

[54] **DEVICE FOR EXPOSING SMALL
ROLLABLE BODIES TO SPUTTERING**

[75] Inventors: **John Edwin Greenlay**, Montreal;
Bruce Denis William Pulling,
Otterburn Heights; **Arthur**
Francis Morton, St. Hubert, all of
Quebec, Canada

[73] Assignee: **Northern Electric Company,**
Limited, Montreal, Quebec, Canada

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198/33 AA, 198/220 BC

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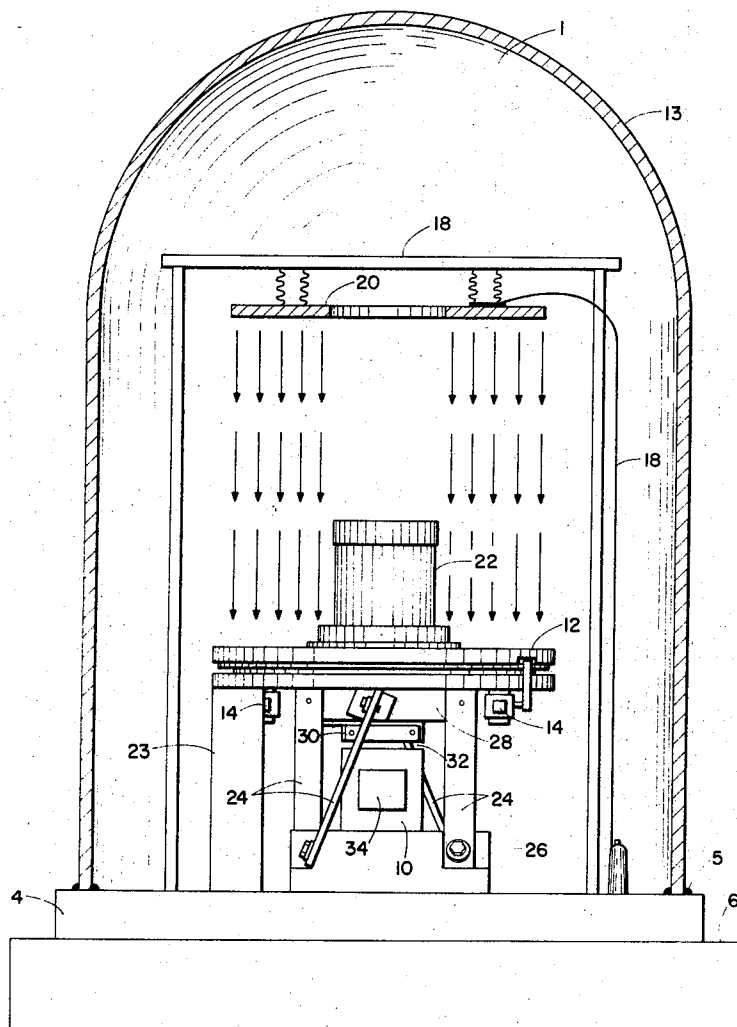
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Primary Examiner—John H. Mack
Assistant Examiner—Sidney S. Kanter
Attorney—Philip T. Erickson

[57] **ABSTRACT**

Cylindrical ceramic blanks are fed endwise down grooves in a vibratory table and simultaneously caused to revolve about their axes, while subjected to the deposition of material sputtered from above. The endwise movement can be stopped by closing gates at the end of the grooves, in order to prolong exposure to sputtering. The blanks are loaded in a central hopper of a round table vibrated by a torsional vibrator of the type used for tangential feeders. The grooves are offset from the radial direction so that the vibration of the table will impart slight outward impulses to the blanks, which are additionally led forward by a slight downward slant of the grooves. The grooves are semicylindrical and a few per cent larger in diameter than the blanks in order to produce a smooth rolling motion.

