US 20030196599A1

(19) **United States**

(12) **Patent Application Publication**

Sun et al.

(10) **Pub. No.: US 2003/0196599 A1**

(43) **Pub. Date: Oct. 23, 2003**

(54) **APPARATUS FOR CLAMPING A PLANAR SUBSTRATE**

(75) Inventors: **Hoi Cheong Steve Sun**, Monmouth Junction, NJ (US); **Bogdan Brycki**, Mt. Laurel, NJ (US)

Correspondence Address:
ALLEN BLOOM
C/O DECHERT
PRINCETON PIKE CORPORATION CENTER
P.O. BOX 5218
PRINCETON, NJ 08543-5218 (US)

(73) Assignee: **Delsys Pharmaceutical Corporation**, Monmouth Junction, NJ

(21) Appl. No.: **10/423,785**

(22) Filed: **Apr. 25, 2003**

Related U.S. Application Data

(60) Division of application No. 09/769,227, filed on Jan. 25, 2001, now Pat. No. 6,592,671, which is a continuation of application No. 09/095,321, filed on Jun. 10, 1998, now Pat. No. 6,399,143.

Publication Classification

(51) **Int. Cl.**[7] **B05C 5/02**

(52) **U.S. Cl.** **118/621**

(57) **ABSTRACT**

The disclosure relates to an apparatus for electrostatically adhering grains to a planar substrate comprising:

a. an electrostatic chuck having a collection surface with at least one grain collection zone for, when the planar substrate is layered on the collection surface, electrostatically directing charged grains to a corresponding surface on the planar substrate; and

b. a pattern of holes through the electrostatic chuck allowing a source of low pressure to act through the electrostatic chuck to adhere the planar substrate.

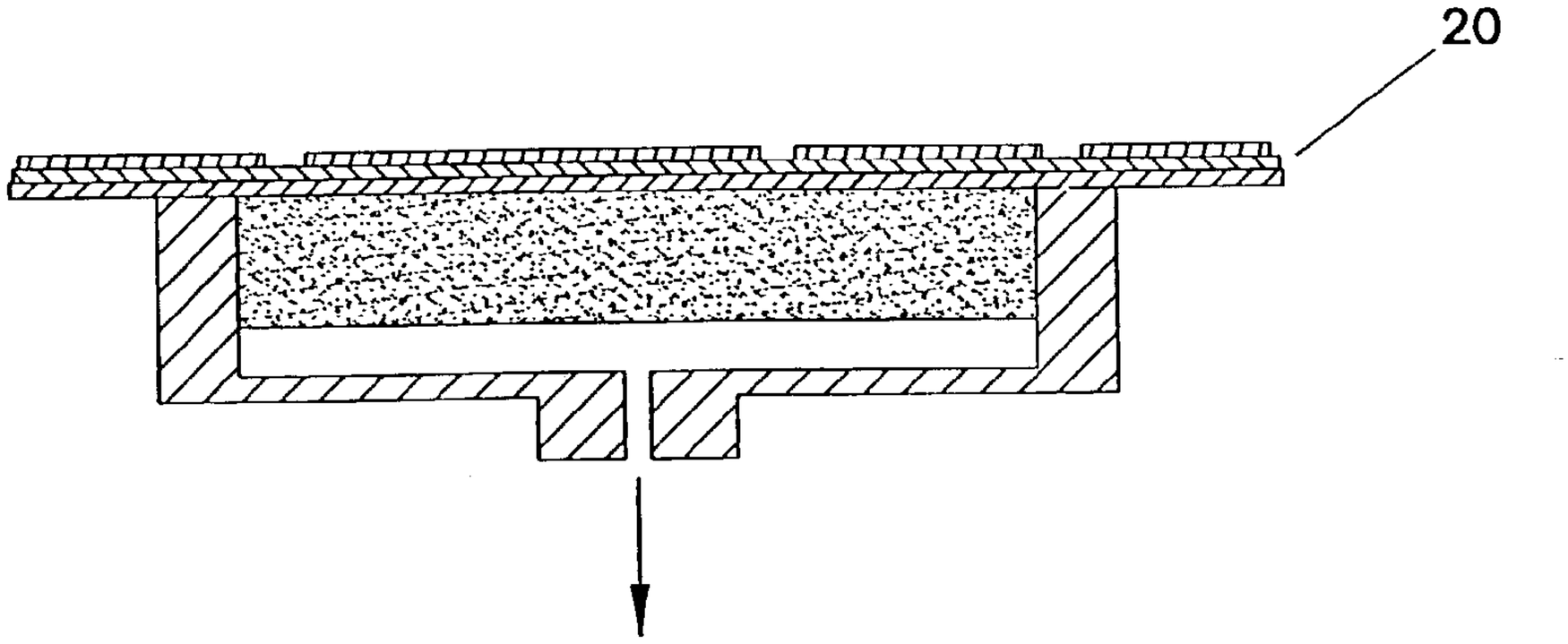


FIG. 1A

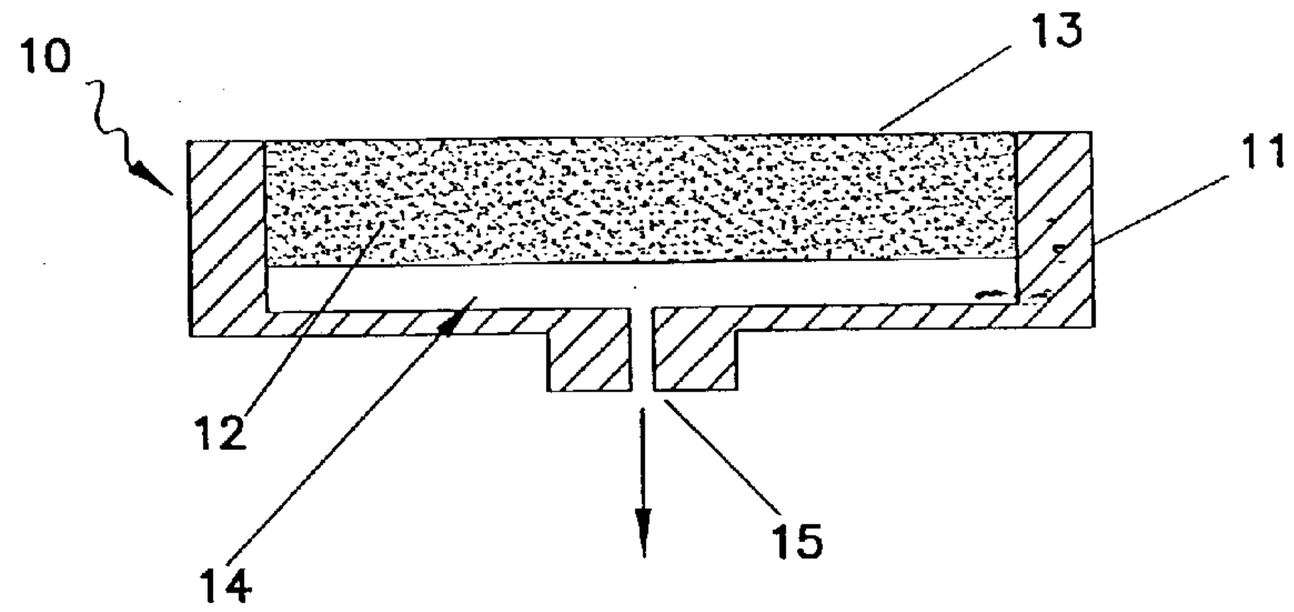
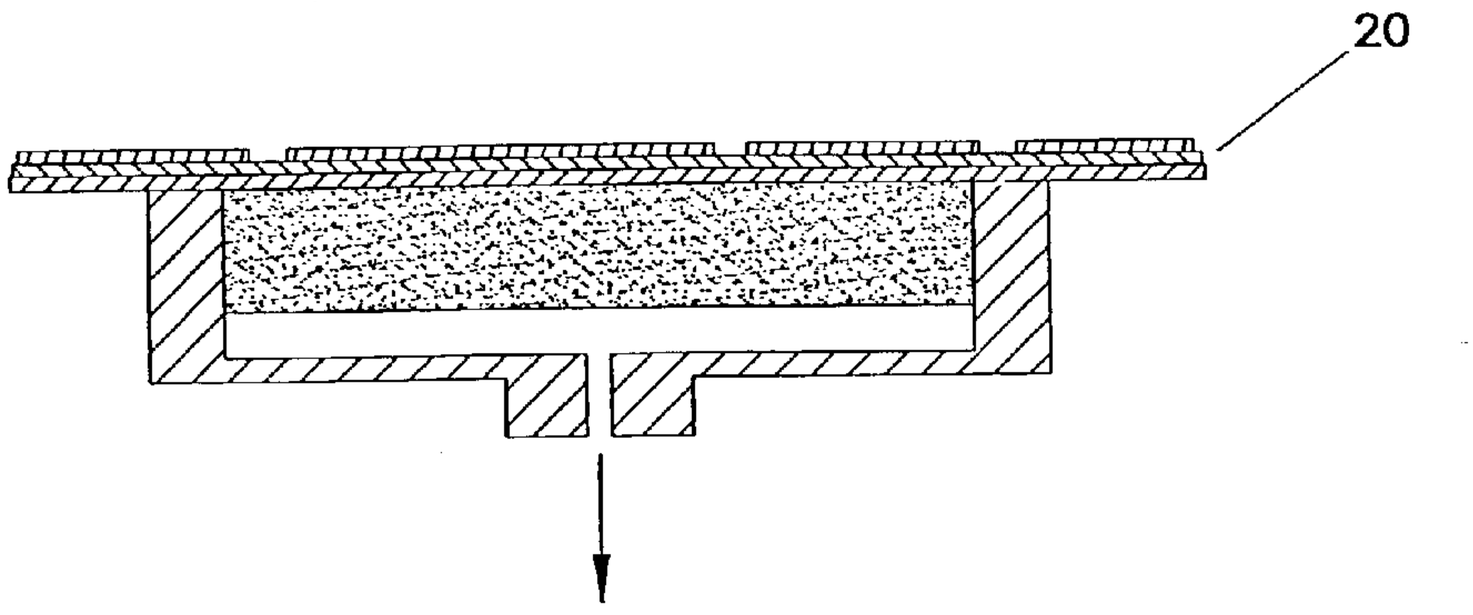


