United States Patent [19]

Porter et al.

[11] **3,749,052**

[45] **July 31, 1973**

[54] **TILTING VARIABLE SPEED ROTARY SHADOWER**

[75] Inventors: **John Halsted Porter**, Winooski; **William Alexander Ladd**, Burlington, both of Vt.

[73] Assignee: **Ladd Research Industries, Incorporated**, Burlington, Vt.

[22] Filed: **Nov. 15, 1971**

[21] Appl. No.: **198,511**

Related U.S. Application Data

[62] Division of Ser. No. 89,575, Nov. 16, 1970, Pat. No. 3,663,273.

[52] **U.S. Cl.** **118/48**, 118/53

[51] **Int. Cl.** **C23c 13/08**

[58] **Field of Search** 118/48–49.5, 53; 117/107.1; 269/55

[56] **References Cited**

UNITED STATES PATENTS

3,656,453	4/1972	Tousimis	118/49
3,486,237	12/1969	Sawicki	118/49 X
3,128,205	4/1964	Illsley	118/49

Primary Examiner—Morris Kaplan
Attorney—William R. Hulbert

[57] **ABSTRACT**

Method and apparatus for completely and uniformly coating a specimen for examination by a scanning electron microscope. The specimen is rotated and precessed for exposure of all upper portions to the beam of coating vapor, and is variably shielded from the beam to ensure uniformly thick coating of all portions.

6 Claims, 9 Drawing Figures

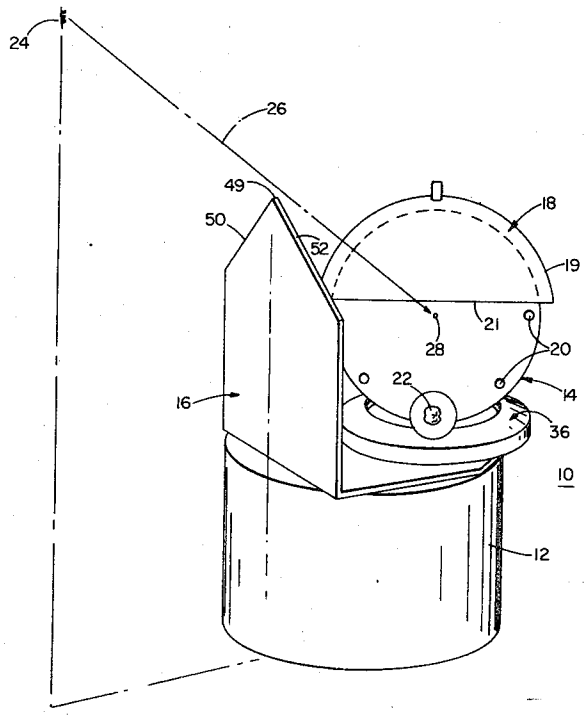
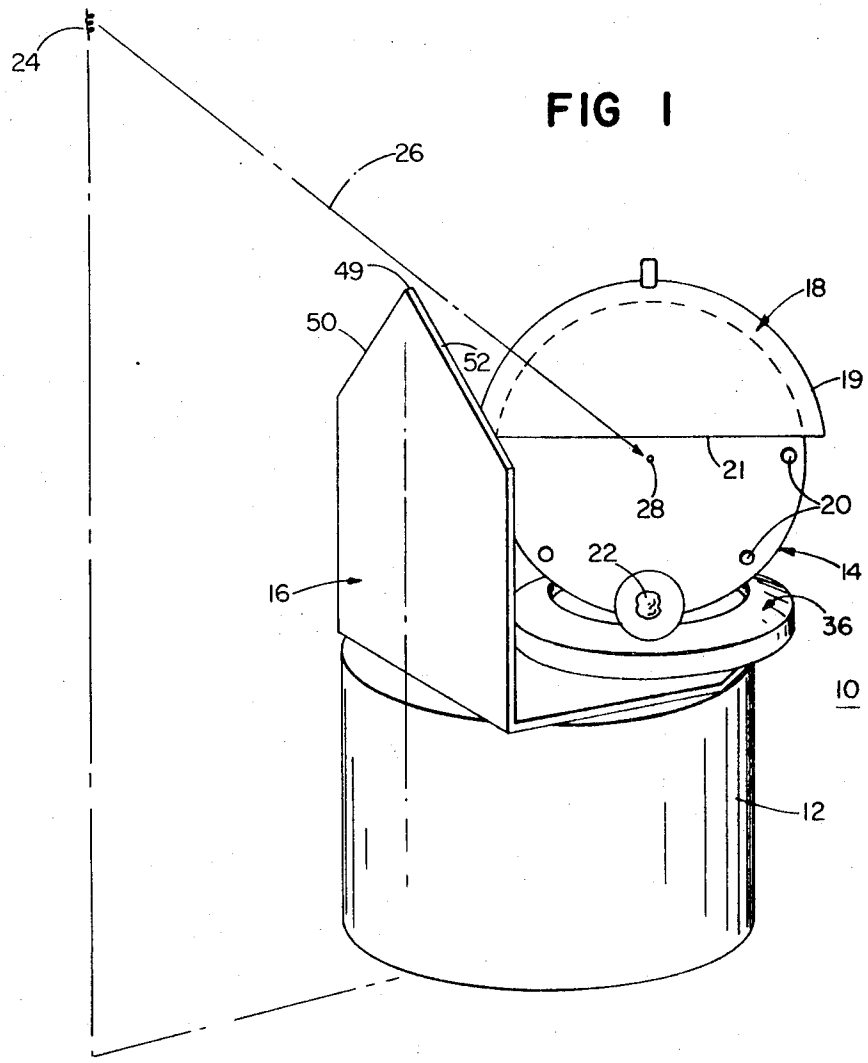


