said emitter into a strip beam extending the entire length of said emitter and accelerating means for accelerating the particles emitted from said emitter, said accelerating means including a high voltage transformer positioned in an oil bath within a housing, a hollow cylindrical insulating member positioned on the wall of said housing, and extending into said oil bath, and means for closing the interior end of said insulating member whereby reduced pressure can be maintained within said insulating member, said particle emitter being supported on said means closing the interior end of said insulating member whereby high voltages can be connected to said emitter and said accelerating means at the interior end of said insulating member while maintaining reduced pressure on one side and oil bath on the other side of said means closing the interior end of said insulator.

4. Apparatus for irradiating a long material comprising a longitudinal particle emitter adapted and arranged to emit particles along the longitudinal extent thereof, focusing means for focusing the particles emitted from said emitter into a strip beam extending the entire length of said emitter, accelerating means for accelerating the particles emitted from said emitter and means for passing material to be irradiated past said strip beam, said accelerating means including an anode, a high voltage alternating current source, and means for coupling said high voltage source between said anode and emitter so that particles are accelerated from said emitter towards said anode only during the half cycle of said source when the anode voltage is greater than the emitter voltage, whereby particles from said emitter are intermittently accelerated to a high velocity the acceleration of said particles being limited to the region of said apparatus between said particle emitter and said anode.

5. Apparatus for irradiating a long material comprising a first longitudinal particle emitter, focusing means for focusing the particles emitted from said first emitter into a strip beam extending the entire length of said first emitter, accelerating means for accelerating the strip beam emitted from said first emitter, a second longitudinal particle emitter, focusing means for focusing the particles emitted from said second emitter into a second strip beam extending the entire length of said second emitter, accelerating means for accelerating the second strip beam of particles emitted from said second emitter in a direction opposite to the direction of said first strip beam, said accelerating means for accelerating said first and second strip beams including first and second anode means, means for producing a pulsating high voltage between said first and second emitters and said first and second anodes, respectively, a housing surrounding said means for producing high voltage, said first and second emitters, said focusing means, and said first and second anodes being supported from said housing, and means for passing material to be irradiated past said first and second strip beam whereby opposite sides of said material are given a cumulative irradiation dose by said first and said second strip beams.

6. The apparatus of claim 5 wherein said means for passing the material to be irradiated past said strip beam includes directing means for directing the material at an acute angle with respect to a normal to the length of said first and said second strip beams whereby said material is given a uniform irradiation dose.

7. Apparatus for irradiating material with particles comprising beam generating means for generating a first strip beam of such particles, means for generating a sec-

ond strip beam of such particles spaced from and directed in a direction substantially opposite to the direction of said first strip beam, the axis of the means for generating said first and said second strip beams longitudinally of said strip beams being separated by both a horizontal and a vertical distance whereby a material can be passed substantially transversely of said first and said second strip beams and be irradiated on opposite sides by said first and said second strip beams.

8. The apparatus of claim 7 wherein the beam generating means for generating said first and said second strip beams are rotatable about longitudinal axis thereof whereby the beam generating means can be rotated thereby to change the width of the space between the first and the second beam generating means to accommodate materials of different thicknesses for irradiation.

9. The apparatus of claim 7 where each of the beam generating means for generating said first and said second strip beams is provided with a detachable beam stopping portion positioned in the path of the oppositely directed beam generating means and cooling means for each of said beam stopping portions whereby said beam stopping portions limit the volume through which the strip beams pass and upon removal permit monitoring of the strip beam which they oppose.