FIG. 1B



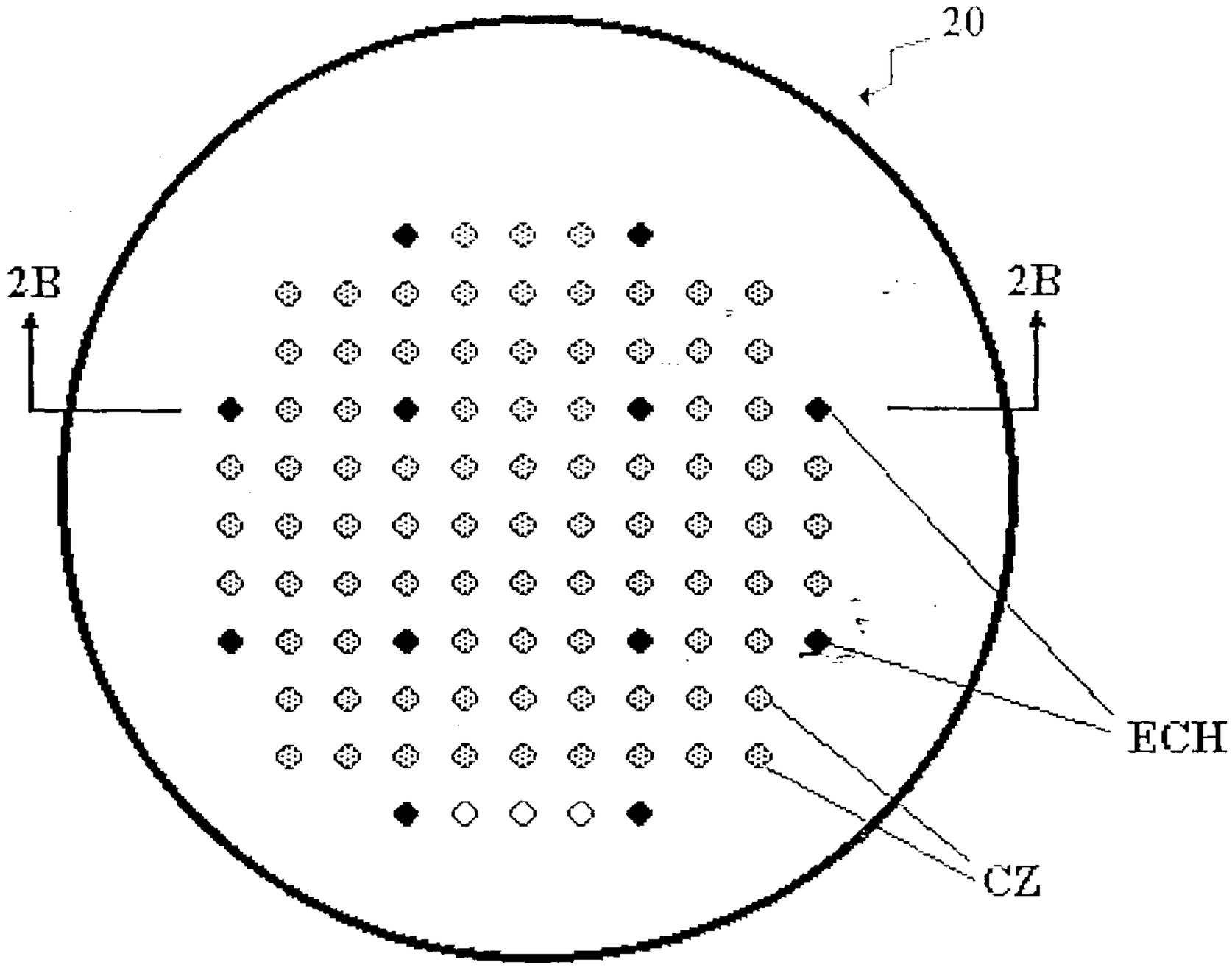


Fig. 2A

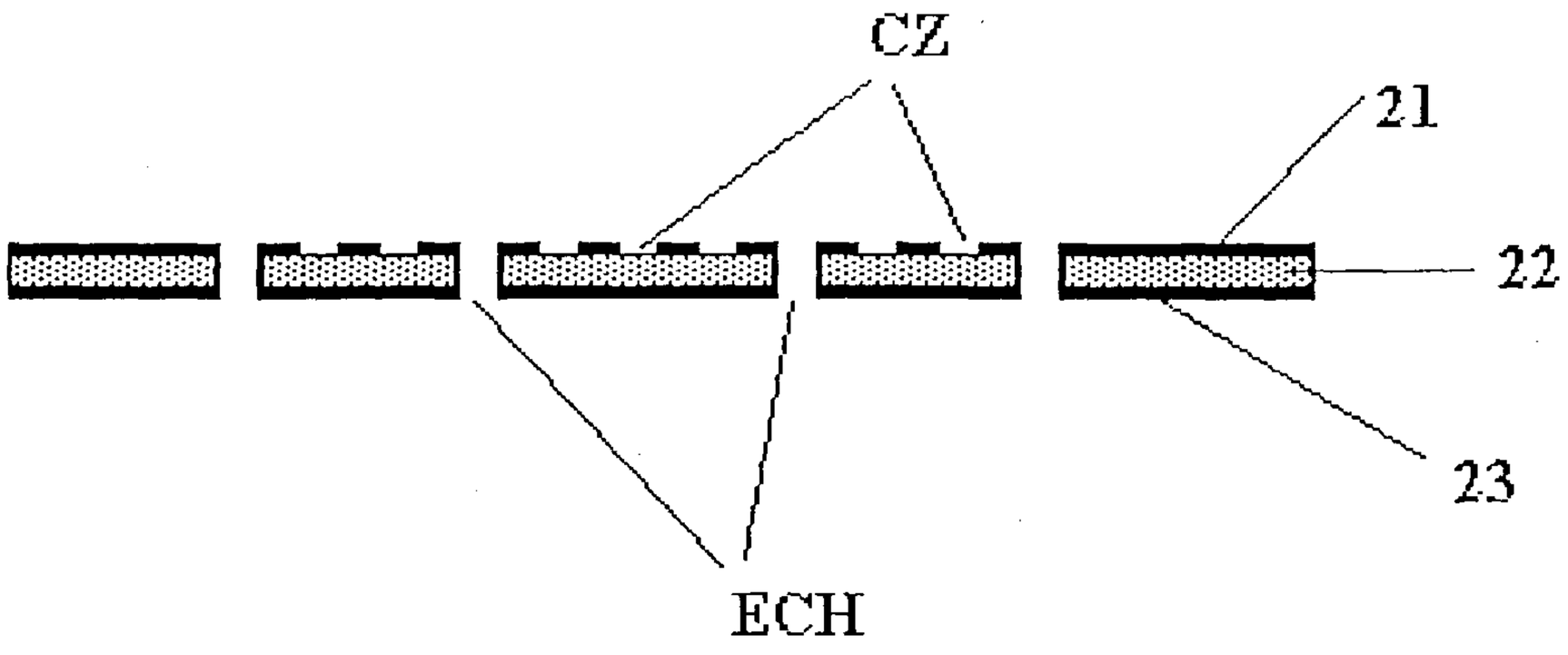


Fig 2B

FIG. 3A

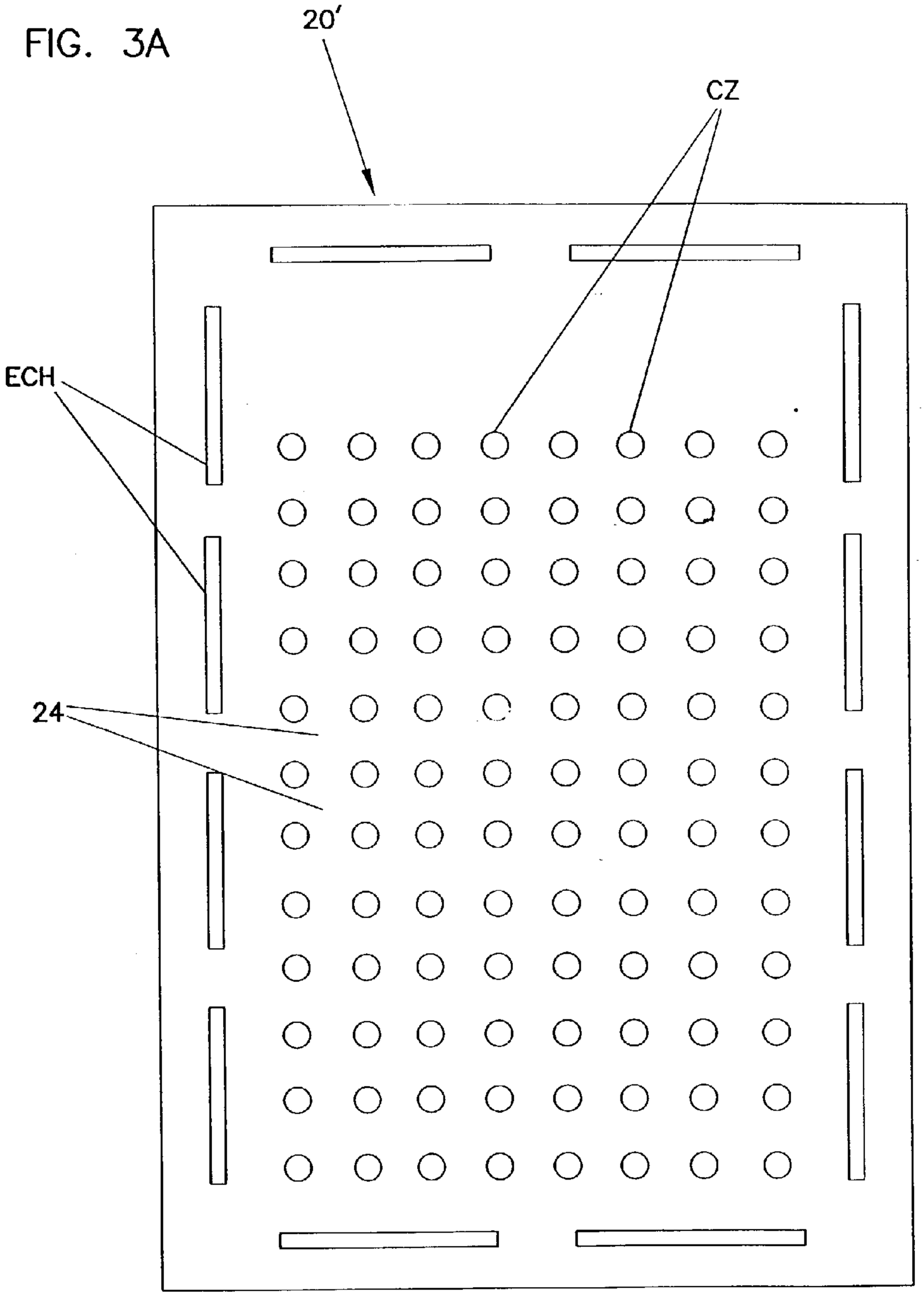
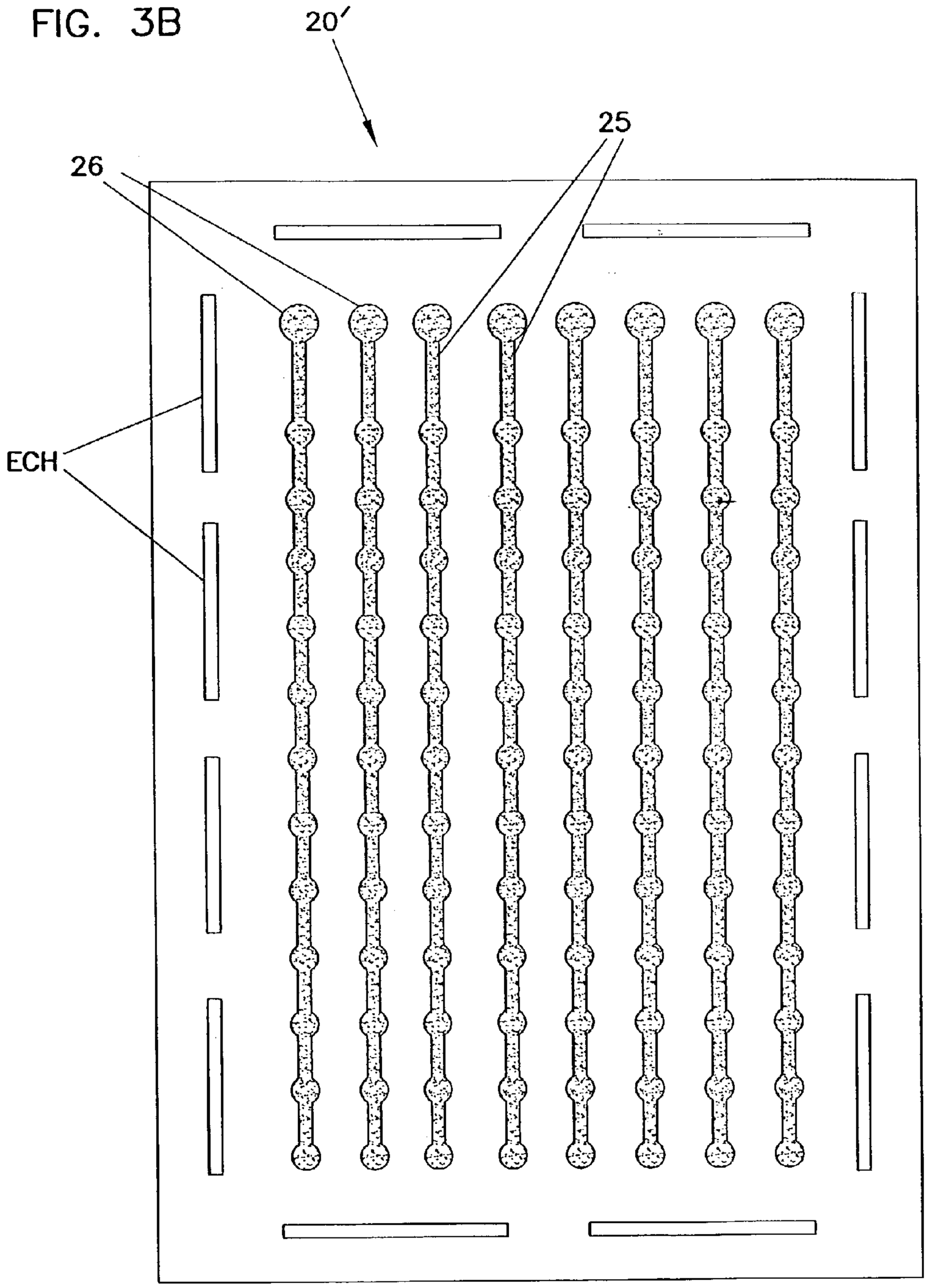


