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[54] **ELECTRIFIED PARTICLES GENERATING APPARATUS**

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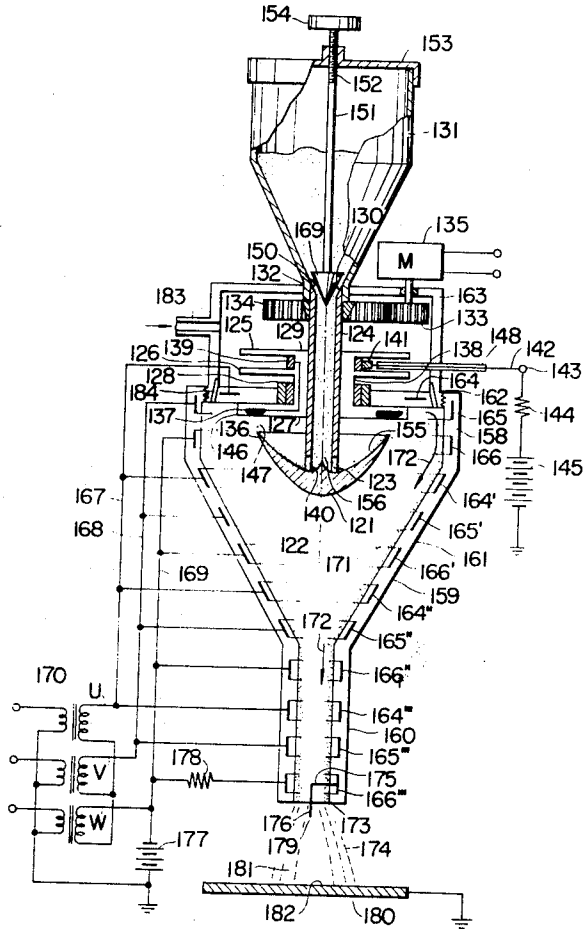
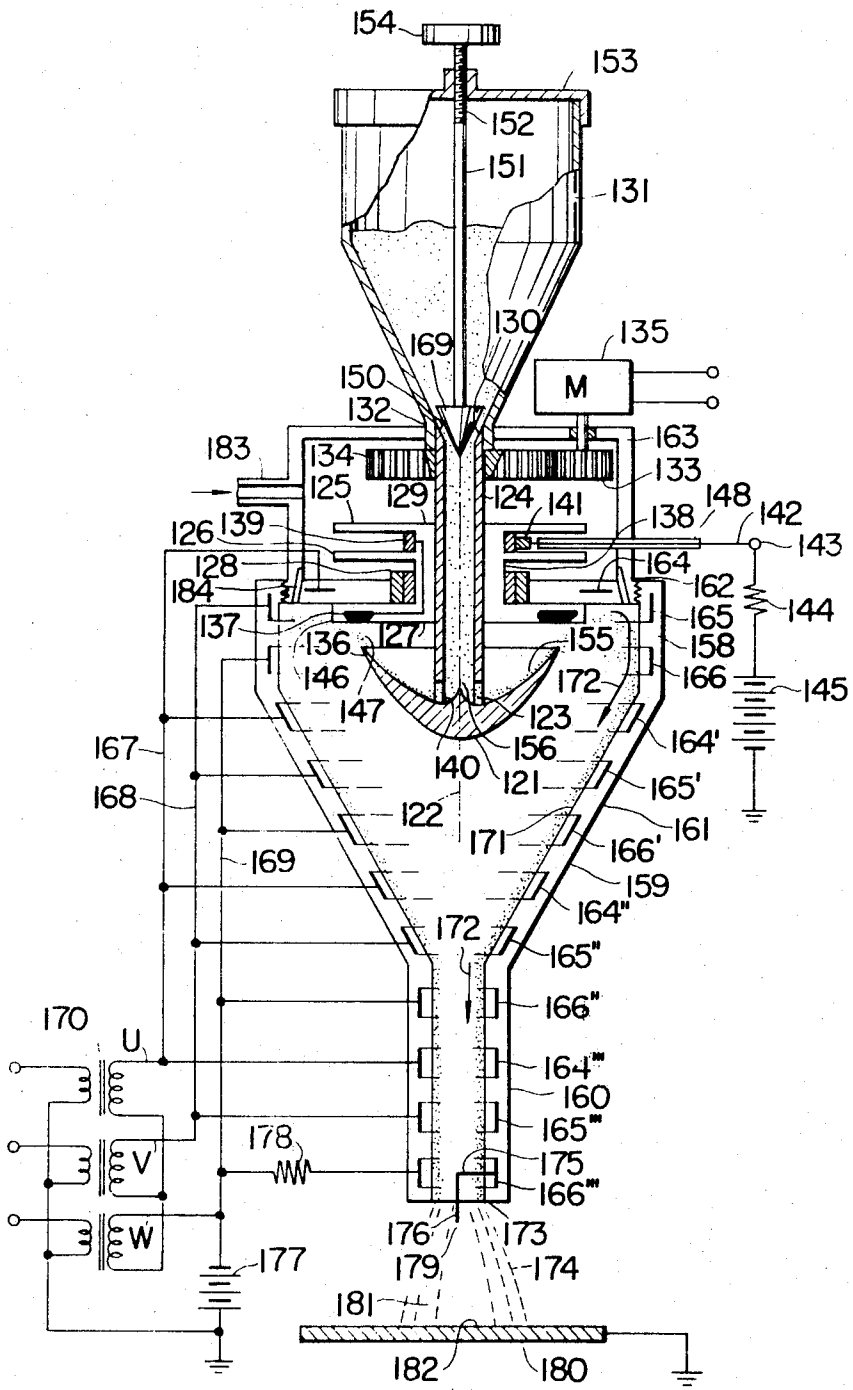
[57] **ABSTRACT**