FIG 1



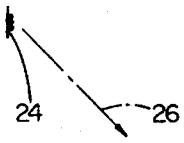
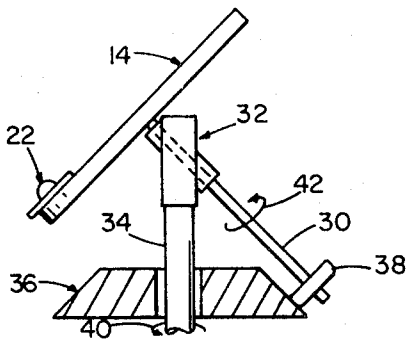


FIG 2



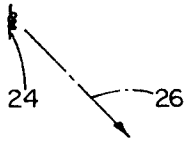
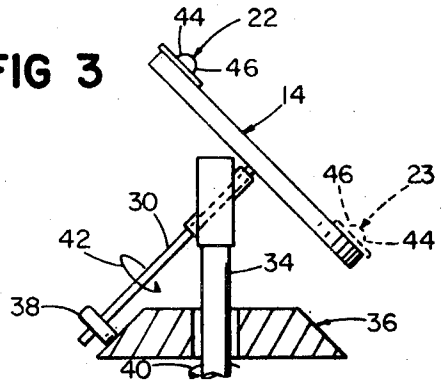


