United States Patent

Lucas

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[54] **SPECIMEN STAGE FOR AN ELECTRON MICROSCOPE**

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[73] Assignee: **Associated Electrical Industries Limited,** London, England

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[51] **Int. Cl.**.....**H01j 37/20**

[58] **Field of Search**.....250/49.5 B, 65 R

[56] **References Cited**

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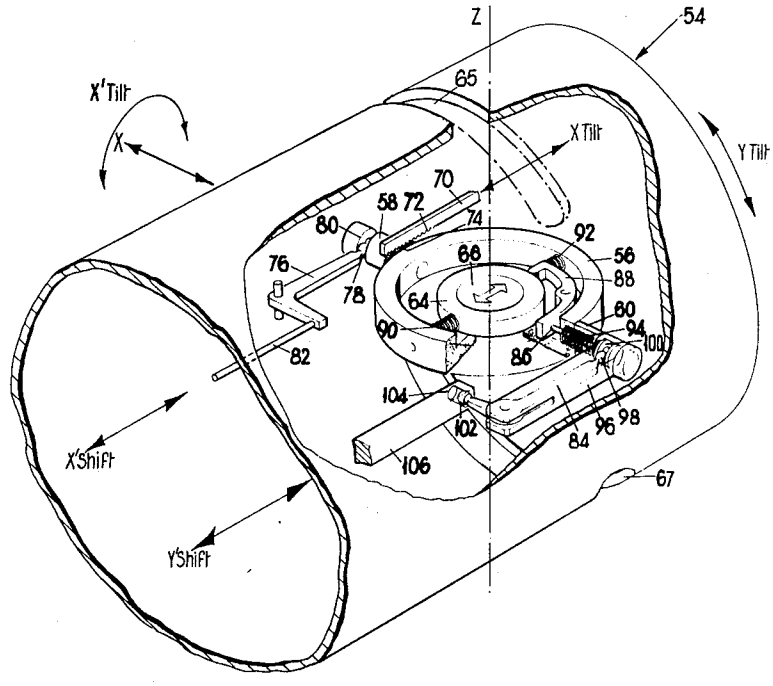
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Primary Examiner—James W. Lawrence
Assistant Examiner—C. E. Church
Attorney—Watts, Hoffmann, Fisher & Heinke

[57] **ABSTRACT**

A specimen stage for an electron microscope which allows tilting and translation of the specimen. The translation does not shift the tilt axes. Thus, once the point of intersection of the tilt axes is aligned with the optical axis, it will remain aligned irrespective of subsequent translation of the specimen. Thus, tilting of the specimen will not affect the field of view. The stage comprises first and second gimbals, the second gimbal carrying a specimen mounting. The second gimbal can be translated with respect to the first gimbal along the second gimbal axis. The specimen mounting can be translated with respect to the second gimbal in a direction inclined to the second gimbal axis. In a preferred embodiment, the first gimbal is a tube, and the second gimbal is an annulus supported within the tube.