15 Claims, 8 Drawing Figures



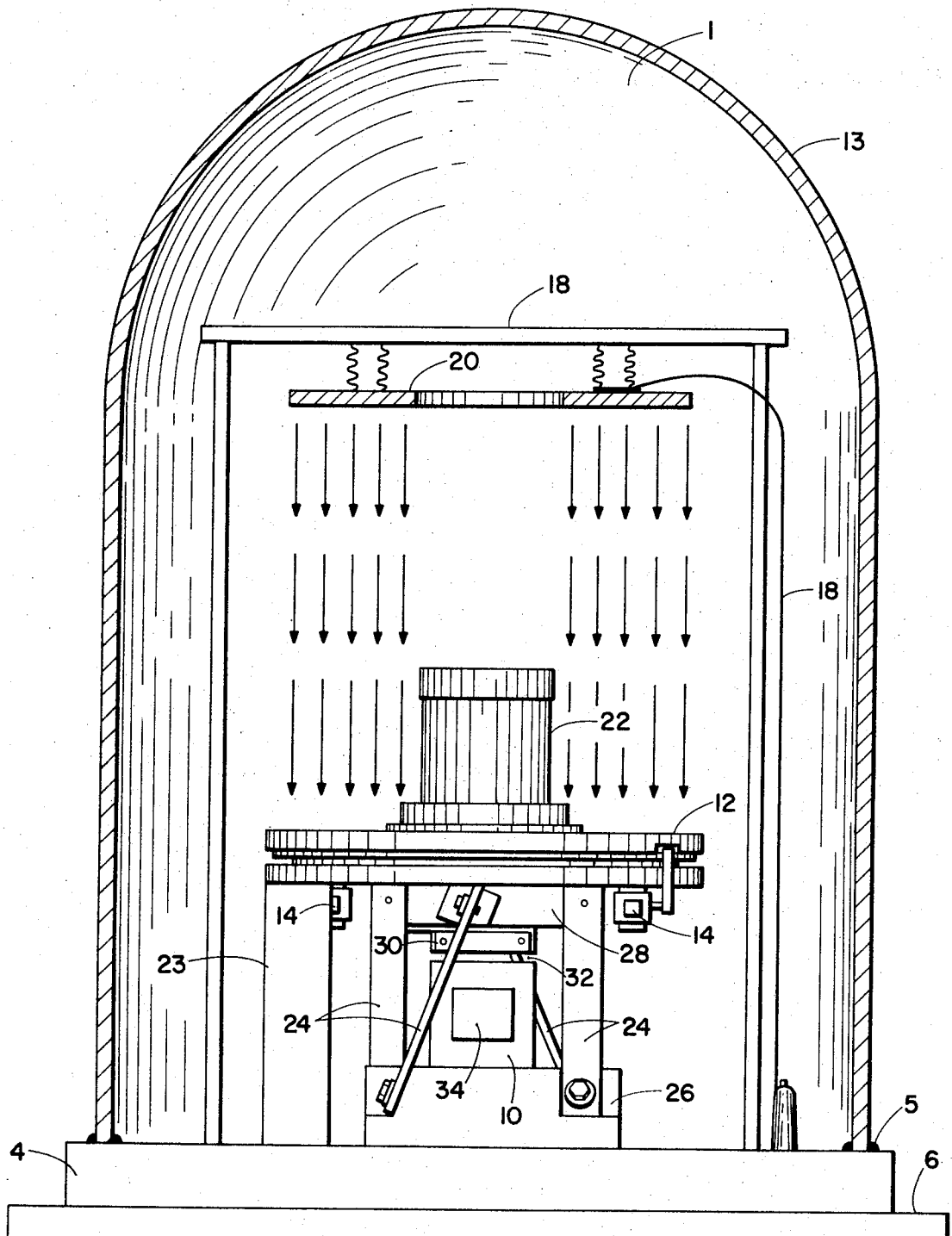


Fig. 1

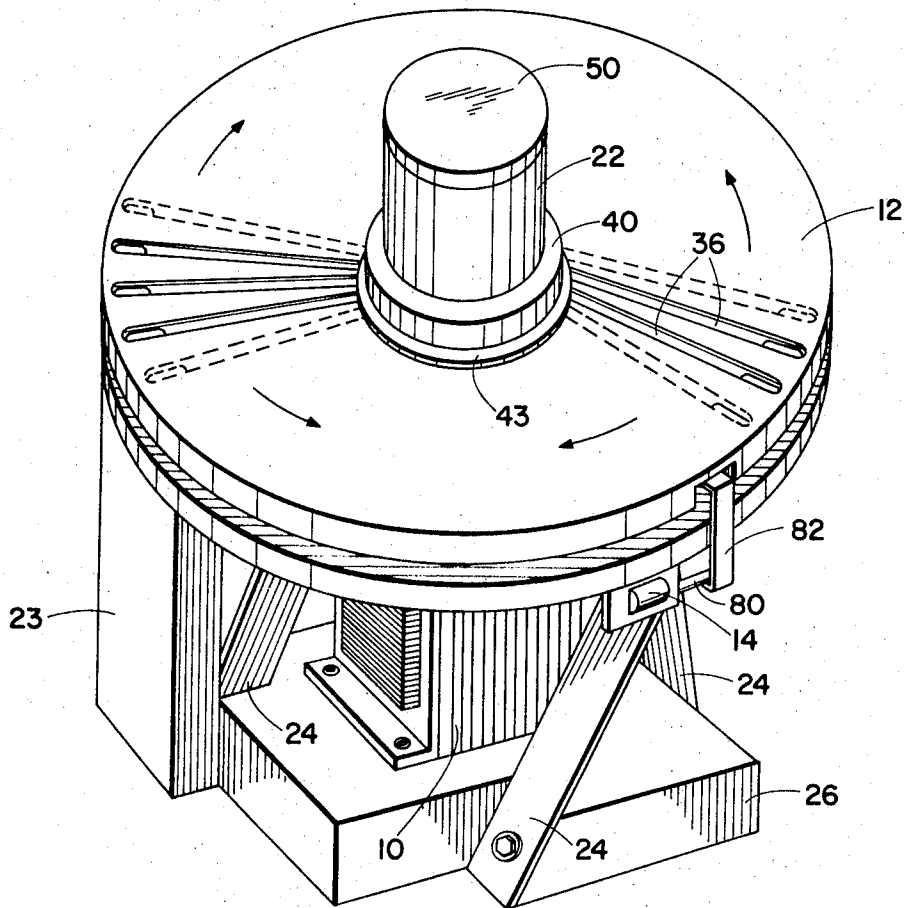


Fig. 2

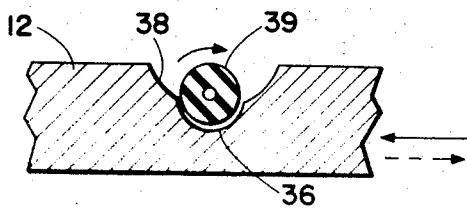


Fig. 3

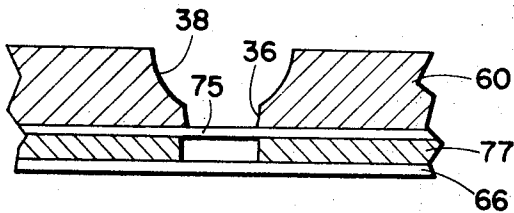


Fig. 8