FIG 3



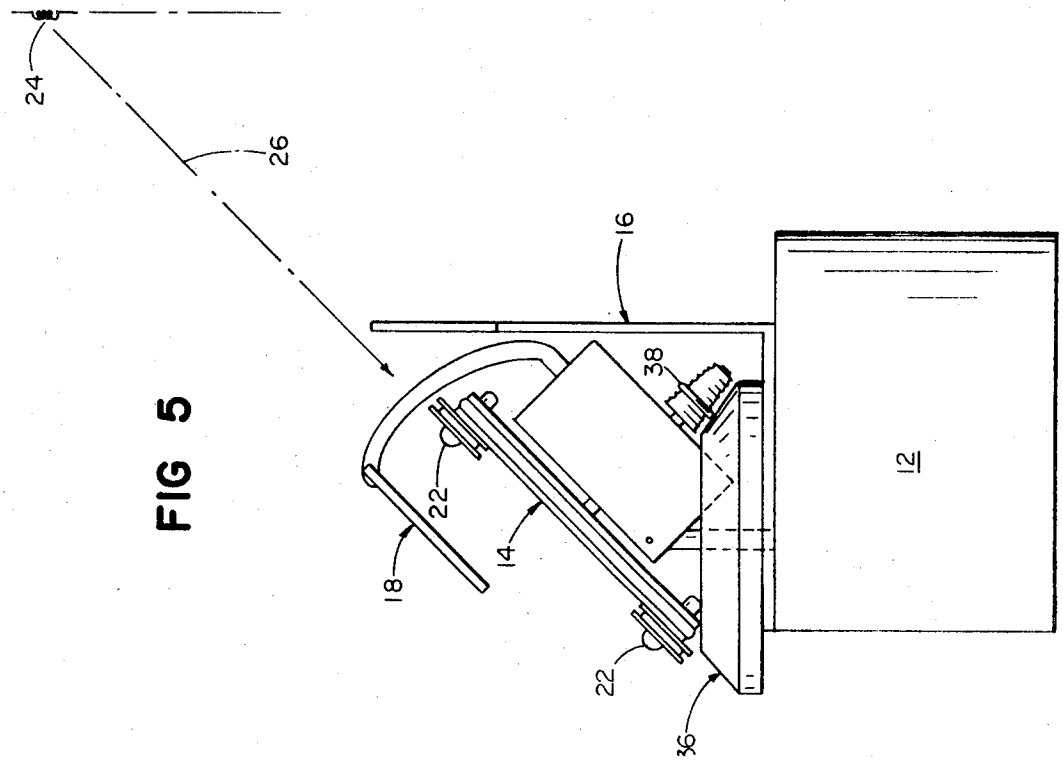


FIG 5

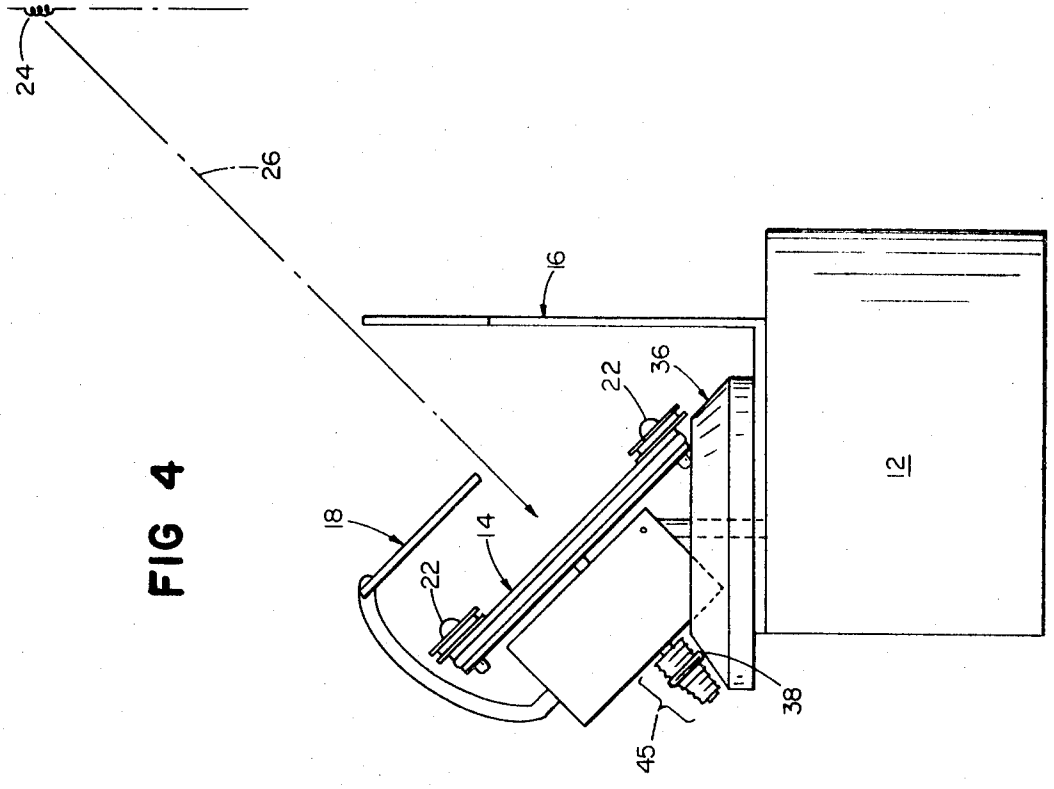


FIG 4

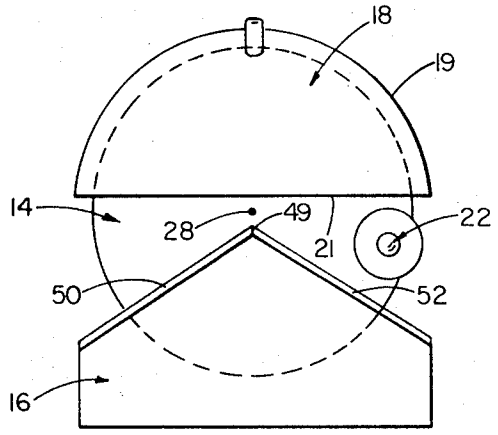


FIG 6

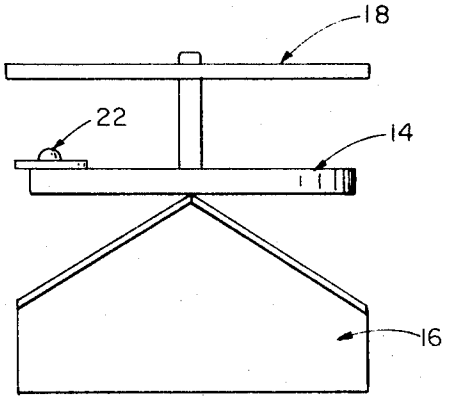


FIG 7