9 Claims, 4 Drawing Figures



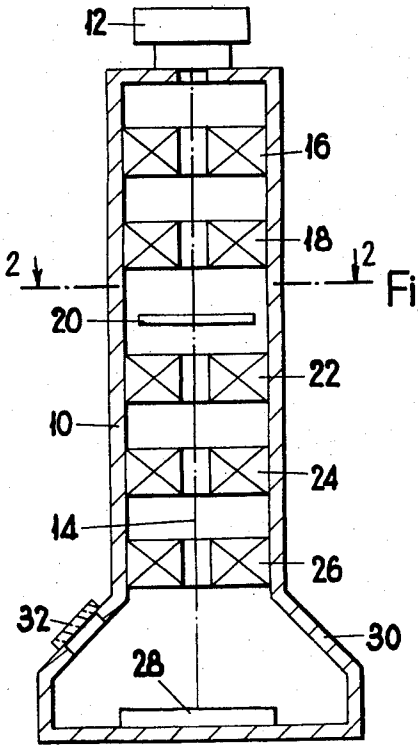

12
16
18
2
2
20
22
10
24
14
26
32
30
28

Fig.1

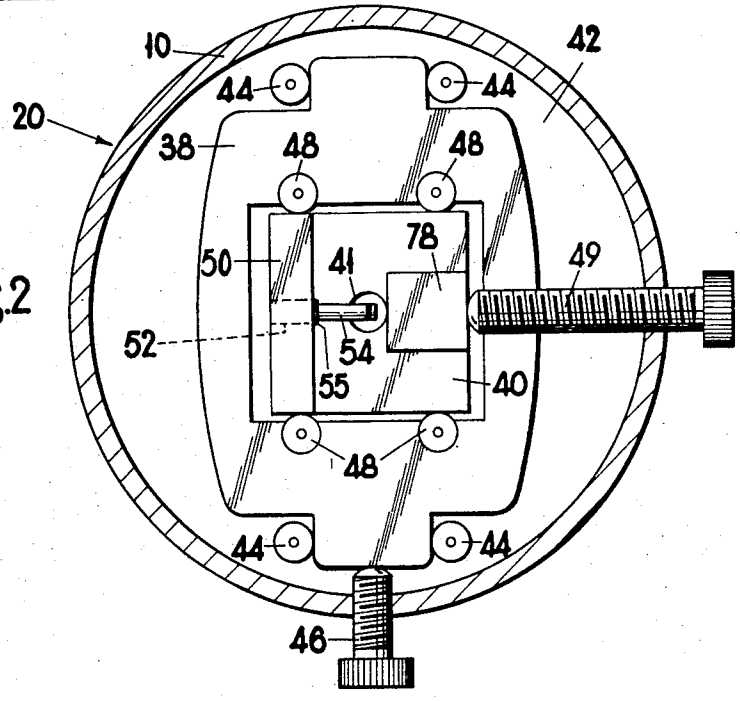

10
42
44
44
20
38
48
48
50
41
78
49
52
54
55
40
48
44
44
46

Fig.2

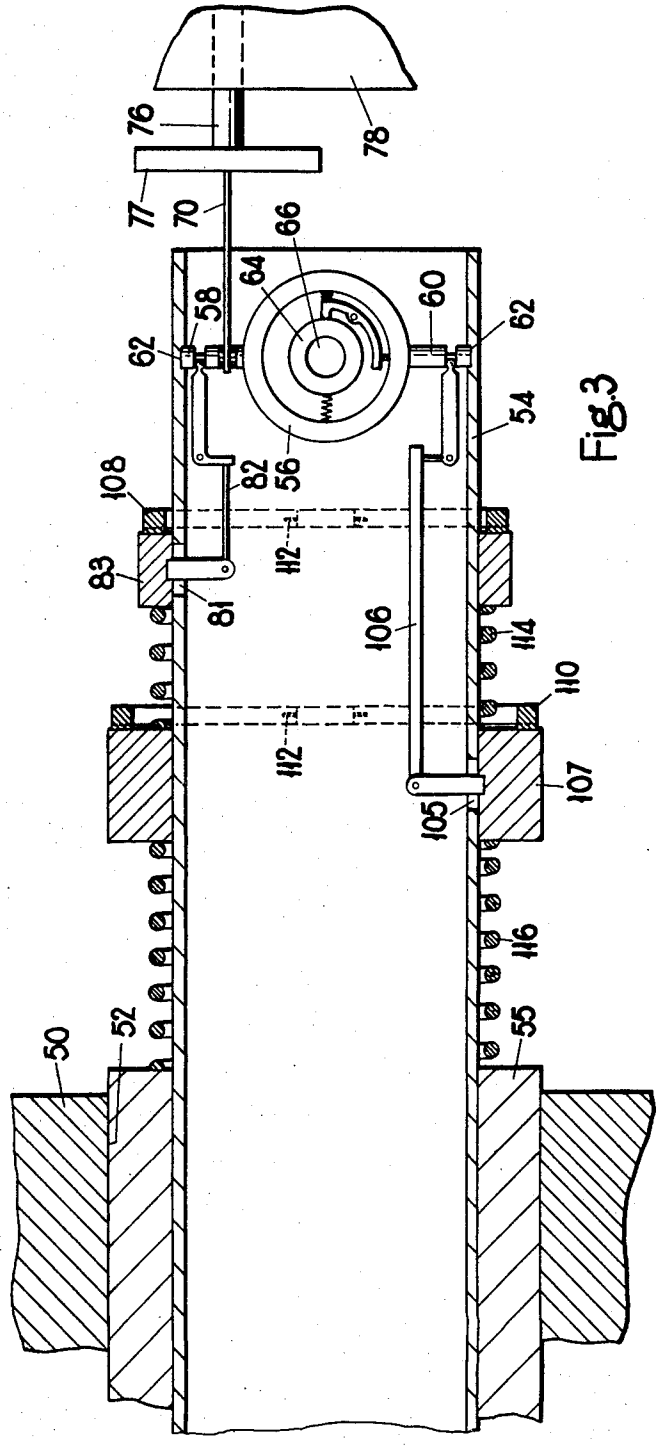

76
78
77
70
66
64
58
60
62
62
54
56
82
108
112
83
81
106
114
110
112
107
105
116
52
50
55