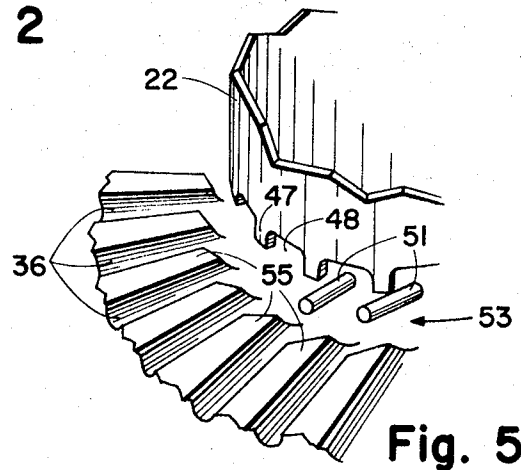


Fig. 5

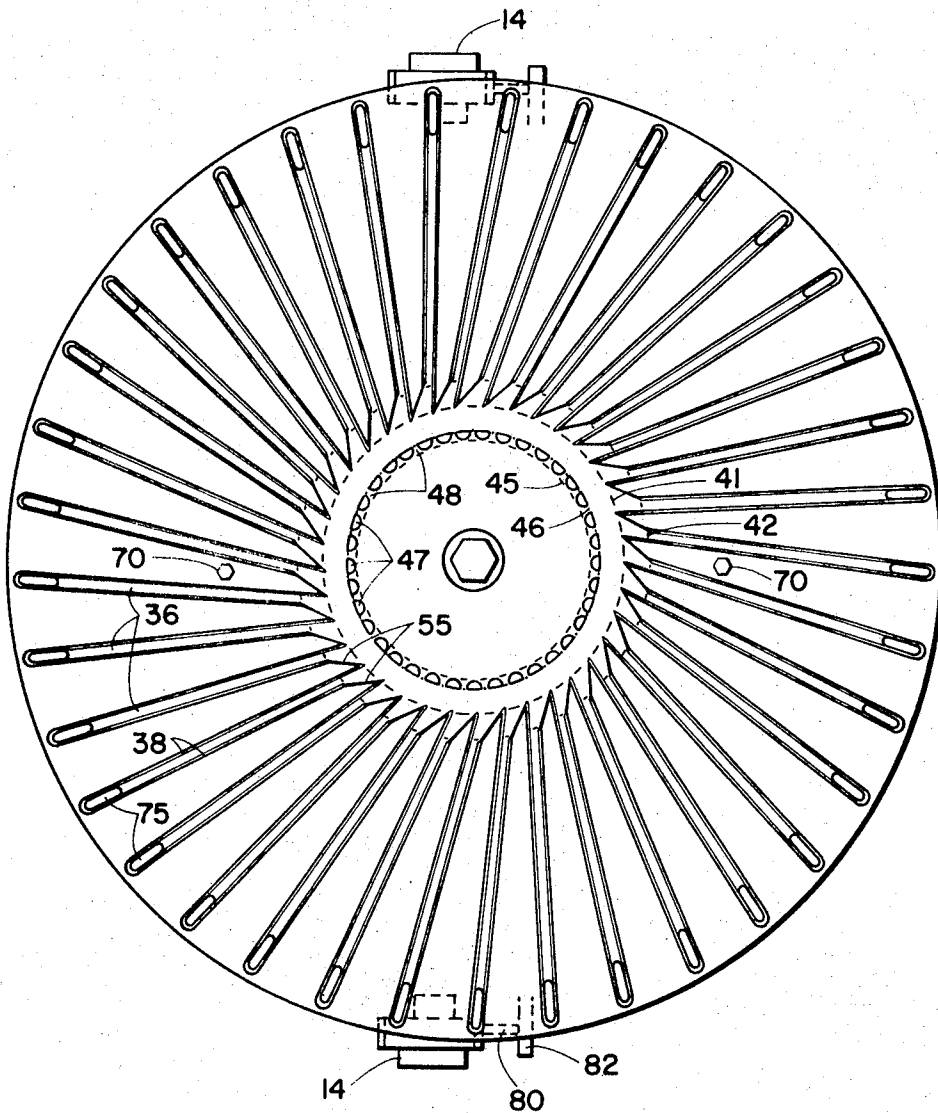


Fig. 4

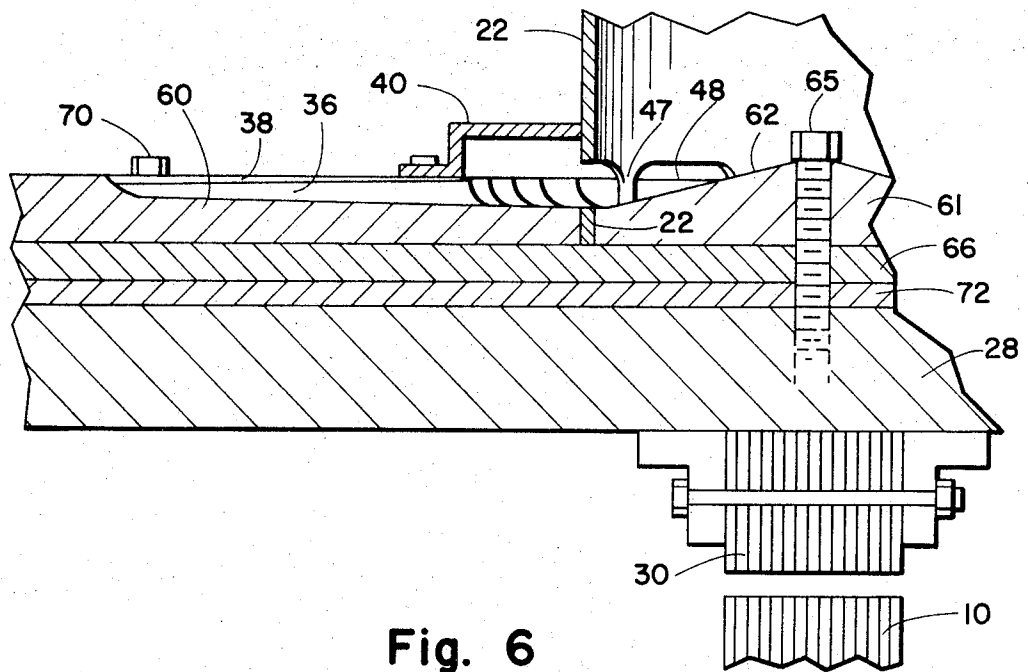


Fig. 6

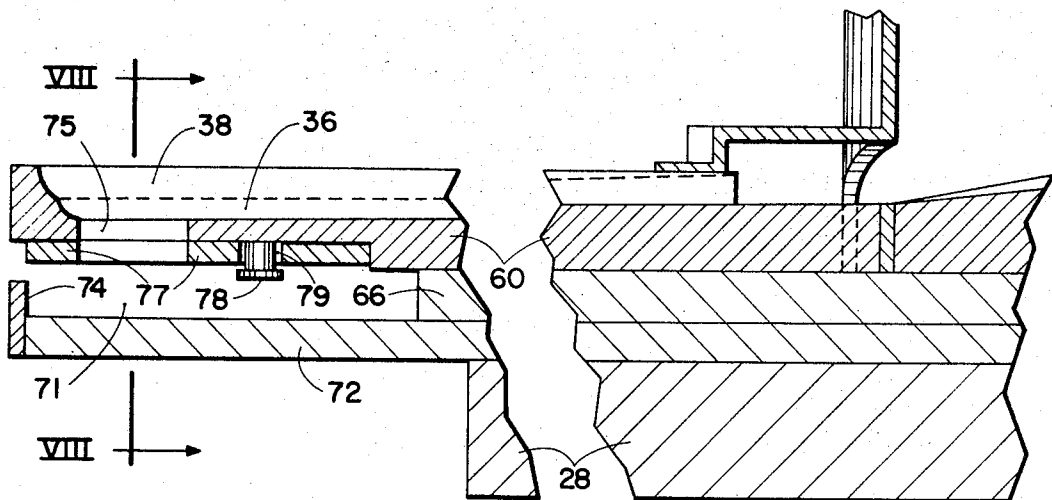


Fig. 7

DEVICE FOR EXPOSING SMALL ROLLABLE BODIES TO SPUTTERING

This invention relates to the formation of films on the cylindrical surfaces of elongated small cylindrical bodies, and more particularly to the formation of film type electrical components on cylindrical insulating blanks by sputtering techniques.