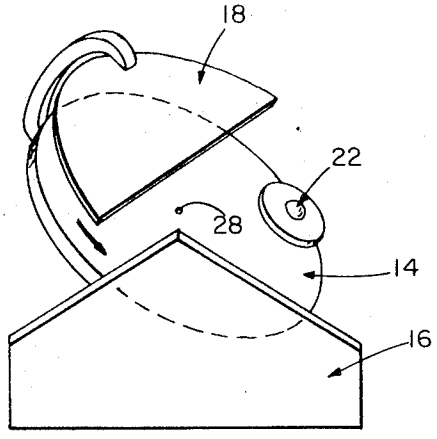


FIG 8

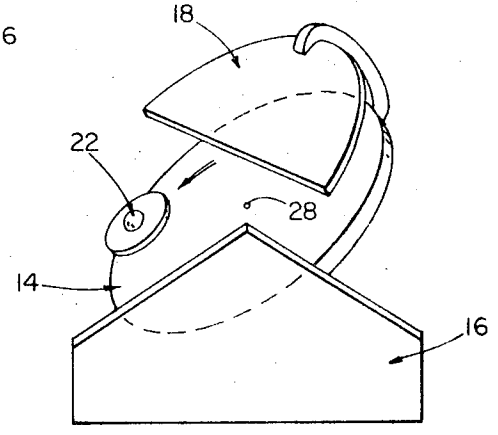


FIG 9

TILTING VARIABLE SPEED ROTARY SHADOWER

This is a division of application Ser. No. 89,575 filed Nov. 16, 1970 and now U.S. Pat. No. 3,663,273.