Particulate material is fed onto a certrifuge constrained to rotate coaxially in the wide upper portion of a funnel-shaped receptacle of insulating material. Particles are centrifugally propelled toward the inner surface of the receptacle through a space at which there is a corona discharge that electrically charges them. Annular electrodes embedded in the receptacle wall at vertically spaced intervals are connected to terminals of an a.c. voltage source to produce a constantly varying electric field that repels charged particles from the wall. Particles are further charged in leaving the bottom outlet of the receptacle, to be electrostatically attracted to an article to be coated with them.

6 Claims, 1 Drawing Figure

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ELECTRIFIED PARTICLES GENERATING APPARATUS

This invention relates to apparatus for effecting controlled movement of powder-like or fine grained particulate material from a source thereof to an article to be coated with the material; and the invention is more particularly concerned with apparatus of that type that is especially suitable for use in electrostatic powder coating processes, wherein the particles of the material must carry an electrical charge in at least the last stage of their movement towards an article to be coated, so that they can be electrostatically attracted to the article.

Up to now in generating electrified particles in space for the purpose of electrostatic painting a method is mainly resorted to in which the particles are dispersed in a gas and made to pass for electrification through an ionic current produced by a corona discharge. However, where the electrified particles generated by this means are to be used in a precise process such as printing, particle classification, drawing, development in electrophotography, electrostatic painting, electrostatic dyeing, production of IC or LSI, etc., the viscous force on the particles of the flowing gas disturbed the action of the electric force and caused the occurrence of errors in the processing.

If the velocity of gas flow was reduced for avoiding these errors, the electric force on the particles passing the corona electric field become effective, and the electrified particles were more powerfully attracted to the electrode opposing the corona electrode and adhered to it or had their trajectories markedly deviated, as the result of which satisfactorily electrified particles did not arrive at the necessary position and defects occurred because only the particles of lesser electric charge were delivered to the areas to be coated.

The object of the invention is to provide an apparatus in which the above defects are overcome and wherein a gas flow need not be utilized, the apparatus being arranged, instead, to generate a beam-like flow of strongly electrified particles and to provide for accurate control of such flow electrodynamically, thus enabling the above mentioned types of processes to be accurately performed.

The above object is, in the present invention, attained in that, by utilizing an electrodynamical action of drawing out the particles by means of an alternating constantly varying electric field, the particles are electrified by contact with other bodies or by mutual contact and are peeled off the opponent of the contact or one another, and are drawn out into a space and then applied to the article to be coated.

In this case as the mating objects for making contact with the dust particles and so producing contact electrification there can be used metals, semi-conductors, dielectrics and other arbitrary suitable bodies. But, from the standpoint of convenience and the quantity of contact needed for the operation of the present apparatus, dielectrics, especially teflon, polystyrol or other organic dielectrics, are preferably to be used.