10. Apparatus for generating a strip beam for the purpose of irradiating matter comprising an elongated particle emitting filament adapted and arranged to emit particles along the elongated extent thereof, a focusing member extending the entire length of said filament for focusing the particles emitted from said filament into a strip beam extending the entire length of said filament, a plurality of insulator members supported on and spaced along the length of said focusing member, a support wire held in each of said insulator members and connected to said filament for supporting said filament in spaced relation from said focusing member, a particle accelerating anode member surrounding and spaced from said filament and said focusing member and provided with an opening therein to pass said strip beam therethrough, a vacuum tight particle permeable window closing off the opening in said accelerating anode member, said accelerating means including an anode, a high voltage alternating current source, and means for coupling said high voltage source between said anode and filament so that particles are accelerated from said filament towards said anode only during the half cycle of said source when the anode voltage is greater than the filament voltage, whereby particles from said filament are intermittently accelerated to a high velocity material passing transversely of said window will be irradiated by said strip particle beam emitted from said emitter and passing through said window the acceleration of said particles being limited to the region of said apparatus between said particle emitting filament and said particle accelerating anode.

11. Apparatus for generating a pulsating strip particle beam for the purpose of irradiating matter comprising a longitudinal particle emitter adapted and arranged to emit particles along the longitudinal extent thereof, focusing means for focusing the particles emitted from said emitter into a strip beam extending the entire length of said emitter and accelerating means for intermittently accelerating particles emitted from said emitter, said accelerating means including an anode and means for producing a pulsating high voltage between said emitter and said anode whereby particles from said emitter are intermittently accelerated to a high velocity for irradiation of said matter and means for passing said matter to be irradiated past said pulsating strip beam with the direction of travel of said matter arranged at an acute angle with respect to a normal to the length of the strip beam.

12. Apparatus for generating a pulsating strip particle beam for the purpose of irradiating matter comprising a longitudinal particle emitter adapted and arranged to emit particles along the longitudinal extent thereof, focusing means for focusing the particles emitted from said emitter into a strip beam extending the entire length of said emitter and accelerating means for intermittently accelerating particles emitted from said emitter, said accelerating means including an anode and means for producing a pulsating high voltage between said emitter and said anode whereby particles from said emitter are intermittently accelerated to a high velocity for irradiation of said matter, and wherein said anode substantially surrounds said particle emitter and is adapted to pass said pulsating strip beam through a longitudinal opening therein and including a particle permeable member closing the opening in said anode and a housing surrounding said means for producing high voltage; said emitter, said focusing means and said anode being supported from said housing surrounding said means for producing high voltage and metallic support members positioned across the opening in said anode on the interior surface of said particle permeable member at an acute angle with respect to a line across the opening in said anode normal to said emitter whereby said support members support and carry heat away from said particle permeable member and the matter on which said strip beam is directed is evenly irradiated.

13. Apparatus for generating a pulsating strip beam comprising an elongated particle emitting filament adapted and arranged to emit particles along the elongated extent thereof, a focusing member extending the entire length of said filament for focusing the particles emitted from said filament into a strip beam extending the entire length of said filament, a plurality of insulator members supported on and spaced along the length of said focusing member, a support wire held in each of said insulator members and connected to said filament for supporting said filament in spaced relation from said focusing member, a particle accelerating anode member surrounding and spaced from said filament and said focusing member and provided with an opening therein to pass said strip beam therethrough, a vacuum tight particle permeable window closing off the opening in said accelerating anode member and means for producing a pulsating high voltage between said filament and said anode member whereby particles emitted from said filament form a pulsating strip beam and pass through said window and material passing transversely of said window will be irradiated by said strip particle beam emitted from said emitter and passing through said window, and means for passing a material to be irradiated past said pulsating strip beam with the direction of travel of said material arranged at an acute angle with respect to a normal to the length of the strip beam.

References Cited in the file of this patent

UNITED STATES PATENTS

1,941,157	Smith	Dec. 26, 1933
2,434,779	Willis	Jan. 20, 1948
2,617,953	Brasch	Nov. 11, 1952
2,724,059	Gale	Nov. 15, 1955
2,810,933	Pierce et al.	Oct. 29, 1957
2,858,442	Dewey	Oct. 28, 1958
2,887,599	Trump	May 19, 1959
2,914,450	Hammesfahr et al.	Nov. 24, 1959
2,972,196	Early et al.	Feb. 21, 1961
2,989,633	Wilson	June 20, 1961
3,013,154	Trump	Dec. 12, 1961