FIG. 3B



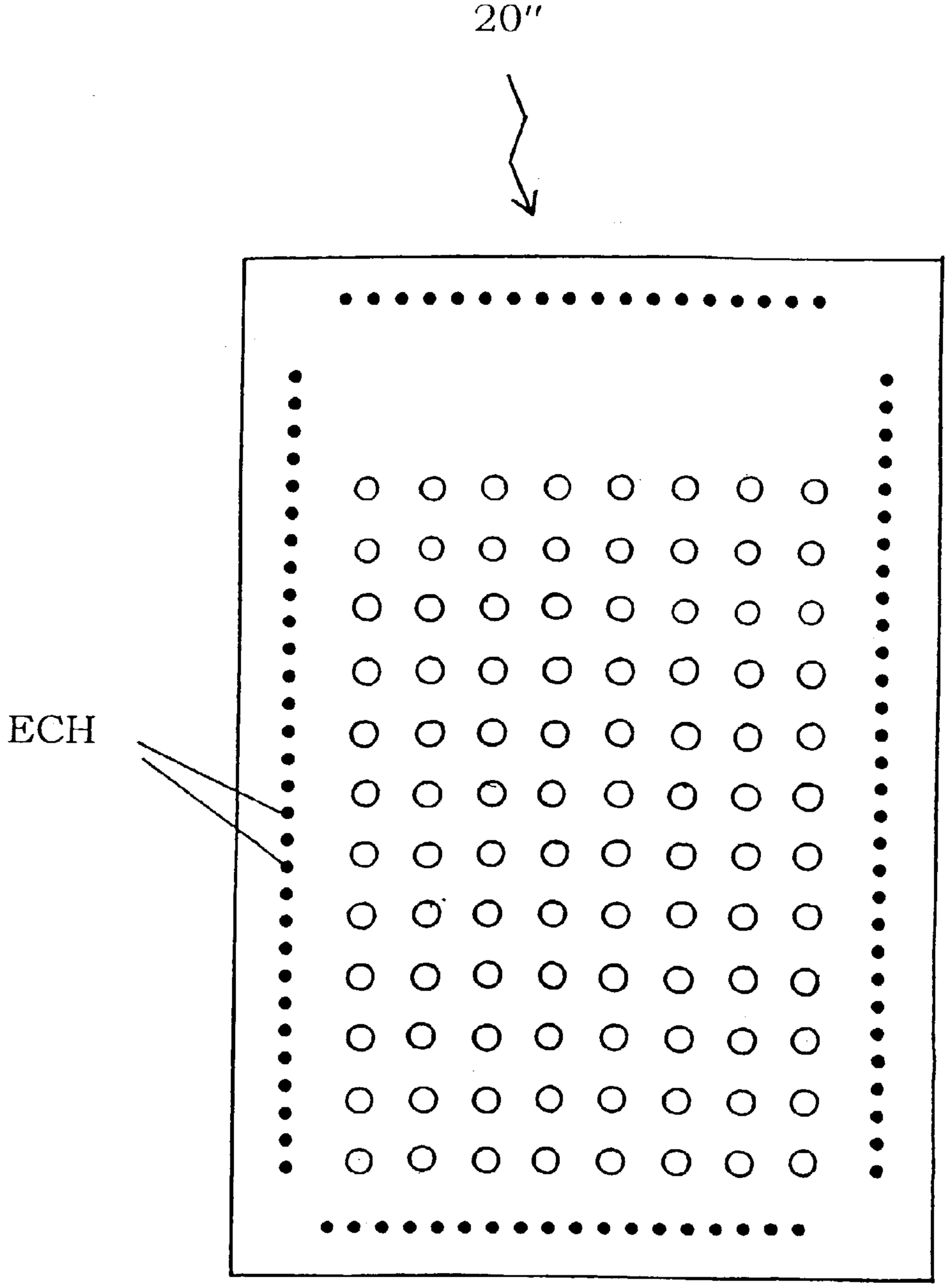


Fig. 3C

FIG. 4A

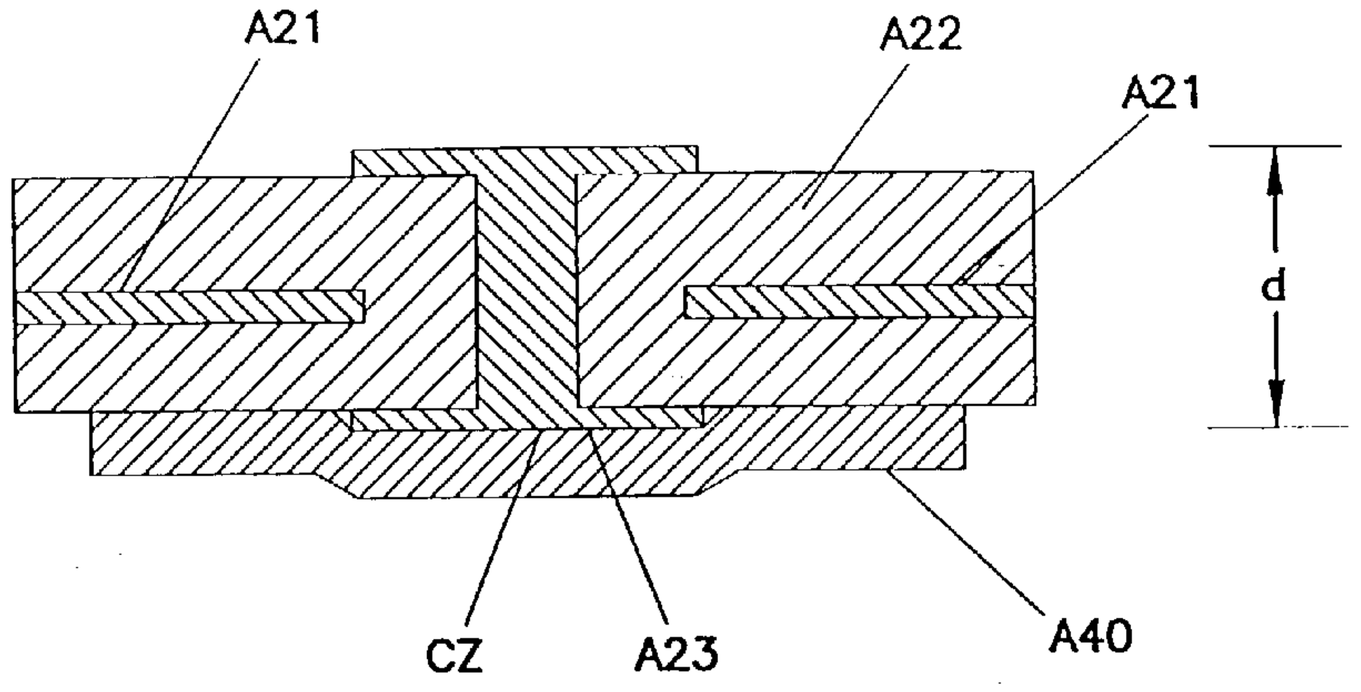


FIG. 4B

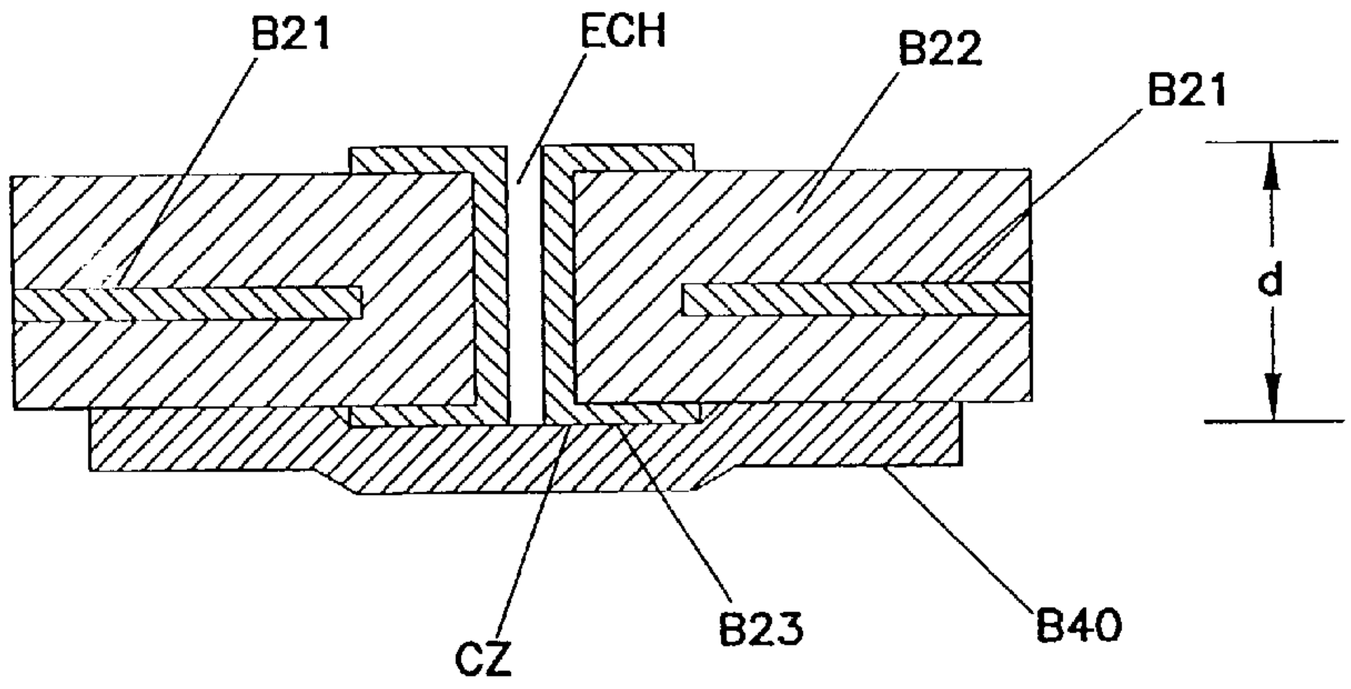


FIG. 4C

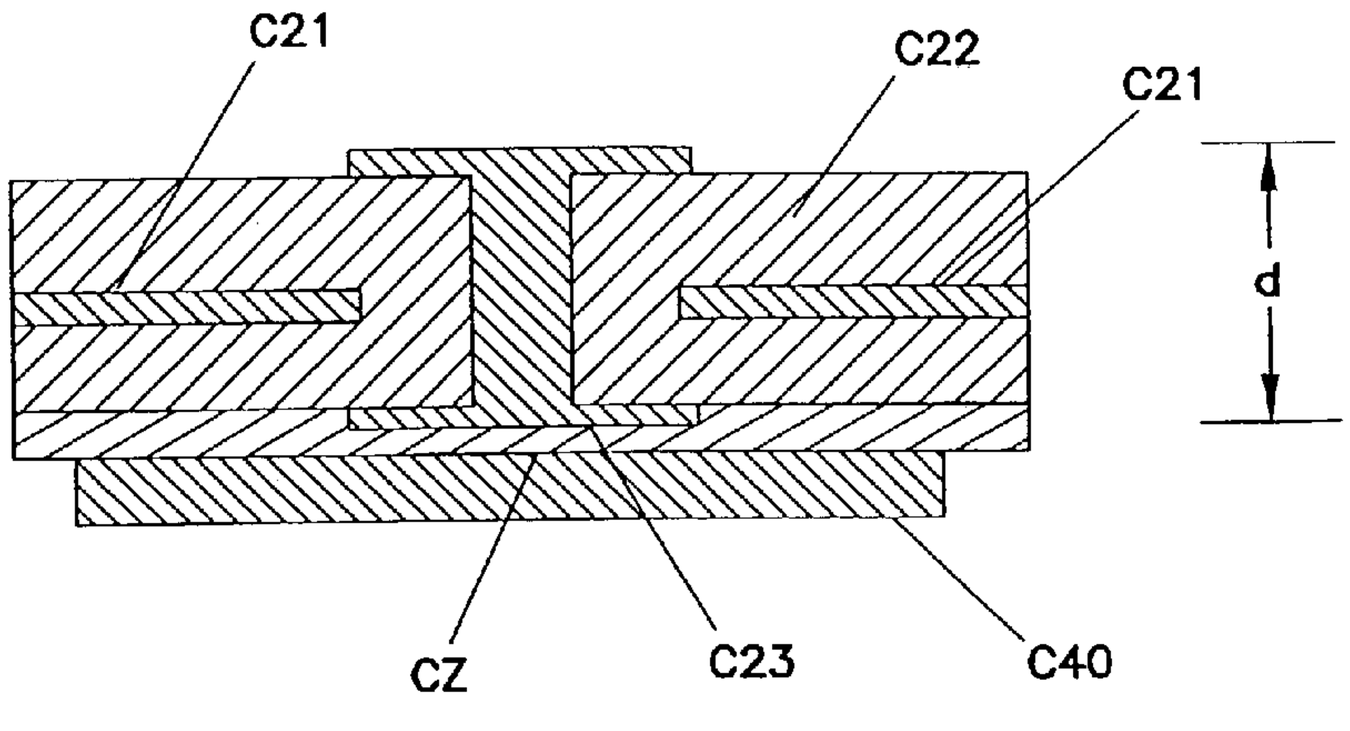


FIG. 5