In recent years, film type electrical resistors using metallic or partially oxidized metallic film, in which the metal may be zinc or tantalum for example, deposited on an insulating substrate such as high quality ceramic, have acquired a certain preference in the electronics industry because of the relatively high stability of their electrical characteristics. A preferred method for the manufacture of such film type electronic components has been sputtering in high vacuum under the influence of a strong electric field, with an electrode of the material to be sputtered serving as a cathode, and with the work or the work support as the anode. The sputtering process lends itself readily to the manufacture of films of the desired thickness on flat ceramic or glass substrates and in the case of resistors, the higher values of resistance can be made by etching, leaving a zig-zag film path for the active portion. There is, however, a continuing interest in manufacturing film type components on cylindrical ceramic substrates because of the compact nature of such components and the ease of obtaining a wide range of values with such components by a helixing operation that lends itself easily to accurate automatic control.

In order to manufacture cylindrical film type components by sputtering techniques, the necessity of evenly exposing cylindrical surfaces to rectilinear or radial sputtering has posed difficult problems. One solution has been to take advantage of the hollow core frequently provided on cylindrical ceramic blanks in order to support a multiplicity of blanks axially end to end on an array of turning rods, but the loading and unloading of such a sputtering apparatus is necessarily time consuming.

This invention provides a supporting electrode for cylindrical blanks undergoing sputtering which will both advance the blanks from an input hopper to an output hopper and also rotate them about their axis while advancing through the sputtering zone. In addition, a gate may be provided to arrest the progress of the blanks through the sputtering zone, while they continue to be caused to rotate to expose their cylindrical surfaces uniformly to sputtering. This is accomplished by feeding the blanks into round-bottom grooves slightly wider than the blanks and inclined to lead the blanks by gravity towards the output hopper and providing a vibration transverse to the grooves preferably slightly off the perpendicular to the grooves, with an asymmetrical vibratory momentum to cause the cylindrical blanks to rotate about their axes. The machine works better if the vibration imparts a slight forward motion to the blanks, although most of the force imparted is used to produce rotation. We prefer to accomplish this operation on a round supporting table with grooves, fanning outward from the center, that are not strictly radial, but rather such that if they were extended inward they would be tangent to a circle about the center. This structure lends itself readily to the provision of a central loading hopper and a receiving hopper at a chosen point on the periphery and also to in-

stallations of the equipment in a cylindrical bell jar type vacuum enclosure, with the sputtering cathode at the top. The vibrating drive for the support can in this case be of the well known type used for feeders for small parts. The vibrator has a relaxation type of oscillation which communicates more momentum in one direction than the other.

In the drawings which describe an embodiment of the invention:

FIG. 1 is a side elevation partly in section of an apparatus for sputtering metallic films on small cylindrical blanks;

FIG. 2 is a perspective view of the vibrating table of the apparatus shown in FIG. 1;

FIG. 3 is transverse cross-section of one of the grooves of the table with a cylindrical blank, also shown in section, seated in the groove;

FIG. 4 is a plan view of the table with part of the central superstructure removed and another part shown in section;

FIG. 5, appearing with FIGS. 2 and 3, is a partial perspective view of the inner portion of the table with a covering element removed;

FIG. 6 is a part of a radial vertical section of the table;

FIG. 7 is part of a vertical section of the table taken along the axis of one of the grooves, and

FIG. 8, appearing with FIGS. 2 and 3, is a transverse section of a portion of the table along the line 8—8 of FIG. 7.

As shown in FIG. 1, the sputtering process is conducted in an evacuated enclosure 1 typically enclosed by a domed glass cylinder 3 mounted on a base 4 with a demountable vacuum seal 5. Means for establishing, maintaining and releasing the vacuum are not shown but it is understood that these will normally be provided going through the base 4 and that the sub-base 6 will have appropriate perforations and/or channels for these facilities. The electrical connections are likewise not shown and they would similarly be brought out through the base 4, not only to supply the high voltage for generating the sputtering phenomenon, but also for energizing the actuator 10 of a vibrating table 12 and for actuating the gate solenoids 14 the function of which will be described later.

A mesh screen, not shown, may be provided over all or much of the surface of the glass enclosure 3 to limit the high voltage field to the inside of the enclosure. Such a screen would naturally be grounded.

An insulated structure 18, preferably made entirely out of insulating material so as not to disturb the electric field, suspends the annular cathode 20, which is shown in cross-section so that its shape may be apparent. At least the lower surface of this electrode is made of the metal to be sputtered. It is held far enough above the table 12 so that any distortion of the electric field by the central loading hopper 22 will not disturb the downward sputtering direction of the particles of metal shown by the arrows in the drawing.