Further, for generating the electrified particles continuously by the above-mentioned method, a method may be resorted to in which the particles are made to contact with said stationary contact bodies, and are sent slidingly into an alternating unequal electric field portion to be driven out continuously by dint of gravity,

wind velocity, centrifugal force, mechanical force, etc., and, in producing such driving force, said particles and said alternating electric field are made to move relatively and continuously. But by means of a suitable method, the particles are made to adhere to contacting bodies continuously and at the same time the particles adhering to said contacting bodies and the alternating electric field for driving out the particles are made to move relatively.

This relative motion may be achieved by putting the alternating electric field at rest and moving relative to it the contacting bodies to which the particles adhere. But reversely the same object may be attained by letting the latter be at rest and, by forming an electric field curtain of traveling type, as will be shown in detail hereinafter, along the contacting bodies.

By the above-mentioned means, the first object of the present invention, i.e., no use of gas flow, is attained. However the electrified particles thus generated are liable to be dispersed by the mutual Coulomb's repulsive force and to adhere to other bodies by electrostatic induction, and so it is generally very difficult to introduce them into aimed position effectively and without any contact.

In order to overcome this difficulty the present invention utilizes a transporting apparatus of electric field curtain type devised by the inventer. The inventor has found that if a group of electrodes is arranged in insulating relation, in parallel at equal intervals and divided into two groups connected alternately with a single-phase alternating current power source, a series of stationary wave alternating constantly changing electric fields is formed in neighboring relation to each other along said group of electrodes and this has a powerful electro-dynamical repulsive force against the electrified particles and he has named said electric field series an electric field curtain of stationary wave type. Further he has found that if said group of electrodes is divided into n groups by connecting them at intervals to n electrodes, and these are connected one after the other in order to an n-phase alternating current power source, then a traveling wave constantly varying electric field progressing in an orderly direction along said group of electrodes is formed, this having a repulsive force against the electrified particles as well as an action of transportation in the traveling direction. He has named this electric field the electric field curtain of traveling wave type.

Accordingly if an electric field curtain of stationary wave type or traveling wave type is formed along a surface of a predetermined cylinder, for example, by a group of coaxial annular electrodes perpendicularly to the axis and at equal intervals along said surface of the cylinder, then the group of electrified particles introduced into this region is held in a space near its axis without any contact with other surfaces and can be transported within the cylinder while being propelled by a suitable driving force such as gravity, wind force, Coulomb's repulsive force between each particle, transporting force due to the traveling wave unequal electric field, etc., thus providing an electrodynamical electrified particle transporting apparatus which furnishes the particles in a beam-like flow from the end of the cylinder to the wanted position. Now if it is assumed that the operation of drawing out the electrified particles is done in the interior of said electrified particle transporting apparatus and that the stationary wave

alternating unequal electric field or the traveling wave unequal electric field formed along its circumferencial surface is used again for the driving out of the electrified particles, then the electrified particles generated by the present invention can be furnished to arbitrary positions effectively and without any contacting with other surfaces.

In this case it is not necessary to move the contacting body and it becomes possible to make the apparatus of perfect statical type.

In the present invention the above stated object are attained as follows: initially particles are dispersed radially by centrifugal force imparted to the particles by means of a rotating disc, rotating cup, blade wheel, etc.; the particles are electrified intensively, in spite of their comparatively large quantities, by utilizing ionic collisions in making them pass through a positive or negative ionic current curtain extending across the traveling direction of the particles and surrounding the outer periphery of said particle revolving and supplying apparatus, by means of a corona discharge electrode arranged along the whole of the outer periphery of said particle revolving and supply apparatus, and an electrode confronting said corona electrode; the electrified particles thus generated and traveling in a radial direction after being suppressed on pass near the inner surface of a receptacle comprising a dielectric wall which is arranged near, or embeds, a group of electrodes for the formation of a stationary or traveling alternating electric field that encircles said particle revolving and supply apparatus and the whole or the greater part of said corona discharge electrode and opposing electrode; then by utilizing the intense repulsive and perturbing action of said stationary alternating unequal electric field and gravity action on the adhered electrified particles, or the intense repulsive and perturbing action and transportation action on the adhered electrified particles of said traveling alternating electric field, said electrified particles are conducted to an outlet along the inner surface of said dielectric wall body.