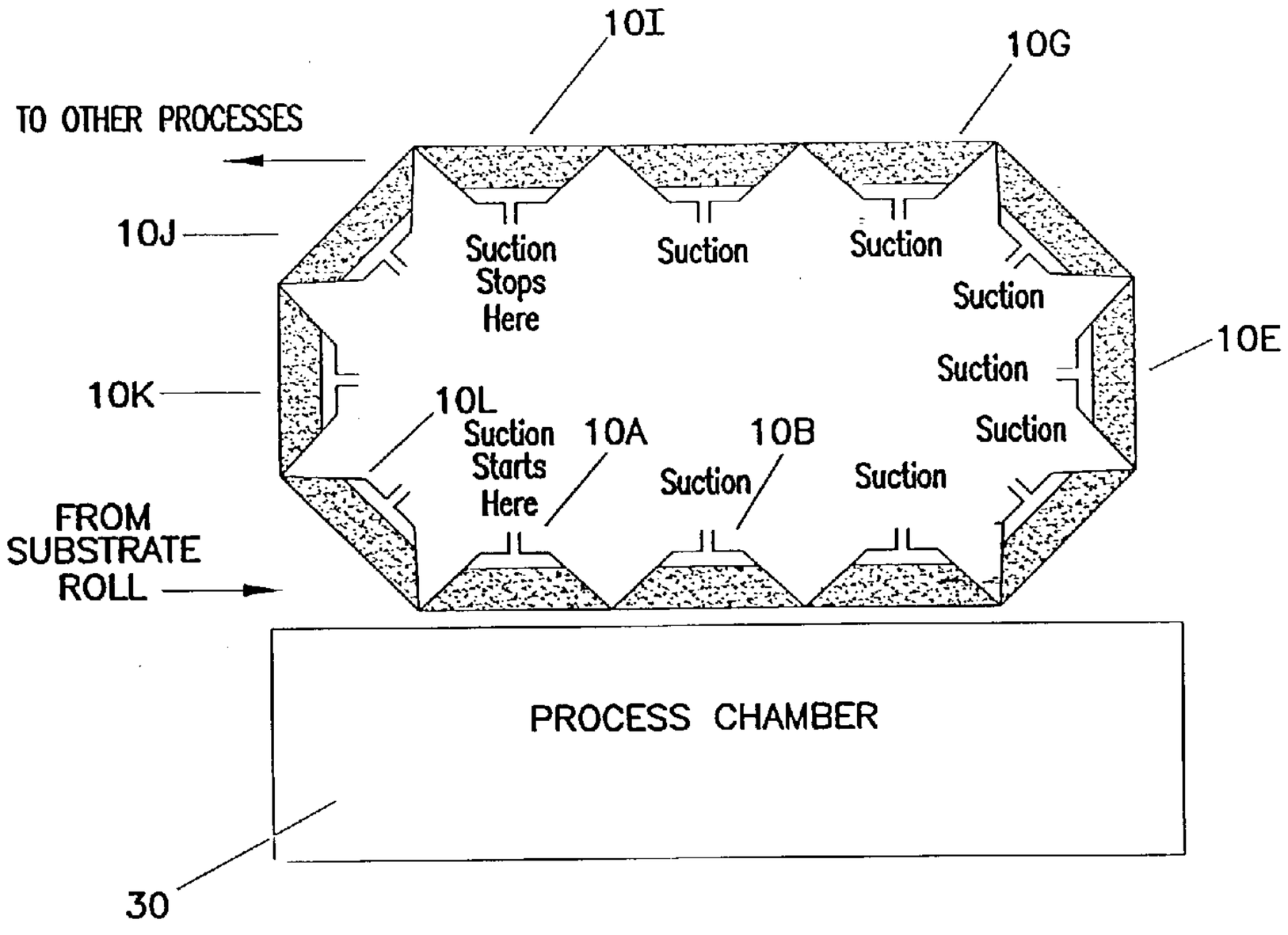

10I
10G
TO OTHER PROCESSES
10J
Suction Stops Here
Suction
Suction
Suction
Suction
10E
10K
10L
Suction Starts Here
10A
10B
Suction
Suction
Suction
Suction
FROM SUBSTRATE ROLL
PROCESS CHAMBER
30