Fig.3

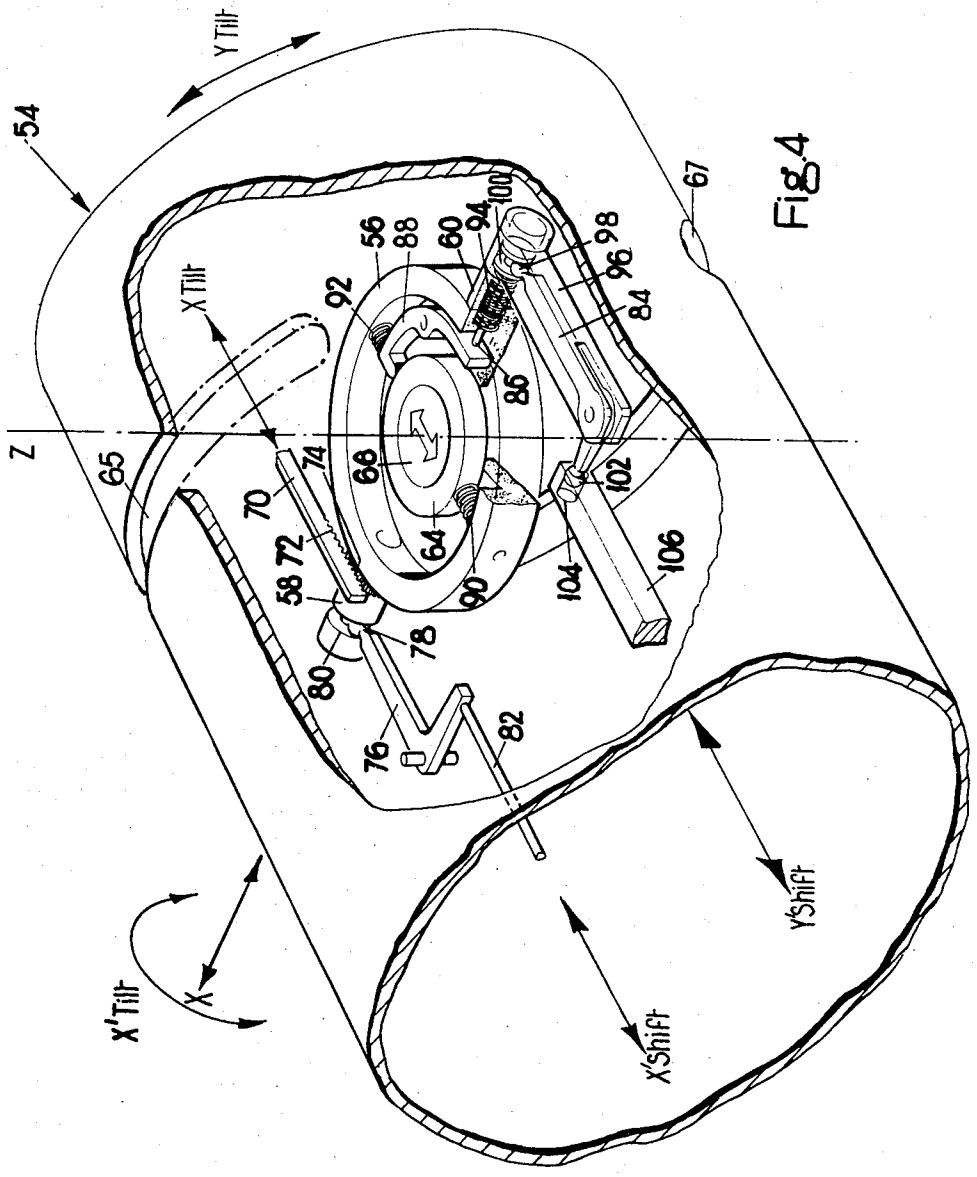

Y Tilt
54
67
X Tilt
Z
65
56
88
60
94
100
98
96
84
92
86
74
68
70
72
58
64
90
102
104
106
78
80
76
82
X'Tilt
X
X'Shift
Y'Shift

Fig.4

SPECIMEN STAGE FOR AN ELECTRON MICROSCOPE

BACKGROUND OF THE INVENTION

This invention relates to specimen stages for electron microscopes.