The table 12 is mounted on four oblique stiff leaf springs 24 connecting a heavy base block 26 with a square mounting block 28 in the well known arrangement of torsional vibrators. Beneath the block 28 is suspended the armature 30. A narrow air gap 32 separates armature 30 from actuator 10. Alternating current through coil 34 of actuator 10 will impose a vertical vibratory force on armature 30 and springs 24 will cause

the vibration of the table 12 to be torsional in nature, with a relaxation type of characteristic tending to impart a unidirectional tangential momentum to particles on the surface of the table.

FIG. 2 shows the surface of the table 12 in perspective. The grooves 36 are not radial. They radiate from the central area surrounding the hopper 22, but they are tangent to a small circle concentric with the circumference of the table. The diameter of the table is preferably between 1 and 2 feet and the diameter of the circle to which the grooves are tangent is about 1 inch. The circle to which the grooves are tangent is most appropriately related to the outer diameter of the distribution area which feeds the grooves. Such a relation fixes the angle of the grooves to the radii that they intersect at their innermost ends. In these terms, our findings are that the diameter of the circle to which the grooves, or their center lines rather, are tangent, is preferably between an eighth and a quarter of the diameter of the largest circle that can be inscribed in the distribution area (e.g. the circle which defines the inner ends of the grooves). The central input hopper is part of a distributing head for the blanks to be treated. It is a cylindrical container mounted on the table 12 with a series of broad slots just above the level where the container meets the surface of the table, to permit the cylindrical blanks loaded into the container to spread out on the surrounding surface of the table and to feed into the grooves 36. It has a cover 50 removable for loading. The outer distributing zone has a fixed cover 40 to shield the blanks from sputtering at this stage.

FIG. 3 is a transverse cross-section of a groove with a cylindrical blank in it, illustrating the action of the table. The operative round bottom groove 36 is preferably semi-cylindrical. The bottom of the groove is not horizontal, but rather inclined slightly to lead blanks towards the edge of the table. Even where the groove is nearest the top surface of the table 12 it should be deep enough to be semi-cylindrical. It is therefore convenient to provide additional grooving in the form of shallower curved surfaces 38 above at least the deeper parts of the groove so that the working groove will be semi-cylindrical along its whole length. Instead of providing the broader curved surfaces 38, the upper surface of the table 12 could be very slightly conical, lower at the edge than in the center, so that the grooves 36 could be semi-cylindrical, flush with the surface and also slanted the right amount downwards. The downwards inclination is preferably of the order of 3°.

The diameter of the grooves 36 is only slightly larger than that of the blanks to be treated in the apparatus, one of which is shown in cross-section at 39 in FIG. 3. The movement of the table 12 is such as to propel particles on its surface to the left, viewed from the edge (solid arrow at right on FIG. 3). The rotation imparted to the cylindrical blanks is clockwise, viewed from the edge of the table (curved arrow, FIG. 3). If the grooves are too wide, the blanks will be caused to roll around somewhat irregularly. We prefer a groove diameter about 5 percent greater than the diameter of the blanks to be treated.

FIG. 4 is a top view of the table with the cover 40 removed. Dashed circles 41 and 42 enclose the area where the flange 43 of cover 40 fits over the table. Dashed circles 45 and 46 are the projection of the walls of hopper 22, which is shown in section just barely

above the level of the table, so that only the posts 47 between the slots 48 are present at this level.

FIG. 5 shows a few blanks 51 in the portion of the table where the blanks are distributed into the various grooves 36. The arrow 53 shows the direction in which the blanks 51 impelled by the motion of table 12 as they come out by gravity through the elongated apertures 48 of the hopper 22. The momentum imparted to the blanks is tangential and, besides, there is a slight outward slope to the surface on which they move after coming out of hopper 22, so that by a combination of forces the blanks 51 are propelled into the grooves 36. The vibratory motion of the table keeps the blanks from sticking in place by friction and makes them sensitive to the effect of the small inclination of the surfaces on which they move.

When the machine is in use, the blanks come out of the hopper 22 close together and rather completely fill the distribution area just outside the hopper. The ends of the lands 55 are faired away to open up each groove on the side from which the blanks come to it. This shaping serves to lead the blanks easily into the grooves. When the distribution area is well filled with a single layer of blanks, all the grooves are continuously fed with blanks. Even as the supply of blanks runs out, the combined rotation, vibration and advancement imparted in the grooves by the motion of the table, together the inclination of the surfaces, keeps the blanks progressing and rotating smoothly in the grooves.

FIG. 6 is a radial cross-section of the distribution area of the table 12. Hopper 22 is shown fitting into a central hole in the upper member 60 of the table into which the grooves 36 are cut. One of these is sectioned at a small angle to its axis, so that the surface of its far side and one of the surfaces 38 appear in FIG. 6.

An insert 61 provides a floor for the hopper 22 and preferably has a conical surface 62 somewhat steeper than the downward inclination of the grooves and distribution area of the table 12. A central machine screw 65 (and lock washer, not shown) holds the insert 61 in place and also serves to hold the spacing disc 66 to the square block 28 which is actuated by the armature 30 in cooperation with the springs 24 (FIGS. 1 and 2). Machine screws 70 located on the lands between the grooves 36 serve to hold the upper portion 60 of the table 12 to the spacing disc 66 and the square block 28.