FIG. 6

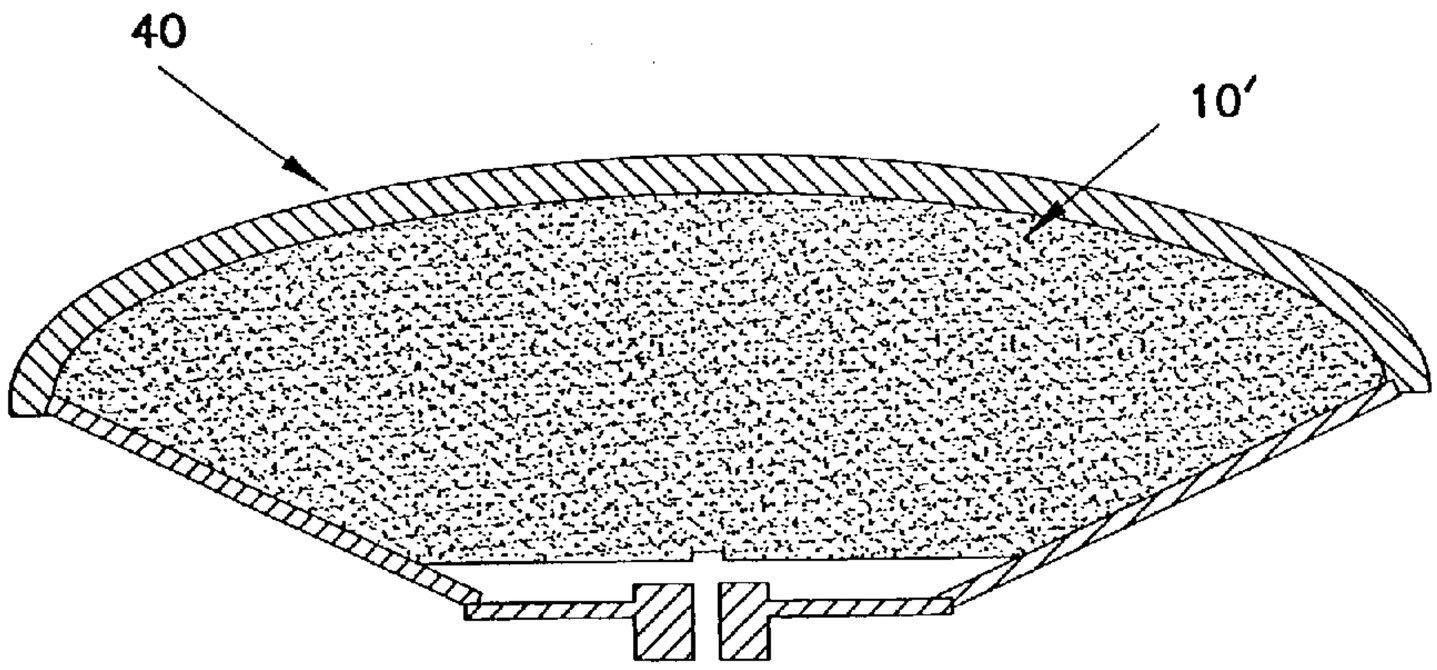

40
10'

FIG. 7

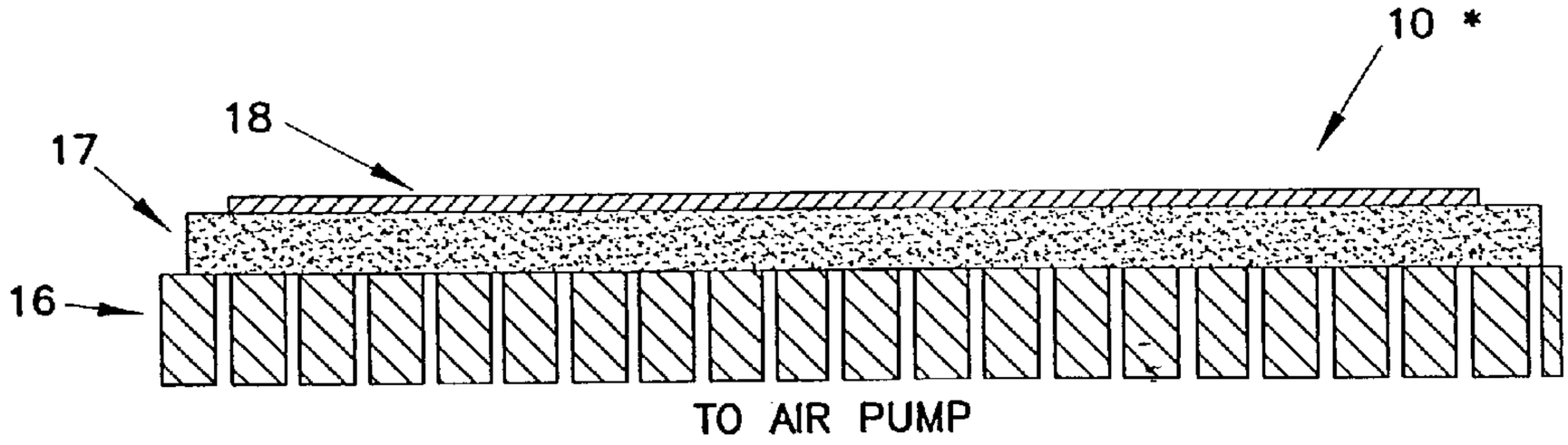
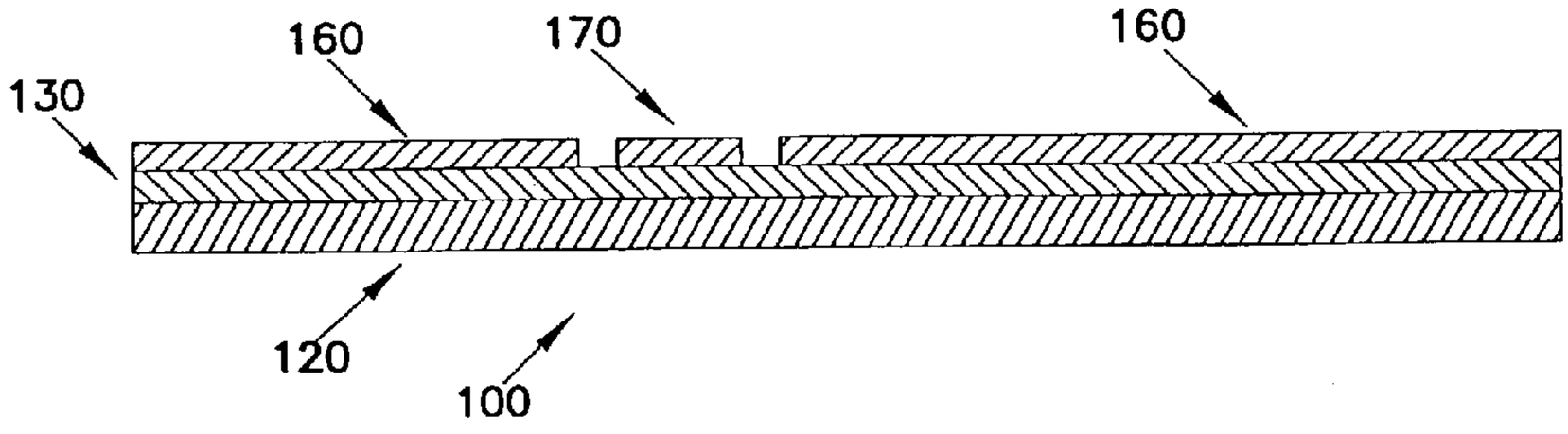


FIG. 8



APPARATUS FOR CLAMPING A PLANAR SUBSTRATE

[0001] The present invention relates to a apparatus and method for using a vacuum chuck to assure adhesion of a planar substrate, while using electrodes to attract grains (e.g., dry powder) to adhere to the planar substrate. The electrodes may also participate in holding the planar substrate.

[0002] In the field of semiconductor processing, semiconductor wafers have been held in place for processing with clamps, magnetic clamps, electrostatic chucks and vacuum chucks. Such semiconductor processing typically seeks to direct mask material, mask developing materials such as photoresist, dopant and etchant to the semiconductor. In directing etchant to the semiconductor, electromagnetic fields may be used to direct the majority of etching to occur in a given direction; such directed etching processes were not intended to coat the semiconductor with grains. For example, Weeks et al., U.S. Pat. No. 5,692,873, McKinley et al., U.S. Pat. No. 5,724,121 and Hasegawa et al., U.S. Pat. No. 5,676,758 all describe vacuum chucks in connection with various semiconductor apparatuses, and also mention that electrostatic chucks can also be used to clamp the semiconductor wafer. A Di Milia et al. patent, U.S. Pat. No. 4,551,192, describes a pinchuck that can be used to hold a substrate during a lithography process using vacuum or electrostatic forces.

[0003] Electrostatic chucks can be used to direct grains of material to a substrate to provide a coated substrate. Various methods can be used to assure that such coating techniques apply an accurate and, in some cases, spatially resolved, coating of material, making it feasible to use electrostatic coating technology to apply pharmaceuticals. "Spatially resolved" refers to depositions at defined subregions of a surface. Examples of technology in this area include Sun, "Chucks and Methods for Positioning Multiple Objects on a Substrate," U.S. application Ser. No. 08/630,012, filed Apr. 9, 1996; Sun et al., "Electrostatic Chucks," U.S. application Ser. No. 08/661,210, filed Jun. 10, 1996; Pletcher et al., "Method and Apparatus for Electrostatically Depositing a Medicament Powder Upon Predefined Regions of a Substrate," U.S. application Ser. No. 08/659,501, filed Jun. 6, 1996; and Sun et al., "Acoustic Dispenser," U.S. application Ser. No. 08/661,211, filed Jun. 10 1996. These documents are incorporated by reference herein in their entirety.

[0004] In the course of testing such accurate deposition apparatuses to coat flexible planar substrates, applicant has discovered that while the electrostatic chuck can be used to hold the planar substrate and direct the electrostatic deposition of grains, a combination further using vacuum forces on the chuck increases the processing efficiency such that the planar substrate more reproducibly becomes adhered without deformations and air pockets. Such a combination preferably takes the form of a vacuum chuck onto which is layered a thin, e.g., about 25 μm to about 250 μm thick electrostatic chuck having holes through which the vacuum is communicated to the planar substrate.