This invention relates to the preparation of specimens for examination by an electron microscope.

In scanning electron microscopy, an electron beam scans the specimen being examined. The specimen must not accumulate charge, as this would deflect the beam and prevent the formation of an image. Therefore, a non-conducting specimen must be coated with an electrically conductive material, such as a metal before being examined in such a microscope. Such coating, also called shadowing, is accomplished by vaporizing a metal (usually a combination of palladium and gold) in a vacuum, and directing the vaporized metal toward the specimen. All portions of the specimen except the bottom are then coated with the metal. It is desirable to provide a coating that completely covers the sample surface and is uniform in thickness.

Previous standard methods of coating a specimen for this purpose have involved rotating the specimen at constant speed in one plane, in a chamber under a vacuum, while evaporating a metal in the chamber to coat the sample. This procedure results in a specimen that is coated from a particular angle, the angle of incidence of the metal vapor, but if the specimen surface is not smooth, some areas of it may be missed and hence cannot be scanned.

It is therefore an object of this invention to provide an apparatus that ensures complete coating of all parts of the surface of a specimen. It is a further object to ensure that this coating be of uniform thickness over all areas. It is another object to provide apparatus for such coating that is compact and simple, permitting easy and rapid installation or removal from the vacuum evaporator.

The invention features an apparatus for rotating a specimen about a first axis, while simultaneously rotating the first axis about a second axis inclined to the beam direction of the incident metal vapor at about 45°. The first axis intersects the second at about 45° for precessional motion of the first axis and corresponding motion of the specimen between a first position in which, when the first axis is parallel with the beam direction, the top portion of the specimen intersects the beam direction, and a second position in which, when the first axis is normal to the beam direction, the equatorial portions of the specimen intersect the beam direction, with intermediate positions in which remaining upper portions of the specimen intersect the beam axis. The specimen is exposed to the beam during a part of each revolution of the specimen about the first axis; this part decreases from an entire revolution in the second position to approximately ¼ of a revolution in the first position. This variable exposure of the specimen ensures a uniform coating of all exposed portions of the specimen.

Apparatus to coat a specimen by this method comprises a rotatable support table adapted to hold a specimen at a location spaced from the axis of the table, and a mechanism for moving the table bodily about a second axis inclined to the axis of the table while simultaneously rotating the table about its own axis, for precessional movement of the rotating table between a first position in which a beam is incident normally on the table surface for exposure of the top of the specimen to the beam, and a second position in which the beam is parallel to the table surface for exposure of side portions of the specimen to the beam. Shielding means is provided for shielding the specimen from the beam during a part of each revolution of the specimen about the axis of the table; this part increases from nothing in the second position to about ¾ of a revolution in the first position. The total exposure of the specimen throughout the precessional motion is thereby made uniform for all areas of the upper portion of the specimen.

In preferred embodiments, the apparatus comprises a specimen support table having peripheral specimen support means, a first shaft supporting the specimen table, a rotatable second shaft, rotatably supporting the first shaft, a drive track concentric with the second shaft, cooperative drive means on the first shaft engaging the drive track, and power means to rotate the second shaft for precesional motion of the support table and first shaft about the second shaft. The support table is thereby moved between a first position and a second position as previously described. The apparatus further provides shielding means, comprising a first fixed shield and a second shield rotatable about the second shaft. The shields cooperate to shield the specimen during a part of each revolution, increasing from nothing when the beam is incident on the side portions of the specimen to approximately ¾ of a revolution when the beam is incident normally on the top of the specimen. The total exposure of the specimen throughout the precessional motion is thereby made uniform for all areas of the upper portion of the specimen.