As shown in FIG. 7, the purpose of the spacing disc 66 is to provide a peripheral channel 71 on the upper surface of the lower member 72 of the table 12 between the circumference of disc 66 and a retaining lip 74 provided on the circumference of the disc 72. The ends of the groove in the upper member 60 of the table have gate apertures 75 of such size as to permit a treated blank to drop through to the channel 71 and a gate shutter 77 is provided for the purpose of controllably opening or closing the gates 75. The shutter 77 is a flat annular member with apertures that may be brought into register with the gate apertures 75 and it is mounted on a plurality of supports, such as support 78 shown in FIG. 7. These supports project through slots 79, which are shaped to permit sufficient rotary movement of the shutter 77 to enable it to open or close the gates 75.

The shutter 77 is actuated by the solenoids 14, one of which is adapted to pull the shutter around to open the gates 75 and the other of which is adapted to pull it back in the opposite direction to close them. In order

that the solenoids 14 may be mounted on the underside of the lower member 72 of the table 12, the armatures 80 of the solenoid 14 are provided with actuator details 82 for transmitting the motion of the armatures to the shutter 77.

FIG. 8 shows a cross-section along the lines 8—8 of FIG. 7.

When the treated blanks are permitted to drop through the gates 75 into the channel 71, the vibratory motion of the table then propels them in the channel 71 around the table until they are gathered by the output hopper 23, into which they fall.

The shutter 77 serves to permit the sputtering of the blanks to be prolonged in the event that a straightforward passage through the groove 36 would not build up a sufficiently heavy film of the sputtered material on the blanks. In that case, the shutter can be closed except for intervals just long enough to drop into the channel 71 those blanks which have been sputtered since the last opening of the shutter, and the blanks can be held on the table 12 for the necessary length of time to build up the desired film. When the shutter is closed, the blanks will simply rotate in the grooves 36. As soon as the shutter opens and the end blank falls through the gate 75, the forward progress of the blanks in the grooves is resumed. It is difficult to design the gate so as to keep the end blank rotating when the gate is shut and we prefer to place the gate beyond sputtering range or to provide the gates with a cover (not shown).

We recognize that of course an apparatus of a similar design could be made in which the blanks move from the outside of the table to the inside, in which case the angle of the grooves to the radius of the table should be in the opposite sense, assuming that the direction in which particles on the table are propelled remains the same. Blanks could also be caused to advance in long parallel grooves and subjected to a transverse vibration, in which case again the direction of vibration should be somewhat off the perpendicular to the axes of the grooves, in the direction such as to give the blanks a slight forward component from the vibration to add to the gravity effect from the slight inclination of the grooves. The form of apparatus here shown, however, is preferred because it not only provides a smooth rotation and advancement of the particles over a considerable range of vibration amplitude, but it provides a simple loading system adapted to keep all the grooves filled as the process goes on and a collecting system which makes use of the same motion of the table that is used to cause the rotation of the blanks.

The speed of the rotation of the blanks can be controlled by a variable autotransformer controlling the alternating current supplied to the actuator 10. By thus varying the power input, the blanks in the grooves can be made to rotate slowly, at moderate speed, or fast. We prefer to have them rotate at moderate speed during processing so that in the unlikely case that some of the apertures 48 get jammed during operation, the power input to the actuator 10 can be momentarily raised to an input corresponding to a high rotation speed of the blanks, so that the additional agitation in the hopper 22 will clear the apertures.

Aluminum is preferred as a material for the upper member 60 of the table 12 because sputtered metals used in the process do not stick to it, so that the table is easily cleaned after use. Similarly, aluminum is pre-

ferred for the hopper 22 and its cover 50 and for the cover 40 for the distributing area of the table 12.

Pulse-rotatory holding devices of this invention such as the one illustrated in the drawings are not limited to manipulating cylindrical blanks. Various types of rectilinearly rollable bodies such as prolate spheroids of material, spherical bodies, or helical bodies of at least two turns, or dumbbell shaped bodies can be handled, so long as the rolling diameter is a few per cent smaller than that of the grooves. These various types of bodies can thus be exposed to application of material or influences from above and, if desired, simultaneously advanced across the exposure zone by the same type of grooved vibrating table.

The grooves 36 are preferably cylindrical in shape in the strictest sense, that is, semicircular in cross-section, although a semi-elliptical cross-section would be operable if the major axis is horizontal and the eccentricity is small. The bodies to be handled by the table must be able to roll freely and in a straight line on a flat surface and their length must be at least equal to the rolling surface diameter and preferably considerably in excess thereof, so that they will not topple in the axial direction as the result of forces propelling them axially.