As based on the construction and the operational mechanism as mentioned above the novel electrified particle generating apparatus according to the present invention presents a remarkable effect in that a relatively large quantity of intensely electrified dust particles can be suppled to a required space without relying upon any gas flow.

In the following the constitution and operation will be explained in details with reference to the accompanying drawing, in which:

The single FIGURE is a longitudinal sectional view of an embodiment of an electrified particle generating apparatus for drawing out and supplying electrified particles to a necessary space by making them intersect with ionic current produced by a corona discharge.

In the FIGURE, **121** is a revolving cup made of conductor, semiconductor or dielectric having symmetry about an axis of revolution **122**, and which gives particles a revolving motion, but which is supported on a metallic hollow cylinder or tube **124** that is concentric with the axis **122** and has a hole **123** at its lower end where it is attached to the cup. Said metallic tube **124** has three concentric discs **125, 126, 127** fixed to it at axially spaced intervals, and it is supported freely rotatably around the axis **122** by a bobbin **129** which is in turn supported freely rotatably by a bearing **128.** Said metallic tube **124** has its upper end **130** sealingly and freely rotatably received in the lower outlet portion **132** of a fixed concentric dust particle storing tank **131.** A gear **134** is concentrically fixed on the tube **124,** in mesh with a smaller gear **133** driven by a driving motor **135,** so that the tube is rotated about the axis **122** integrally with the revolving cup **121** and the bobbin **129.** In the insulator disc **127** at the lowest portion of said insulator bobbin **129** is concentrically arranged an annular metallic electrode **137** confronting the sharp-edged rim **136** of the revolving cup **121.** The lower edges **146** of said annular electrode **137** are rounded so as not to excite a corona discharge. The electrode **137** is connected to a metallic slip ring **139** fixed on the insulator body **138** of the bobbin, via a conductor embedded in said body **138,** and is thereby connected to a positive direct current high voltage power source **145** via a brush **141,** the conductor **142,** the terminal **143** and a protective resistance **144.** Said annular electrode **137** thus confronts the sharp-edged circumferential portion **136** of the earthed revolving cup **121** across a space **147.** Slip ring **139** and the brush **141,** to which a high voltage is applied, are insulated by the insulator coating **148** on the conductor **140** and by the two insulator discs **125, 126** between which the slip ring and brush are located. A valve **169** for regulating the supply quantity of dust particles is received in the neighborhood of and cooperates with an inner surface **150** of conical joints formed in both the lower opening **132** of the tank **131** and the upper portion **130** of said metallic tube **124.** The valve is adjustably supported on the upper tank lid **153** by means of the screw **152.** By making the valve rise and fall by rotating the knob **154,** the gap between the said inner surface **150** and the valve can be made to vary and so the supply quantity of the dust particles may be regulated. The upper surface **155** of the revolving cup **121** has a mountain shaped projection **156** and by this means drives the dust particles supplied into its central portion through the cylinder **124** radially away from its centre, thus bringing the particles under the action of centrifugal force.

A receptacle **161** composed of insulator walls has a closed top through which the hollow cylinder **124** extends, an upper portion **158,** a conical middle portion **159** and a lower cylindrical outlet portion **160** concentrically arranged with respect to the axis **122** and surrounding the above-mentioned revolving cup **121.** The lowermost disc **127** of the insulator bobbin is arranged and fixedly supported in an air-tight manner to a closed insulator box **163** fixed in the outside of the lower outlet portion **132** of the tank **131** near the closed top of the receptacle **161.** In the insulator wall of every part of the above-mentioned receptacle **161,** as shown in the FIGURE, are embedded a group of annular concentric electrodes **164, 165, 166, 164', 165', 166', 164'', 165'', 166''**; and every third one of them is connected respectively with one of the conductors **167, 168, 169,** so that they are divided into three groups, as: **164, 164', ...; 165, 165', ...** and **166, 166', ...**; and then, upon said conductors being connected to the output terminals V, V, W of a three-phase alternating current power source **170** the electrodes are supplied with three-phase alternating voltage, the voltage applied to each electrode being out of phase with that applied to its neighbors by 120°. By this means an alternating constantly varying electric field traveling in the direction of the arrow **172** is produced, and it presents an intense repulsive and perturbing action, and a trans-

porting action in the direction of the arrow **172**, on the electrified particles adhered on said inner wall **121** by its proper electrodynamical action, as was explained in detail by the inventor in the Japanese patent application "A Method of Constituting an Electric Field of Contact Type and an Electric Field of Contact Type utilizing This" (Japanese Patant Appln. No. 31860/71).