SUMMARY OF THE INVENTION

[0005] In one embodiment, the invention relates to an apparatus for electrostatically adhering grains to a planar substrate comprising:

[0006] a. an electrostatic chuck having a collection surface with at least one grain collection zone for, when the planar substrate is layered on the collection surface, electrostatically directing charged grains to a corresponding surface on the planar substrate; and

[0007] b. a pattern of holes through the electrostatic chuck allowing a source of low pressure to act through the electrostatic chuck to adhere the planar substrate.

[0008] The apparatus can further comprise:

[0009] c. a low pressure chuck having an adhesion surface having a plurality of holes for aligning with the holes to connect the holes to the source of low pressure.

[0010] The adhesion surface can be a porous material.

[0011] In one embodiment, the electrostatic chuck comprises (i) the collection surface, (ii) a dielectric layer located behind the collection surface, (iii), behind the dielectric layer, one or more attraction electrodes for attracting grains to the collection zones. Also, the electrostatic chuck can further comprises (iv) one or more shield electrodes for discouraging charged grains from being directed away from the collection zones. A rotatable cluster of a plurality of said low pressure chucks can be used, where the low pressure chucks rotate to repeatedly and sequentially present the adhesion surfaces to the charged grain dispenser. A low pressure control mechanism can be operated to sequentially apply low pressure to low pressure chucks and sequentially releasing the low pressure from low pressure chucks such that there is a contiguous collection of the low pressure chucks to which low pressure is applied and a contiguous collection of the low pressure chucks with no applied low pressure, thereby allowing a sheet of planar substrate to be presented to the charged grain dispenser while adhered to an electrostatic chuck and low pressure chuck and then released for further processing.

[0012] Also provided is an electrostatic deposition apparatus for electrostatically depositing grains onto a planar substrate comprising:

[0013] i. at least one low pressure chuck having an adhesion surface having a plurality of holes for conveying low pressure to the adhesion surface;

[0014] ii. layered on the collection surface, at least one electrostatic chuck having a collection surface with at least one grain collection zone for, when the planar substrate is layered on the collection surface, electrostatically directing charged grains to a corresponding surface on the planar substrate, the at least one electrostatic chuck having a pattern of holes through the electrostatic chuck allowing the low pressure to act through the electrostatic chuck to adhere the planar substrate; and

[0015] iii. a charged grain dispenser for directing charged grains towards the grain collection zones.

[0016] Still further provided is a method of electrostatically applying a grains to a planar substrate comprising:

[0017] a. adhering the planar substrate to an electrostatic chuck with a pressure differential conveyed to the planar substrate via passages through the electrostatic chuck;

[0018] b. applying a voltage to the electrostatic chuck to attract charged grains to at least one grain collection zone defined by the electrostatic chuck;

[0019] c. directing charged grains towards the charged grain collection zone; and

[0020] d. electrostatically adhering charged grains on a portion of the planar substrate corresponding to the grain collection zone.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] **FIG. 1A** illustrates a vacuum chuck used with the apparatus for electrostatically adhering grains of the present invention.

[0022] **FIG. 1B** shows an electrostatic chuck adhered to an adhesion surface of the vacuum chuck.

[0023] **FIG. 2A** shows the upper surface of a three-layer electrostatic chuck.

[0024] **FIG. 2B** shows the cross-section indicated in **FIG. 2A**.

[0025] **FIG. 3A** shows the upper surface of another electrostatic chuck.

[0026] **FIG. 3B** shows a rear surface of the electrostatic chuck.

[0027] **FIG. 3C** shows an alternative embodiment where the through holes are rounded holes instead of slots.

[0028] FIGS. **4A-4C** show cross-sections of various alternative designs for electrostatic chucks.

[0029] **FIG. 5** shows a planar substrate transporter made up of a series of vacuum chucks that define a belt shape.

[0030] **FIG. 6** illustrates a vacuum chuck with a rounded surface.

[0031] **FIG. 7** illustrates a vacuum chuck that utilizes pliable porous materials.

[0032] **FIG. 8** shows a cross-section of an electrostatic chuck that incorporates a floating electrode.

DEFINITIONS

[0033] The following terms shall have, for the purposes of this application, the respective meaning set forth below.

[0034] delivery to an animal: A delivery device for delivering defined amounts of reagents to an animal delivers such defined amounts to a tissue of the animal. For example, the device can deliver reagents orally, sublingually, rectally, nasally, vaginally, topically (including the use of a patch or other transdermal delivery device), by pulmonary route (for instance by use of an aerosol or powder cloud), or parenterally (including, for example, intramuscularly, subcutaneously, intraperitoneally, intraarterially, intravenously or intrathecally).

[0035] dry deposited: A material is "dry deposited" if deposited without applying the material in a liquid vehicle.

[0036] excipient: Excipients are pharmaceutically acceptable organic or inorganic carrier substances suitable for parenteral, enteral (e.g., oral or inhalation) or topical application. Preferably, these excipient do not react deleteriously with the active compositions. Suitable pharmaceutically acceptable carriers include but are not limited to water, salt solutions, alcohols, gum arabic, benzyl alcohols, gelatine, carbohydrates such as lactose, amylose or starch, magnesium stearate, talc, silicic acid, hydroxymethylcellulose, polyvinylpyrrolidinone, and the like.

[0037] effective amount: The meaning of "effective amount" will be recognized by clinicians but includes amount effective to (1) reduce, ameliorate or eliminate one or more symptoms of the disease sought to be treated, (2) induce a pharmacological change relevant to treating the disease sought to be treated, or (3) prevent or lessen the frequency of occurrence of a disease, or the symptoms thereof.

[0038] electro-attractive dry deposition: This term refers to methods that use an electromagnetic field, or an electrostatically charged surface to dry deposit charged grains (e.g., particles).

[0039] grains are, for the purposes of this application, either aggregates of molecules or particles, preferably of at least about **3**nm average diameter, preferably at least about 500 nm or 800 nm average diameter. Grains are, for example, particles of a powder such as a dry powder.

[0040] planar substrate is intended to denote a substrate which is predominately formed with two major dimensions, such as a tape or sheet. The term does not imply that the substrate is flat.

DETAILED DESCRIPTION OF THE INVENTION

[0041] Combined Electrostatic and Vacuum Chucks

[0042] **FIG. 1A** illustrates a vacuum chuck used with the apparatus for electrostatically adhering grains of the present invention. The vacuum chuck **10** is made up of a porous disk **11**, on which is mounted a porous material **12**, such as a sintered material such as a sintered ceramic. The upper surface of the porous material is an adhesion surface **13**. Beneath the adhesion surface **13** is a vacuum chuck manifold **14**, which connects to a source of low pressure via outlet **15**. **FIG. 1B** shows an electrostatic chuck **20** made up of three layers (described further below) adhered to the adhesion surface. It should be noted that all references to relative orientation such as "upper,""beneath" and the like are made to facilitate describing the invention with reference to the exemplary drawings, and are not intended to limit the invention.

[0043] The illustrated vacuum chuck **10** has a porous disk **11**, which can be for example a porous metal such as aluminum or steel, a sintered ceramic, or a sintered glass. The average pores of the disk can be, for example, from out 20 μm to about 500 μm, such as about 20 μm. The vacuum transmitting surface can also be, for example, a surface in which a series of holes have been formed.

[0044] **FIG. 2A** shows the upper surface of a three-layer electrostatic chuck **20**. **FIG. 2B** shows the cross-section

indicated in **FIG. 2A**. The electrostatic chuck has through holes ECH that allow the vacuum from a vacuum chuck such as vacuum chuck **10** to be conveyed through the electrostatic chuck 20 to the planar substrate. While in many embodiments the electrostatic chuck is adhered to the vacuum chuck by, for example, a clamp or adhesive, the vacuum can assure that the electrostatic chuck, which can be quite thin and flexible, is conformed to an appropriate shape. The electrostatic chuck **20** is made up of a shield electrode **21**, a dielectric layer **22** and a grain-attracting electrode **23**. Openings in the shield electrode **21** define collection zones CZ. Openings through the electrostatic chuck define the through holes ECH. The grains attracted are typically appropriately charged as described below and in the documents described therein. An appropriate potential, such as without limitation about 200 V to about 2,500 V or to about 3,000 V of a given polarity is applied to the grain-attracting electrode **23**, while a ground potential or an opposite potential is applied to the shield electrode **21**. (As indicated in copending U.S. application Ser. No. _____, "AC Waveform Biasing for Bead Manipulating Chucks," filed concurrently herewith [SAR 12610], the grain-attracting voltage can be applied in a pulsatile manner, allowing better results in attracting grains to conductive substrates.)

[**0045**] The illustration is not to scale. Electrostatic chucks that have been used with the invention have been, for example, about 10 cm in diameter, or about 10 by 15 cm. The thickness of the shield electrode is, for example, about 0.1 μm to about 50 μm, or about 10 μm to about 25 μm. The thickness of the dielectric layer is, for example, about 10 μm to about 75 μm, or about 15 μm to about 25 μm. The thickness of the grain-attracting electrode is, for example, about 0.1 μm to about 50 μm, or about 15 μm to about 25 μm. These thicknesses are selected to assure that the bead-attracting electrode can create a sufficient field to attract grains to regions of the planar substrate located above the collection zones CZ. Additionally, the thickness of the dielectric layer **22** and the planar substrate can be selected so that, once deposited on the planar substrate, the charged grains cause charge redistributions in the grain-attracting electrode that create an image force that can be larger than that due to the voltage applied to the grain-attracting electrode.

[**0046**] In one embodiment, the grain-attracting electrode **23** can be fabricated by depositing, using known techniques, such as using a 5000 Angstrom layer of gold (Au) onto the dielectric layer **22**. Alternatively, grain-attracting electrode **23** can comprise, for example, a 100 Angstrom layer of chromium (Cr) and with a 5000 Angstrom gold (Au) overcoat. Dielectric layer **22** can be made of, for example, Dupont® Kapton® polyimide film (type 300 HN, for example, 3 mil thickness, from Dupont DeNemours, Willmington, Del.) or on Corning Pyrex 7740 glass, for example of 10 mils thickness (Coming Glass, Coming, N.Y.). Shield electrode **21** can comprise, for example, a 35 micron deposition of copper (Cu) onto the dielectric layer **22**.