A frustoconical body would not meet these requirements. A symmetrical base-joined biconical body could be handled by the device after a fashion but its instability of rolling might make its motion irregular. On the other hand a prolate spheroid or a ball would give no difficulties. We may describe the bodies to be handled by machines of our invention as rollable to express the meaning just explained and the qualification "rollable in a straight line" is to be understood. It is also to be understood that a rollable body as meant herein has dimension along the axis of rolling at least as great as the rolling diameter, and usually considerably greater.

While grooves 36 of the preferred embodiment disclosed herein are straight, they could be curved to achieve greater length in the same table diameter and greater dwell of the bodies moving therealong in the sputtering region.

What is claimed is:

1. A machine for exposing to treatment the peripheral surface of rollable bodies comprising:

- a. a grooved vibratory table, having round bottom grooves slightly inclined to the horizontal and of a diameter slightly in excess of the rolling diameter of said bodies
- b. a distributing head adapted to be loaded with said bodies and to distribute them to the upper ends of said grooves of said table;
- c. means for vibrating said table with a dynamically asymmetric vibration generally transversely of said grooves and having a small component thereof in the direction of descent of said grooves whereby said bodies are caused to rotate in their rolling mode and influenced also to descend said grooves,
- d. means for treating the peripheral surfaces of said bodies as exposed in said grooves, and
- e. means for collecting said bodies after they arrive at the lower ends of said grooves.

2. A machine as defined in claim 1 in which the said round bottom grooves are straight.

3. A machine as defined in claim 2 in which each of said grooves terminates at its lower end in a gate and in which there is a shutter adapted to open and to close said gates simultaneously for alternatively arresting the

progress of said bodies down said grooves or permitting them to proceed to said collecting means.

4. A machine for exposing to treatment the peripheral surface of rollable bodies comprising:

- a. a torsional vibrator of the type adapted to propel particles tangentially on a surface carried thereby,
- b. an output feeder carried by said vibrator having a peripheral channel and an output orifice therefrom,
- c. a grooved treatment table superposed on said output feeder having a distribution depression for said bodies at its center, a multiplicity of round-bottom grooves slightly wider than said bodies extending outwardly and slightly downwardly from said depression and leading outwardly away therefrom in a direction diverging, at a small angle, from the radial direction towards the direction of propulsion of said vibrator,
- d. an aperture located over said channel of said feeder at the outer end of each of said grooves, of a size adapted for passage of said bodies one at a time from the groove to said channel of said feeder,
- e. a distributing head including a loading hopper mounted over said depression, and
- f. a collecting container disposed below said output orifice of said feeder.

5. A machine as defined in claim 4 in which said grooves are straight and semicylindrical.

6. A machine as defined in claim 5 in which the edges of said grooves are at least in large part below the upper surface of said table and are bordered by lateral bench surfaces lowering the table surface in the immediate neighborhood of said groove edges.

7. A machine as defined in claim 6 in which said bench surfaces are concave and cylindrical.

8. A machine as defined in claim 4 which the lands between the said grooves are faired away where the grooves meet said distribution depression, said fairing being solely or preponderantly on that side of a groove from which said bodies tend to arrive to it as the result of being impelled tangentially in the outer part of said distribution depression by said vibrator.

9. A machine as defined in claim 4 in which said loading hopper is cylindrical at least in its lower portion and has a floor higher in the center than at its periphery, which at said periphery is flush with and communicates with said distribution depression through openings adapted for feeding said bodies in a single layer to said distribution depression.

10. A machine as defined in claim 9 in which the floor of said distribution depression is inclined slightly, in a very flat conical manner so that the outer part is a little deeper than the inner.

11. A machine as defined in claim 4 which also includes a shutter mounted at the underside of the outer portion of said table operable to hold either of two positions, one of which blocks all of said apertures and the other of which leaves all of said apertures open, and means for operating said shutter.

12. A machine as defined in claim 11 in which said means for operating said shutter are remotely controllable.

13. A machine as defined in claim 11 in which said means for operating said shutter are a pair of solenoids, each of which is adapted to pull said shutter into one of its positions.

14. An apparatus for treating the peripheral surface of rollable bodies comprising:

- a. a base;
- b. a machine as defined in claim 4 mounted on said base;
- c. an enclosure removably supported on said base and forming therewith a gas tight enclosure surrounding said machine; and
- d. means for establishing an environment within said enclosure to which said bodies are exposed for treatment.

15. An apparatus as defined in claim 14 for electrostatic sputtering of cylindrical cores in high vacuum further comprising:

- e. a pressure seal on said base adapted to permit said enclosure to be opened when vacuum is released;
 - f. means for opening and closing said enclosure when no vacuum is present; and
 - g. means for initiating, controlling and arresting the operation of said machine from outside said enclosure,
- said means for establishing an environment within said enclosure comprising:
- h. a high voltage sputtering electrode mounted on said base at a distance above said base;
 - i. means for establishing a high vacuum in said enclosure, for maintaining the same and for releasing the same; and
 - j. means for applying sputtering voltage to said electrode.

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