In electron microscopy it is often required to perform certain positioning operations on a specimen while the specimen is under observation. Thus, it is often required to tilt the specimen about two mutually inclined axes with respect to the electron optical axis of the microscope. This allows the specimen to be viewed from a range of different angles. Additionally, it may be required to translate the specimen in two mutually inclined directions in a plane transverse to the electron optical axis. This allows different portions of the specimen to be brought into alignment with the optical axis and therefore into the field of view of the microscope.

Where tilting of the specimen is provided, it is desirable that the specimen stage be so arranged that the tilt axes intersect the optical axis. If the specimen is tilted about an axis which does not intersect the optical axis, the region of the specimen under observation will move laterally with respect to the optical axis. This region will therefore tend to move out of the field of view of the microscope. The field of view can be restored by applying a translational movement to the specimen simultaneously with the tilting. However, this must usually be done in a stepwise manner, and the procedure is therefore very slow and tedious, and results in the specimen being exposed to long doses of radiation.

In most known stages which provide both translational movement and tilting of the specimen, applying translational movement to the specimen also shifts the tilt axes relative to the optical axis. Thus, in such a stage, it is impossible to maintain alignment of the tilt axes and the optical axis while observing different regions of the specimen.

SUMMARY OF THE INVENTION

The invention overcomes this difficulty by providing a specimen stage in which translational movement can be applied to the specimen without affecting the position of the tilt axes. Then, if the point of intersection of the tilt axes is initially aligned with the optical axis, it will remain aligned irrespective of the translational movement applied to the specimen.

The specimen stage comprises a support, a first gimbal pivotally mounted on the support for rotation about a first axis, and a second gimbal pivotally mounted on the first gimbal for rotation about a second axis which is inclined to and intersects the first axis. A specimen mounting is carried by the second gimbal. Thus, by tilting the gimbals about their axes, a specimen in the specimen mounting can be tilted about two mutually inclined axes with respect to the optical axis of the microscope. Means are provided for translating the second gimbal relative to the first gimbal in a direction parallel to the second gimbal axis. This permits translation of the specimen in that direction without affecting the positions of the gimbal axes. Means are also provided for translating the specimen mounting relative to the second gimbal in a direction inclined to the second gimbal axis. This permits translation of the specimen in that direction also, without affecting the positions of the gimbal axes.

It is to be understood that the term "gimbal" as used herein is not intended to be restricted to a ring-shaped member. The gimbals may be of any convenient shape. In a particular embodiment, for example, the first gimbal is a tubular member.

Accordingly, it is the principal object of the invention to provide a specimen stage for an electron microscope for tilting and translating a specimen, wherein the specimen can be translated without affecting the positions of the tilt axes.

BRIEF DESCRIPTION OF THE DRAWINGS

This and other objects and advantages of the invention will become apparent from the following description of a preferred embodiment of the invention, as read in conjunction with the accompanying drawings in which:

FIG. 1 is a schematic sectional elevation of an electron microscope;

FIG. 2 is a diagrammatic sectional plan view of the specimen stage of the microscope as seen from the plane indicated by the line 2—2 in FIG. 1;

FIG. 3 is an enlarged diagrammatic sectional plan view of a portion of the specimen stage of FIG. 2; and

FIG. 4 is a cut-away perspective view of a portion of the specimen cartridge shown in FIG. 3.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1, the electron microscope comprises a generally tubular evacuable housing **10** at one end of which is mounted an electron gun **12** for producing a beam of electrons directed along the axis **14** of the housing **10**. The axis **14** constitutes the optical axis of the microscope, and is referred to as the Z axis.

The electrons pass through a pair of condenser lenses **16, 18** which focus the beam to a fine spot. A specimen stage **20** is provided for supporting a specimen at this spot.

Electrons transmitted through the specimen pass through an objective lens **22** and a pair of projector lenses **24, 26**, which produce a magnified electron optical image of a portion of the specimen. This image is made visible by means of a fluorescent screen **28** positioned in a viewing chamber **30** which is provided with an observation window **52**.