Other objects, features and advantages will appear from the following description of a preferred embodiment of the invention, taken together with the annexed drawings thereof, in which:

FIG. **1** is a perspective view of the apparatus of the invention;

FIGS. **2** and **3** are schematic views of the rotating and precessing portion of the apparatus in two positions;

FIG. **4** is a view of the entire apparatus when the beam is incident on the top or polar area of a specimen;

FIG. **5** is similar to FIG. **4** but shows the beam incident on the equatorial regions of a specimen;

FIGS. **6, 7, 8,** and **9** show several positions of a portion of the apparatus as seen from the beam source.

Referring now to the drawings, particularly to FIG. **1,** the apparatus of the invention, indicated generally at **10,** comprises a housing **12** containing a motor, not shown, a specimen support table **14,** a fixed shield **16** and a movable shield **18.** The motor is enclosed in a vacuum-tight, lightweight metal housing, thus eliminating pump-down probelms associated with the use of D.C. motors in a vacuum. The unit is operated by a suitable variable voltage D.C. power supply driven by a 110 v. A.C. power source. Specimen table **14** provides a number of peripherally located specimen holders **20,** in one of which is retained a specimen **22.** Apparatus **10** is illuminated by a source **24,** which directs a beam of metal vapor along beam axis **26** directed to the center **28** of table **14.**

Specimen table **14** is supported on a first shaft **30** (FIGS. **2** and **3**) which is rotatably supported in a pivoted sleeve bearing **32** by a second shaft **34.** Concentric with shaft **34** is a drive track **36.** Shaft **30** provides cooperative drive means comprising a ring **38** of elastomeric material such as rubber encircling shaft **30;** ring **38** frictionally engages track **36.** Thus when shaft **34** is

turned by the motor to rotate in the direction indicated by arrow **40**, ring **38** engages track **36** and causes shaft **30** to rotate as shown by arrow **42**. Shaft **30** may provide a conical portion **45** (FIG. 4) for receiving ring **38**, permitting the diameter of ring **38** to be varied, thereby varying the ratio of angular speed of shaft **30** to angular speed of shaft **34**. Angular speed of shaft **30** may be varied from 10 to 1,000 r.p.m.

The combination of these two rotations results in a precession of shaft **30** about an axis concentric with shaft **34**. Generally shaft **30** rotates several times during a single revolution of shaft **34**. All upper portions of a specimen are illuminated by the beam at some point in this motion.

When table **14** is in the position shown in FIG. **2**, beam axis **26** is incident normally on the table. Since the beam spreads to fill a volume around the beam axis, the top of the polar region of specimen **22** is illuminated by source **24**. Shaft **30** completes one or more revolutions while in the position of FIG. **2**, and the top of specimen **22** is illuminated throughout these revolutions. However, in the position of FIG. **3**, the equatorial regions of specimen **22** are illuminated by source **24**. In particular, when specimen **22** is on the side of table **14** nearest to source **24**, region **44** is illuminated. However, as table **14** rotates about shaft **30**, specimen **22** is carried to the position indicated at **23**, in which region **46** is illuminated but region **44** is not. Thus for revolutions about shaft **30** in the position of FIG. **3**, only a portion of the equatorial region of specimen **22** is illuminated at any one instant.

In practice it is found that the ratio of total coating of any portion of the equatorial region to total coating of the polar region is about 0.25 to 1.0 if the apparatus and method just described is operated without shielding.

The solution to this problem lies in ensuring the even illumination of all regions of the specimen by selectively shielding the specimen during parts of the precessional motion. In practice it has been found most satisfactory to accomplish this by providing shielding means comprising fixed shield **16** and movable shield **18**. While the purpose of the shielding could be accomplished by a movable shield alone, though of different shape and size from shield **18**, it is found desirable to provide fixed shield **16** for protection of the rotating and precessing mechanism from beam **26**, and this shield may be adapted to provide part of the required shielding of the specimen as well.

In the particular embodiment disclosed here, table **14** has a diameter of 2¾ inches. Shield **16** terminates in an apex **49** whose two sides **50** and **52** (FIG. **6**) include an angle of about 83°. Apex **49** extends to within not less than ⅛ inch and not more than 1/16 inch of beam axis **26**.