Now if the motor **135** is put into rotation, with the valve **169** opened by rotating the knob **154**, to supply dust particles from within the tank **131** to the upper surface at the central portion of the revolving cup **121**, through the metallic hollow cylinder **124**, then said dust particles, in tending to adhere to the upper surface **155** of the revolving cup, are pushed away immediately in the radial direction through the hole **123**, and by the influence of the mountain shaped projection, as they revolve with the surface **155**, are driven by the action of centrifugal force to fly out into the space **174**. Since said upper surface **155** is concave, the centrifugal force acting on the particles produces a component of force on the particles that holds them against the surface **155**, and consequently the effect of friction between the particle and the surface **155** is increased to promote the acceleration and dispersion of the particles. As the positive high voltage is applied on the annular electrode **137** arranged on the insulator disc **127**, a negative corona discharge is generated from the sharp-edged periphery **136** of the earthed revolving cup **121** toward the electrode, and a curtain of negative ionic current is formed in the space **147** so that the particles passing through this space are electrified intensely negatively by the collision with negative ions. If the revolving cup **121** is made of conductor or semi-conductor material there occurs of course a negative corona from its periphery **136** but if the revolving cup **121** is an insulator, a creeping corona is produced from the portion of the earthed metallic cylinder **124** that is connected with the upper surface of said cup **121**, and, as the potential of the cup periphery **136** approaches to that of the earth, a negative discharge is produced from the periphery portion **136** as before. And in this case as the above-mentioned creeping corona discharge circuit is put in series, there is an advantage that there is no danger of producing sparks liable to ignite the dust in the space between the periphery **136** and the electrode **137**. And in the construction of the present example as the particles pass through, by necessarily contacting the peripheral portion **136** where the electric field is most strong and pointed, the electrifying effect due to ionic collision becomes most intense and so the quantity of charge becomes enoumously large. And though a portion of particles adhere on the surface of the periphery portion **136** or the annular confronting electrodes **137** on account of the vortices of the air current produced in the space **147**, as both are revolving in the present case, the particles are peeled off immediately by the centrifugal force and both surface are kept clean always and so the corona discharge effect is not prevented. The electrified particles advance in the radial direction within the space **147** and tend to impinge at last on the inner wall **171** of the insulator receptacle **161**, then slide in the direction of the arrow **172** along the inner wall **171** under the action of the electrodynamical repulsion and perturbation of the above-described traveling alternating electric field to be thus supplied to the space **174** just below the outlet opening of the receptacle **161**. In the present embodiment a negative corona discharge electrode **176** of needle shape is arranged on the axis **122**, being supported by a metallic supporting arm **175** projecting inward from an annular electrode **166'''** embedded near the outlet opening **173**. A negative direct current high voltage is applied to the electrode **166'''** via a conductor **169** and a protective resistance **178** from a negative direct current high voltage power source **177**. A negative corona discharge is generated against the earth from the point **179** of electrode **176** and re-electrifies the electrified particles to be supplied outward from the outlet **173**, thus replacing any loss of the charge on them to the wall surface **171** as they move down it. In the present embodiment there is an earthed conductor plate **180** in front of the outlet **173** and the negatively electrified particles **181** supplied from the outlet **173**, being driven by the electric field existing between the needle electrode **176** and said conductor plate **180**, are painted electrostatically on the surface **182** of the conductor plate **180**. A gas inlet **183** is provided on the insulator box **163** and dried air, CO_2, N_2 or other inert gas is introduced from said gas inlet **183** into the insulator receptacle **161** via said box **163** and a gas hole **184**, and then exhausted continuously outward from the outlet **173**. Thus the inner wall **171** of said receptacle **161** is always sufficiently dry so that the charge on the electrified particles contacting said inner wall is not lost in surface leakage owing to atmospheric moisture. If inert gas is used when the dust particles are inflammable, any spark discharge that might by chance occur between the periphery **136** and the electrode **137** will not cause burning or the explosion of the dust particles.