[**0047**] **FIG. 3A** shows the upper surface of electrostatic chuck **20'**, which differs from electrostatic chuck **20** by having electrostatic chuck through holes ECH that are slots and located on the periphery of the electrostatic chuck **20'**. The collection zones CZ are located on a surface **24** otherwise composed of a dielectric material. The through holes ECH are less susceptible to blockage by dust and other particles. **FIG. 3B** shows a rear surface of the electrostatic chuck **20'**, which has addressing electrodes **25** through which each row of the electrodes forming the collection zones CZ can be connected to driving electronics. Electrical contact pads **26** provide contact points for connections to voltage sources. **FIG. 3C** shows an alternative embodiment where the through holes ECH are rounded holes instead of slots.

[**0048**] FIGS. **4A-4C** illustrate features of electrostatic chucks at a collection zone CZ that can be favorably employed in the invention. In **FIG. 4A**, the shield electrode A**21** (also termed a "ground electrode" based on a preferred bias) is layered within a dielectric A**22**, which dielectric can be, for example, made of Kapton® (polyimide film, Dupont de Nemours, Wilmington, Del.)(Kapton® can be used as substrate material for Flexible Printed Circuits and can be etched in alkaline solutions, punched and laser drilled, and can be used to form multilayer polyimide film laminates). The grain-attracting electrode A**23** projects out at the surface that attracts the planar substrate A**40** (which is, for example, 1 mil thick) and can project out at the opposing side where electrical contacts are formed. The width of the electrostatic chuck d can be, for example, 0.01 inches. As such, the electrostatic chuck can be relatively flexible. In the illustration, the planar substrate wraps over the outwardly projecting grain-attracting electrode A**23** in a relatively close-fitting manluer. The grain-attracting electrodes typically play a role in adhering the planar substrate. A vacuum chuck used in conjunction with the electrostatic chuck can also contribute to attracting the planar substrate. Tight, smooth adherence of the planar substrate to the electrostatic chuck, which is not disrupted by trapped gas, increases the reliability of grain deposition at the collection zones.

[**0049**] **FIG. 4B** illustrates an embodiment where the through holes ECH are formed at the grain-attracting electrodes A**23**. **FIG. 4C** illustrates an embodiment where an additional layer of dielectric C**22** separates the grain-attracting electrode C**23** from the planar substrate C**40**. The electrostatic chuck provided by the configuration of **FIG. 4C** can be termed a "Pad Indent Chuck" which is useful, for example for depositions of less than about 2 mg, preferably less than about 100 μg, per collection zone CZ (assuming, for example, a collection zone of 3-6 mm diameter, such as 4 mm diameter). The electrostatic chuck provided by the configuration of **FIG. 4A** can be termed a "Pad Forward Chuck" which is useful, for example for depositions of more than about 20 μg per collection zones CZ (assuming again, a collection zone of 3-6 mm diameter, such as 4 mm diameter), but which is more useful for higher dose depositions than the Pad Indent Chuck.

[**0050**] Planar Substrate Transporter

[**0051**] **FIG. 5** shows a planar substrate transporter made up of a series of vacuum chucks **10** that define a belt shape. The rotation of the vacuum chucks **10** around the belt shape can be used to transport a planar substrate through a process chamber **30** at which charged grains are directed at the planar substrate for adhesion mediated by electrostatic hucks positioned on the vacuum chucks **10**. The illustrated vacuum chucks **10** rotate around the belt shape, and low pressure is applied to the vacuum chucks as illustrated, allowing suction to be smoothly introduced to a tape (not illustrated) of the planar substrate prior to application of the grains. After

application of the grains, the transporter cycles to a point where vacuum is released, allowing the tape of planar substrate to be released and moved to other processes steps. Thus, at time T_1, low pressure is applied to vacuum chuck **20**A, maintained for vacuum chucks **20**B-**20**H, released for vacuum chuck **201**, and vacuum chucks **20**J-**20**L are maintained at atmospheric pressure. At time T_2, which is a time just after that illustrated, low pressure is applied to vacuum chuck **20**L, maintained for vacuum chucks **20**A-**20**G, released for vacuum chuck **20**H, and vacuum chucks **20**I-**20**K are maintained at atmospheric pressure.

[**0052**] **FIG. 6** illustrates a vacuum chuck **10'** with a rounded surface designed to apply a shape to the planar substrate **40** (e.g., spherical, cylindrical, irregular, indented, and the like). Such shaping of the planar substrate **40** can be useful where the coated planar substrate is usefully shaped for later processing, such as in the formation of gelcaps.

[**0053**] Other, more pliable porous materials can be used in the vacuum chucks used in the invention. A vacuum chuck **10'** utilizing such materials is illustrated in **FIG. 7**, where a rigid or semi-rigid backing plate **16** such as a brass plate with holes or a porous disk as described above is used to support a soft, porous material **17** such as porous Teflon (a perfluorinated polymer, DuPont de Nemours, Willmington, Del.). The vacuum chuck **10'** supports a thin substrate **18**.

[**0054**] The planar substrate used with the invention can be any number of materials, but the invention is favorably applied to depositing materials on flexible films such as polyvinylacetate, hydroxypropylmethylcellulose (HPMC), polypropylene, polyester (e.g., Mylar) and polyamide (e.g., nylon) films, which can be plasticized with oils and other known plasticizing agents. One particularly useful embodiment of the invention uses the apparatuses described herein to formulate vehicles for delivering substances to animals, such as vitamins and other bioactive agents, including pharmaceuticals. Accordingly, in many embodiments it is desirable for the planar substrate to be a material suitable for consumption.

[**0055**] Electrostatic and Controlled Field Deposition Methods

[**0056**] In certain electrostatic deposition methods a substrate is sufficiently electrically isolated so that an electrostatic charge can be accumulated on the substrate. One means of accumulating the charge is by taking advantage of the photoelectric effect. In this method the substrate is exposed to ionic bombardment or electromagnetic radiation effective to deposit or strip charges, such as electrons, from the surface of the substrate. Other methods include tribocharging, plasma treatment, induction charging and corona charging. In a more preferred method, an ion emitter is oriented towards the surface on which one intends to create a charge and operated. Such methods of ion printing to controllably electrostatically deposit charged materials such as powders are described in detail in U.S. Pat. No. 5,714,007, and U.S. application Ser. Nos. 08/659,501 (filed Jun. 6, 1996) and 08/733,525 (filed Oct. 18, 1996), which documents are incorporated by reference herein in their entirety.

[**0057**] It should be noted that where the average charge-to-mass ratio of the charged particles of the deposition material is known, the mass of particles that will effectively deposit can be relatively accurately predicted from the amount of charge previously accumulated on the substrate. In particular, for a given type of substrate a calibration database can be compiled. For a given average charge-to-mass ratio of the applied particles, the relationship of accumulated charge to deposited mass can be calibrated for a given set of materials and charging conditions. In a production protocol, the average charge-to-mass ratio of the particles can be monitored, for instance using the velocimeter and a modified quartz crystal monitor described in U.S. Pat. No. 5,753,302 and U.S. application Ser. No. 08/661,210, both filed Jun. 10, 1996, which documents are incorporated herein by reference in their entirety. The illustrative charge-to-mass monitor functions by applying a voltage to a crystal such as a quartz crystal to establish a vibratory frequency, monitoring changes in the vibratory frequency when exposed to the charged particles, and correlating these changes to the mass of the particles that impact the monitor. Another charge-to-mass monitor uses the cage blowoff method of C. B. Schein and J. Cranch, *J. Applied Phys.* 46: 5140, 1975. With the use of one or more charge-to-mass monitors, feedback loops can be incorporated into the electrical controls of a deposition apparatus. In one preferred embodiment, a charge-to-mass monitor is positioned so as to sample the charge-to-mass of particles at their source (examples for source devices described below) and a charge monitor (for example a device for measuring currents created by the deposition of charged particles) is positioned adjacent to the site of deposition. The sampling values produced at these two sites provide diagnostic data on the operation of the deposition apparatus.

[**0058**] A number of additional methods can be used to monitor the amount of material that is deposited on a solid support or substrate. For example, optical methods can include measuring reflectance, transmission, or fluorescence using laser or noncollimated light of broad or narrow band width. Other sources of directed electromagnetic energy can be used, for instance X-ray absorption or fluorescence or microwave absorption can be used. A tuned circuit can be used to monitor an endpoint at which deposited material creates a resonance with an energy source such as a microwave energy source. Acoustic absorption can also be used, where preferably the sound source is an ultrasound source. Another exemplary measuring method can use a profilameter, which is a laser device that measures the amount the a beam of light is deflected by a surface with deposited material to measure the depth of the deposited material. Further electrical methods can include measuring a capacitance between a conductive material associated with the solid support or substrate (for example a conductive material incorporated into the solid support or a conductive material that has the solid support positioned adjacent to it) and another conductor, where the deposited material is located between the two conductors.

[**0059**] A variety of additional factors can be monitored or controlled to increase the reproducibility of the charge-to-mass ratios generated by the charged deposition material source. For example, controlling the humidity of the local environment, the nature and content of bound solvent in the materials sought to be deposited, the purity of materials sought to be deposited, and the rubbing velocity effected in the tribocharging process can be important.

[**0060**] Another method of attracting charged deposition materials to a surface has been termed "controlled field

deposition," and typically involves applying a potential to an electrode which directly or indirectly results in the formation of an attractive electrical field at the surface upon which charged material will be deposited. For example, a substrate can have electrical conductors positioned below the deposition surfaces, and a potential applied to the conductors results in the formation of an attractive field at the surface. Where the separation between the substrate's surface and the conductors is sufficiently small, once an external potential is no longer applied to the conductors the charge of the deposition material results in a charge redistribution in the conductors such that an electrostatic "image" force is formed between the deposition material and the conductors, thereby helping to stabilize the deposition material's adherence to the surface.

[**0061**] Further examples of field-generating means include the use of "floating electrodes." A floating electrode is an electrode which develops a localized field as a result of charge redistributions in the floating electrode, which are for example generated by voltages applied across one or more adjacent bias electrodes. Thus, for example, as illustrated in **FIG. 8, a** floating electrode apparatus **100** can have a backing electrode **120**, a non-conductive layer **130**, a shielding electrode **160** and a floating electrode **170**. In the illustrative floating electrode, a bias potential applied across the backing electrode and the shielding electrode (which two electrodes serve as the bias electrodes) causes a charge redistribution in the floating electrode to create the charged-particle attracting field at the floating electrode. Further description of floating electrodes and other forms of field generating devices for controlled field deposition can be found in U.S. application Ser. Nos. 08/661,210, filed Jun. 10, 1996, which documents is incorporated herein by reference in its entirety. An advantage of floating electrode devices is that the amount of charged particles that will effectively adhere as a result of the field generated at the floating electrode depends on the size of the bias potential. (For more direct field generating apparatuses, the deposition can in principle continue for as long as a potential is applied.)