Movable shield **18** is generally planar and bounded by a curved edge **19** and a straight edge **21** (FIG. **1**). Straight edge **21** extends to within about ⅛ inch of center **28** of table **14**, and the curved edge overlaps table **14** sufficiently to completely shield specimens passing beneath the shield.

The effect of the combination of shields **16** and **18** appears in FIGS. **6**, **7**, **8**, and **9**. Referring to FIG. **6**, when table **14** is in the position of FIG. **4**, the plane of table **14** is normal to beam axis **26** and therefore appears as a full circle seen from the source **24**. Movable shield **18** covers less than a half of table **14**, and together with shield **16** obscures about three quarters of the circumference of table **14**. Thus during a revolution of specimen **22** about center **28**, the specimen is exposed for about ¼ of the time. When table **14** precesses to the position shown in FIG. **5**, the edge of the table is presented to the beam (FIG. **7**) and neither shield **18** nor shield **16** obscures specimen **22** during any portion of its motion around the center of table **14**. Intermediate positions (FIGS. **8** and **9**) result in the specimen's being exposed to the beam during portions of a revolution less than the total but greater than a quarter.

The uniformity of the coating on specimens prepared by this method and apparatus has been checked by placing Formvar test grids at all angles and positions on the platform and coating them simultaneously. After being coated, they were examined with a Philips electron microscope and the thickness was measured by measuring the intensity of the transmitted beam with a densitometer. The coatings were found to be uniform, to within experimental error.

What is claimed is:

1. Apparatus for rotating and precessing a specimen for uniform exposure to an incident beam whose direction of incidence defines a beam axis comprising

a rotatable support table adapted to hold the specimen at a location spaced from the axis of the table, and

mechanism for moving said table bodily about a second axis inclined to the axis of said table while simultaneously rotating the table about its own axis,

for precessional movement of said rotating table between a first position in which said beam is incident normally upon the surface of said table for exposure of the top of said specimen to said beam, and a second position in which said beam is parallel to said table surface for exposure of side portions of said specimen to said beam, and

shielding means for shielding from said beam a specimen held on said table during a part of each revolution of said specimen about said axis of said table, said part increasing from nothing in said second position to approximately ¾ of a revolution in said first position,

whereby the total exposure of the specimen to said beam during said precessional motion is uniform for all areas of the upper portion of said specimen.

2. The apparatus of claim **1** wherein said specimen support table provides peripheral support means, and said mechanism includes

a first shaft supporting said table,

a rotatable second shaft inclined to said first shaft and rotatably supporting it,

power means to rotate said second shaft,

a drive track concentric with said second shaft,

said first shaft having cooperative drive means engaging said drive track,

said drive means comprising an annulus of elastomeric material surrounding a conical portion of said first shaft for adjustable frictional engagement of said drive track, providing a variable ratio of angular speed about said first shaft to angular speed about said second shaft,

whereby, when said second shaft is rotated, said drive means engages said drive track for rotation of said first shaft about an axis that rotates about said second shaft for precessional motion of said first shaft and said specimen support table.

3. The apparatus of claim 2 wherein said specimen support table rotates about said first shaft more than once while said first shaft rotates once about said second shaft.

4. The apparatus of claim 1 wherein said shielding means comprises first and second shields,

said first shield being rotatable about said second axis,

and said second shield being fixed with respect to said second axis.

5. The apparatus of claim 1 wherein

said first shield is generally planar, extends coplanar with said specimen support table and spaced therefrom, covering less than one-half of the area of said support table but more than one-quarter of said area,

and said second shield is generally planar and extends parallel to said second axis to a point just below said beam axis.

6. The apparatus of claim 5 wherein

said first shield extends over approximately 7/16 of said support table area,

and the portion of said second shield proximate to said beam terminates in a point bounded by two straight edges including an angle of about 83°.

* * * * *