Although three-phase alternating voltage is applied to the group of electrodes embedded in the insulator wall **159** of the receptacle **161** in the embodiment here shown, single-phase or poly phase alternating voltage will do as well. In the case of the application of a poly-phase alternating voltage there is generated a traveling alternating constantly varying electric field similar to that in the case of the three-phase and its effect is identical with the case of the three-phase. By the application of a single-phase alternating voltage a stationary alternating constantly varying electric field is generated and has an intense repulsive and perturbing action upon the electrified particles flying onto the inner surface **171** of the wall body **159**, and due to this action together with the action of gravity the electrified particles slide along the inner surface **171** in the direction of the arrow **172**, and are then exhausted and supplied outward from the outlet **173**.

What is claimed is:

1. Apparatus for controlledly supplying powder-like material from a source thereof to a surface of a solid article, said apparatus comprising:

A. electrically insulating wall means defining a receptacle having a substantially funnel-shaped interior surface that is concentric to an upright axis, the end portion of said receptacle that is of larger internal diameter being uppermost and said receptable having a concentric outlet at its lower end;

B. a centrifuging element in the upper end portion of the receptacle confined to rotation about said axis and having a rim that is spaced radially inwardly from the inner surface of the receptacle and axially inwardly from the upper end thereof;

C. means for delivering particulate material from said source thereof to a portion of the upper surface of the centrifuging element that is near said axis;

D. means for rotating the centrifuging element to propel particulate material delivered thereto radially outwardly toward the inner surface of the receptacle;

E. corona electrode means having circumferentially spaced portions in spaced, opposing relation to rim portions of said centrifuging element and cooperating with said rim portions to define a charging space through which particulate material must pass in leaving the centrifuging element, said corona electrode means being connectable with one terminal of a direct current high voltage source;

F. means connectable with the other terminal of said high voltage source and cooperating with said corona means to produce a corona discharge across said charging space by which particles passing therethrough are given an electric charge;

G. a plurality of annular electrodes in concentric contacting relation to said wall means and spaced radially outwardly from said interior surface thereof, said electrodes being spaced apart by substantially uniform distances along the height of the receptacle from the outlet at least up to the level of said charging space;

H. means for connecting each of the annular electrodes with only one of the terminals of an alternating current voltage source, adjacent annular electrodes being connected with different ones of said terminals and the sequence of such connections of the several annular electrodes being a regular one so that a constantly varying electric field is produced that repels charged particles from said interior surface; and

I. another corona discharge electrode substantially concentrically disposed at said outlet and connectable to one terminal of a direct current high voltage source that has its other terminal connected with an article to be coated, for producing a corona discharge which insures that particles passing out of said outlet will be charged and will be attracted to said article.

2. The apparatus of claim **1**, further characterized by: the upper surface of said centrifuging element being substantially bowl shaped, so as to be inclined upwardly and radially outwardly.

3. The apparatus of claim **2** wherein:

1. said centrifuging element has a substantially sharp-edged rim portion;
2. the first mentioned corona electrode means comprises an annular electrode spaced above, concentrically with, and in opposing relation to said rim portion; and
3. said means cooperating with the first mentioned corona electrode means comprises a collector ring and a cooperating brush which are connected with said other terminal of the first mentioned high voltage source and with said centrifuging element so that the rim portion of the centrifuging element cooperates with said first mentioned corona electrode means in producing corona discharge.

4. The apparatus of claim **1**, wherein said alternating current voltage source provides single-phase voltage, further characterized by:

J. means for forcing gas to flow downwardly through said receptacle.

5. The apparatus of claim **1** wherein said alternating current voltage source provides plural-phase voltage.

6. The apparatus of claim **1** wherein said centrifuging element is electrically non-conducting, further characterized by:

1. said means for delivering particulate material from said source to the centrifuging element comprising a coaxial electrically conducting tube having its lower end adjacent to the upper surface of the centrifuging element; and
2. said means cooperating with the first mentioned corona electrode means comprising means connecting said tube with said other terminal of the first mentioned high voltage source.

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