[**0062**] The field generating devices for controlled field deposition can be designed (a) to directly apply deposition material onto apparatuses that incorporate electrodes for generating the field or (b) for use with electrostatic chucks (i.e., field application structures) which operate in conjunction with the substrate on which deposition material is to be applied. In the former case (a), it is generally desirable that the metallization processes used to create the electrodes is susceptible to mass production techniques. For example, the metallization can be created by lithographic techniques where finely patterned electrodes are sought or by adhering or fusing metal layers to the substrate. In design (b), the electrostatic chuck is generally effective to electrostatically adhere the substrate to the chuck. This adherence of the substrate to the chuck does not depend on the application of any process for creating a charge on the substrate, but instead is believed to be the result of a redistribution of charges in the substrate in response to the field generated by the electrostatic chuck. Of course, a charge on the substrate can usefully be employed to strengthen electrostatic adherence. A third option is that the substrate is designed to reversibly couple with a device that provides the electrodes, such that the substrate and the coupled device provide a field-generating apparatus. In this way, the electrode structures that can be a source of manufacturing costs remain separate from a consumable on which reagents for conducting a chemical process will be deposited. In addition to the documents recited above, further information on electrode structures and electrostatic chucks can be found in U.S. application Ser. No. 08/630,012, filed Apr. 9, 1996, which document is incorporated herein by reference in its entirety.

[**0063**] The charge of the particles applied to a substrate can be generated for example by plasma treatment, radiation treatment (including treatment with suitably high energy electromagnetic radiation) or ion bombardment. Moreover, the charge can be generated by tribocharging or induction charging (e.g., passing through a tube that is biased to create a field sufficient to induce a charge in grains passing therethrough), wherein two materials with differing triboelectric constants rub against each other and transfer charge between one another. Such methods as tribocharging and induction charging expose the particles to a low amount of reaction-promoting energy, and hence are less susceptible to causing compounds to degrade. Examples of materials that can be used for tribocharging include polytetrafluoroethylene ("TEFLON"), and polymers of chlorotrifluoroethylene, chlorinated propylene, vinyl chloride, chlorinated ether, 4-chlorostyrene, 4-chloro-4-methoxy-styrene, epichlorhydrin, styrene, ethylene, carbonate, ethylene vinyl acetate, methyl methacrylate, vinyl acetate, vinyl butyral, 2-vinyl pyridine styrene, and ethylene oxide; as well as polysulfones and nylons. See, for example, "Triboelectrification of Polymers" in K. C. Frisch and A. Patsis, *Electrical Properties of Polymers* (Technomic Publications, Westport, Conn.), which article is hereby incorporated by reference in its entirety. For example, polytetrafluoroethylene and polyethylene and will generally adopt a negative charge and create a positive charge on an object rubbed against them. Nylon and other materials will generally adopt a positive charge and create a negative charge on an object rubbed against them. Tribocharging and appliances for dispensing charged particles are describe in U.S. application Ser. No. 08/659,501 (filed Jun. 6, 1996) and U.S. Pat. No. 5,753,302. U.S. Pat. No. 5,753,302 describes, in particular, an acoustic dispenser that uses vibratory energy and gating electric fields to dispense charged particles for deposition onto the substrate, and is incorporated herein by reference in its entirety.

[**0064**] In some embodiments, the charged particles may be made up in a wet toner wherein particles of liquid material or liquid material with suspended solids are charged. Charging of the liquid particles can be by, for example, tribocharging occurring at the time the particles are formed, utilizing contact potential differences between solid particles and the particles, or modifying the differences in electrical potential using surface treatments such as surfactants. (See, L. B. Schein, *Electrophotography and Development Physics,* Laplacian Press, 1996, p. 227.) Often it is favorable to dry deposit materials to avoid issues of solubility and stability of a chemical. On the other hand, however, liquid phase depositions are often practical, especially where cautionary procedures, such as limiting the time of exposure to the liquid phase and selecting appropriate carrier solvents, are employed. Liquid phase deposition is for example useful where a material to be deposited is not readily converted to a dry form that can be deposited, or where the non-deposited dry form does not retain an activity such as a biological activity.

[0065] Several copending applications or issued patents provide information on dry deposition techniques. For example, methods for use of bead transporter chucks and acoustic grain dispensers are set forth in Pletcher et al., "Apparatus for electrostatically depositing a medicament powder upon predefined regions of a substrate," U.S. Pat. No. 5,714,007, issued Feb. 3, 1998; Pletcher et al., "Method and apparatus for electrostatically depositing a medicament powder upon predefined regions of a substrate," U.S. application Ser. No. 08/659,501, filed Jun. 6, 1996; Pletcher et al., "Method and apparatus for electrostatically depositing a medicament powder upon predefined regions of a substrate," U.S. application Ser. No. 08/733,525, filed Oct. 18, 1996; Pletcher et al., "Apparatus for electrostatically depositing and retaining materials upon a substrate," U.S. Pat. No. 5,669,973, issued Sep. 23, 1997; Datta et al., "Inhaler apparatus with modified surfaces for enhanced release of dry powders," U.S. application Ser. No. 08/661,213, filed Jun. 10, 1996; Sun et al., "Acoustic dispenser," U.S. Pat. No. 5,753,302, issued May 19, 1998; Sun et al., "Electrostatic Chucks," U.S. application Ser. No. 08/630,050, filed Apr. 9, 1996; Sun et al., "Electrostatic Chucks," U.S. application Ser. No. 08/661,210 filed Jun. 10, 1996; Sun, "Chucks and Methods for Positioning Multiple Objects on a Substrate," U.S. application Ser. No. 08/630,012, filed Apr. 9, 1996; Loewy et al., "Deposited Reagents for Chemical Processes," U.S. application Ser. No. 08/956,348, filed Oct. 23, 1997; Loewy et al., "Solid Support With Attached Molecules," U.S. application Ser. No. 08/956,737, filed Oct. 23, 1997; Sun, "Bead Transporter Chucks Using Repulsive Field Guidance," U.S. application Ser. No. 09/026,303, filed Feb. 19, 1998; Sun, "Bead manipulating Chucks with Bead Size Selector,", U.S. application Ser. No. 09/047,631; Sun, "Focused Acoustic Bead Charger/Dispenser for Bead Manipulating Chucks," U.S. application Ser. No. _____ filed May 22, 1998 [SAR 12275]. Additional instructional information is found in Sun et al., "AC waveforms biasing for bead manipulating chucks," U.S. application Ser. No. _____, filed concurrently herewith [SAR 12610]; Poliniak et al., "Dry Powder Deposition Apparatus," U.S. application Ser. No. _____, filed concurrently herewith [SAR 12914]; and "Pharmaceutical Product and Method of Making," U.S. application Ser. No. _____, filed concurrently herewith.

[0066] All publications and references, including but not limited to patents and patent applications, cited in this specification are herein incorporated by reference in their entirety as if each individual publication or reference were specifically and individually indicated to be incorporated by reference herein as being fully set forth. Any patent application to which this application claims priority is also incorporated by reference herein in its entirety in the manner described above for publications and references.

[0067] While this invention has been described with an emphasis upon preferred embodiments, it will be obvious to those of ordinary skill in the art that variations in the preferred devices and methods may be used and that it is intended that the invention may be practiced otherwise than as specifically described herein. Accordingly, this invention includes all modifications encompassed within the spirit and scope of the invention as defined by the claims that follow.

What is claimed:

1. An apparatus for electrostatically adhering grains to a planar substrate comprising:

a. an electrostatic chuck having a collection surface with at least one grain collection zone for, when the planar substrate is layered on the collection surface, electrostatically directing charged grains to a corresponding surface on the planar substrate; and

b. a pattern of holes through the electrostatic chuck allowing a source of low pressure to act through the electrostatic chuck to adhere the planar substrate.

2. The apparatus of claim 1, further comprising:

d. a low pressure chuck having an adhesion surface having a plurality of holes for aligning with the holes to connect the holes to the source of low pressure.

3. The apparatus of claim 2, wherein the adhesion surface comprises a porous material.

4. The apparatus of claim 1, wherein the electrostatic chuck comprises (i) the collection surface, (ii) a dielectric layer located behind the collection surface, (iii), behind the dielectric layer, one or more attraction electrodes for attracting grains to the collection zones.

5. The apparatus of claim 4, wherein the electrostatic chuck further comprises (iv) one or more shield electrodes for discouraging charged grains from being directed away from the collection zones.

6. An electrostatic deposition apparatus for electrostatically depositing grains onto a planar substrate comprising:

i. at least one low pressure chuck having an adhesion surface having a plurality of holes for conveying low pressure to the adhesion surface;

ii. layered on the collection surface, at least one electrostatic chuck having a collection surface with at least one grain collection zone for, when the planar substrate is layered on the collection surface, electrostatically directing charged grains to a corresponding surface on the planar substrate, the at least one electrostatic chuck having a pattern of holes through the electrostatic chuck allowing the low pressure to act through the electrostatic chuck to adhere the planar substrate; and

iii. a charged grain dispenser for directing charged grains towards the grain collection zones.

7. The electrostatic deposition apparatus of claim 6, further comprising rotatable cluster of a plurality of said low pressure chucks, wherein the low pressure chucks rotate to repeatedly and sequentially present the adhesion surfaces to the charged grain dispenser.

8. The electrostatic deposition apparatus of claim 7, further comprising:

iv. a low pressure control mechanism for sequentially applying low pressure to low pressure chucks and sequentially releasing the low pressure from low pressure chucks such that there is a contiguous collection of the low pressure chucks to which low pressure is applied and a contiguous collection of the low pressure chucks with no applied low pressure, thereby allowing a sheet of planar substrate to be presented to the charged grain dispenser while adhered to an electrostatic chuck and low pressure chuck and then released for further processing.

9. A method of electrostatically applying a grains to a planar substrate comprising:

a. adhering the planar substrate to an electrostatic chuck with a pressure differential conveyed to the planar substrate via passages through the electrostatic chuck;

b. applying a voltage to the electrostatic chuck to attract charged grains to at least one grain collection zone defined by the electrostatic chuck;

c. directing charged grains towards the charged grain collection zone; and

d. electrostatically adhering charged grains on a portion of the planar substrate corresponding to the grain collection zone.

* * * * *