Referring to FIG. 2, the specimen stage **20** includes first and second support blocks **38, 40**. The first block **38** is slidably mounted on a plane surface **42** within the microscope housing **10**, the surface **42** being perpendicular to the optical axis **14**. The block **38** is guided by rollers **44** for linear movement, the direction of this movement being referred to as the x-axis. This movement is controlled by a screw-threaded rod **46** which bears against the block **38**. The second block **40** is slidably mounted on the plane surface **42**, within the first block **38**, and is guided by rollers **48** for linear movement in a direction (referred to as the Y-axis) perpendicular to the X-axis. This movement is controlled by a screw-threaded rod **49** which bears against the block **40**. Return springs (not shown) are provided for maintaining the blocks **38, 40** in contact with the respective threaded rods **46, 49**.

The block **40** has an aperture **41** aligned with the optical axis **14**, in order to permit the passage of the electron beam.

The inner block **40** has a raised portion **50** with a cylindrical aperture **52** which is adapted to receive a tubular specimen cartridge **54**. The cartridge **54** is inserted into the microscope via an airlock (not shown) in the wall of the housing **10**, and is located by engagement of an enlarged external diameter portion **55** of the cartridge **54** with the internal surface of the aperture **52**. The cartridge **54** extends in the direction of the Y-axis, and can be rotated about its axis of symmetry by means of gears (not shown) meshing with a ring gear on the portion **55**. This rotation is referred to as the Y-tilt.

Referring to FIGS. **3** and **4**, these show the tubular specimen cartridge **54** in greater detail. An annular member **56** is pivotally supported within the tubular cartridge **54** by means of journals **58, 60** which are supported in bearing recesses **62** in the cartridge **54**. In this way, the annular member **56** is pivotal about an axis perpendicular to the Y-axis. This pivoting is referred to as the X′ tilt, since it is about the x-axis when the Y-tilt is zero. The annular member **56** carries a specimen mounting **64** which is adapted to receive a specimen **66**.

Thus, the tubular cartridge **54** and the annular member **56** constitute gimbals for tilting the specimen **66** about two mutually perpendicular, intersecting axes with respect to the electron optical axis **14**.

The cartridge **54** has a pair of diametrically opposite slots **65, 67** which permit an electron bema travelling along the axis **14** to pass through the specimen **66**. These slots **65, 67** are elongated in the circumferential direction in order to allow for rotation of the cartridge **54** about the Y-axis.

The X′ tilt is produced by means of an operating rod **70**, slidably mounted in the tubular cartridge **54** and carrying a rack **72** which engages with a pinion **74** on the journal **58**. The rod **70** engages a push rod **76** which slides within a raised portion **78** of the inner block **40**. The push rod **76** has an enlarged end portion **77**, so as to allow for rotation of the cartridge **54**.

The journals **58, 60** can slide axially in their bearings so as to allow a translational movement of the annular member **56** in the direction of the X′ tilt axis. This movement is referred to as the X′ movement. When the annular member **56** is moved in this way, the pinion **74** slides under the rack **72** so as to accommodate the movement. The X′ movement is imparted to the annular member **56** by means of a bell-crank lever **76** pivotally mounted within the tubular cartridge **54**. One end of the lever **76** carries a ball **78** which fits in an annular groove **80** in the journal **58**. The other end of the lever **76** is activated by an operating rod **82**, housed in the tubular cartridge **54**.

The operating rod **82** is connected, via slot **81** in the cartridge **54**, to an operating ring **83** which slides on the outside of the tubular cartridge **54**.

The specimen mounting **64** is movable linearly within the annular member **56** in a direction perpendicular to the X′ tilt axis, this movement being referred to as the Y′ movement.

The Y′ movement is imparted to the specimen mounting **64** by means of a mechanical coupling comprising a bell-crank lever **84** a push rod **86**, and a further bell-crank lever **88**. The push rod **86** passes axially through the journal **60**, and bears at its inner end upon one end of the bell-crank lever **88** which converts the longitudinal motion of the push rod **86** in the X′ direction into movement of the mounting **64** in the Y′ direction. The mounting **64** is tensioned against the bell-crank lever **88** by means of a spring **90** while the bell-crank lever **88** is tensioned against the push rod **86** by means of a spring **92**. The push rod **86** is provided with a return spring **94**,mounted within the journal **60**. Movement of the push rod **86** is produced by the bell-crank lever **84**, which is pivotally mounted in a housing **96**, pivotally attached to the journal **60**, so as to allow the annular member **56** to be rotated without the housing **96** rotating. One end of the bell-crank lever **84** carries a ball **98** which fits in an annular groove **100** in the outer end of the push rod **86**, while the other end of the lever **84** carries a ball **102** which fits slidably in a slot **104** in an operating rod **106**, slideably mounted within the tubular cartridge **54**. The operating rod **106** is connected via slot **105** in the cartridge **54**, to an operating ring **107** which slides on the outside of the cartridge **54**.

It will be seen that movement of the operating ring **107** produces translational movement of the specimen mounting **64** in Y′ direction, by way of the coupling **106, 84, 86, 88**. It will also be seen that, when the annular member **56** is moved in the X′ direction, the ball **102** slides within its slot **104** to accommodate this X′ movement, so that no movement of the bell-crank lever **84** is produced, and hence no Y′ movement of the specimen mounting **64**. Thus, the Y′ movement of the mounting **64** is independent of the X′ movement of the annular member **56**.

Movement of the two operating rings **83, 107** is effected by means of respective fork levers **108, 110**. These fork levers **108, 110** are mounted on pivots **112** on the block **40**, and are coupled to external controls (not shown). Compression springs **114, 116** are provided to maintain contact between the operating rings **83, 107** and their respective fork levers **108, 110**.

The gap between the prongs of the fork lever **110** is larger than the external diameter of the operating ring **107**, so as to allow the cartridge **54** to be withdrawn from the specimen stage without interfering with the fork lever **110**.

In operation, a specimen **66** is mounted on the specimen mounting **64**. The tubular member **54** is then inserted into the specimen stage, via the airlock (not shown). The support **40** is then adjusted by means of rods **46, 49** to bring the point of intersection of X′ and Y goniometer tilt axes into alignment with the optical axis Z. Tilt can then be applied, as required, to the specimen **66** by tilting the tubular member **54** and the annular member **56**, it being possible to tilt the specimen in any required direction in this manner, up to a certain maximum amount of tilt. Since the tilt axes are centred on the optical axis, there will be no lateral movement of the observed point of the specimen when the X′ and Y tilts are applied, and hence no change in the field of view.

The specimen can be translated, to search for features of interest, by applying the X′ and Y′ translational movements to the specimen mounting **64** by means of the rings **83, 107** operating control rods **82** and **106**. These movements do not shift the X′ and Y tilt axes. Therefore, these axes remain aligned with the Z axis throughout the examination of the specimen.

It will be appreciated that the invention may be applied to electron microscopes of the scanned transmission type, as well as to those of the non-scanned type.

Although the invention has been shown in connection with a preferred embodiment, it will be readily apparent to those skilled in the art that various changes in the form and arrangement of parts may be made to suit requirements without departing from the spirit and scope of the invention as defined by the appended claims.

I claim:

1. In an electron microscope comprising a source of electrons for producing a beam of electrons directed generally along an electron optical axis, and a specimen stage for supporting and controlling the position of a specimen in said beam, the specimen stage comprising:

a support;

first gimbal means pivotally carried by said support for rotation about a first axis;

second gimbal means pivotally carried by said first gimbal means for rotation about a second axis which is inclined to and intersects said first axis;

specimen mounting means carried by said second gimbal means;

means for translating said second gimbal means relative to said first gimbal means in a direction parallel to said second gimbal axis; and

means for translating said specimen mounting means relative to said second gimbal means in a direction inclined to said second gimbal axis.

2. A specimen stage according to claim 1 wherein said first gimbal means comprises a tubular member.

3. A specimen stage according to claim 2 wherein said tubular member is removable from the remainder of the specimen stage.

4. A specimen stage according to claim 2 wherein said first axis is the axis of symmetry of said tubular member.

5. A specimen stage according to claim 2 wherein said second gimbal means comprises an annular member mounted within said tubular member.

6. A specimen stage according to claim 1 wherein said second gimbal means is pivotally mounted on said first gimbal means by means of journals which are supported in bearings, said journals being axially slidable within said bearings so as to allow translation of the second gimbal means relative to the first gimbal means.

7. A specimen stage according to claim 1 wherein said means for translating the specimen mounting means relative to said second gimbal means includes a push rod slidable along said second axis, and means for converting movement of said push rod into movement in said direction inclined to said second axis.

8. A specimen stage according to claim 1 wherein said support is mounted in the electron microscope so as to be movable in a plane transverse to the electron optical axis, whereby the point of intersection of said axes may be aligned with the optical axis.

9. An electron microscope including a specimen stage as claimed in claim 1.

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