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MASARU WATANABE ET AL
SPECIMEN HOLDING DEVICE WITH MEANS TO TILT, ROTATE
AND SHIFT THE SPECIMEN

3,240,934

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2 Sheets-Sheet 1

FIG. 1

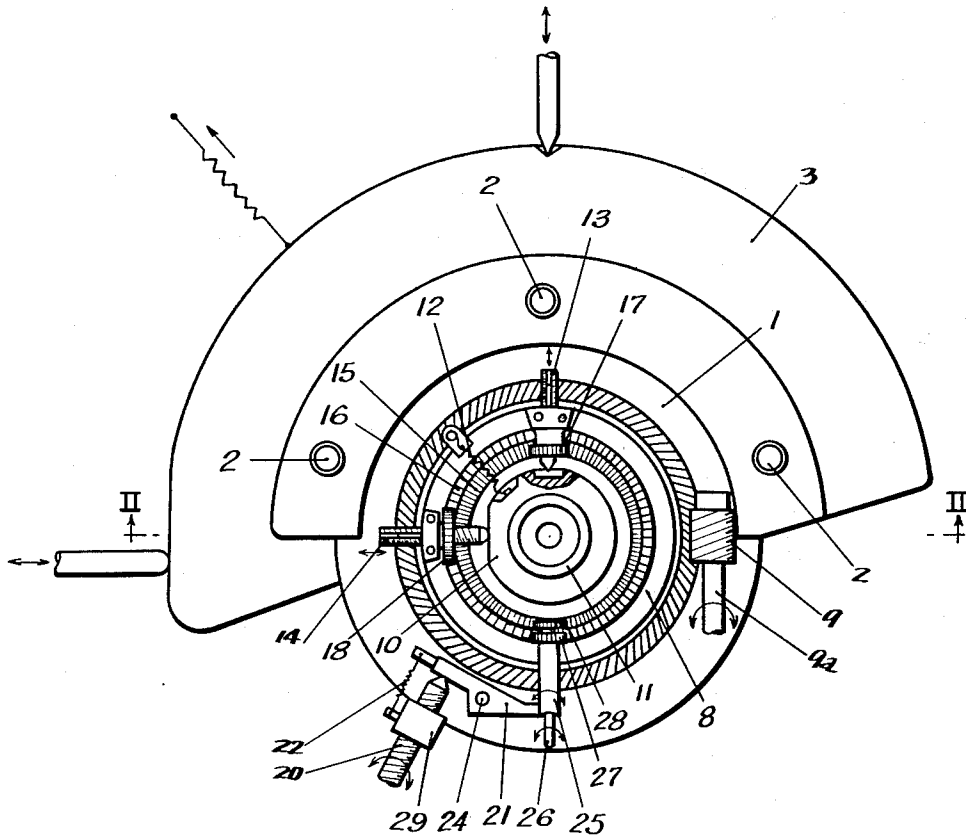
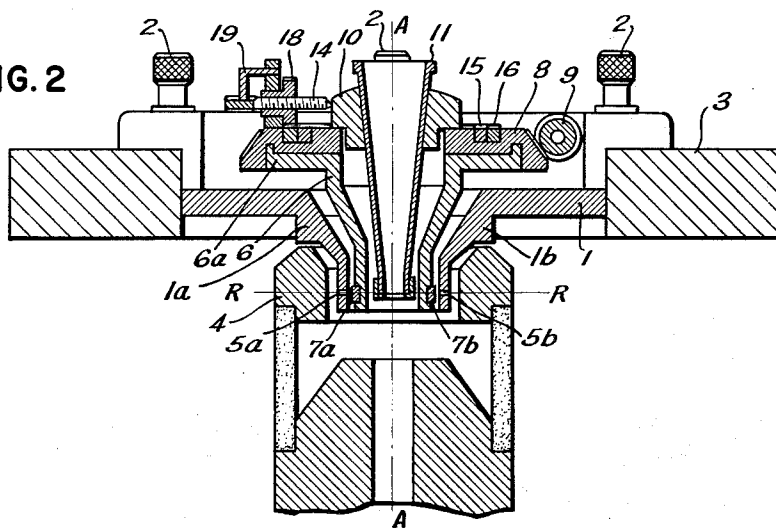


FIG. 2

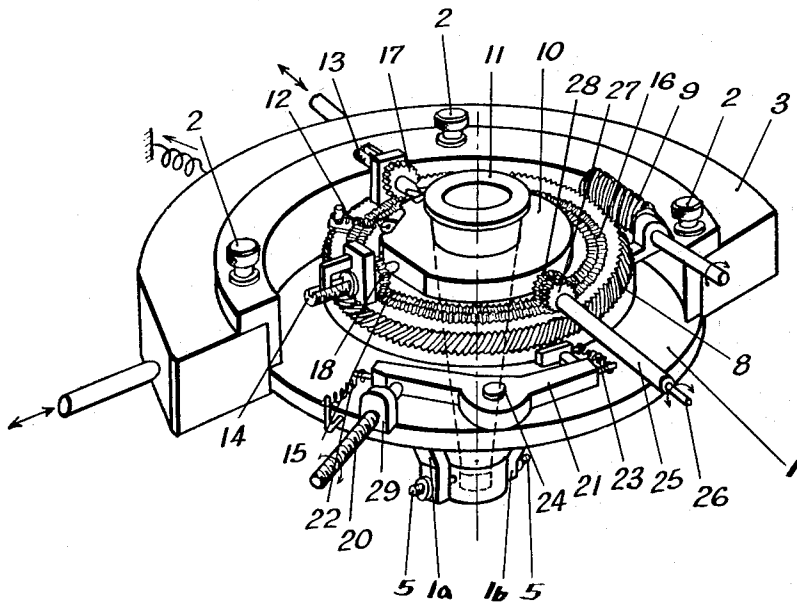


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SPECIMEN HOLDING DEVICE WITH MEANS TO TILT, ROTATE
AND SHIFT THE SPECIMEN

2 Sheets-Sheet 2

FIG.3



1

3,240,934

SPECIMEN HOLDING DEVICE WITH MEANS TO TILT, ROTATE AND SHIFT THE SPECIMEN**Masaru Watanabe, Shigeru Suzuki, and Yoriaki Nagahama, Tokyo, Japan, assignors to Nihon Denshi Kabushiki Kaisha, Tokyo, Japan****Filed Feb. 13, 1963, Ser. No. 258,339****Claims priority, application Japan, Feb. 14, 1962, 37/5,453****3 Claims. (Cl. 250—49.5)**

This invention relates to a specimen holding device for use in electron beam apparatus such as electron microscopes, electron diffraction cameras, etc.

In the use of electron beam devices such as electron microscopes, it is becoming more and more important to be able to tilt the specimens. This is brought about by the fact that in the study of crystalline structures or in the examination of individual crystals, it is necessary to be able to examine such crystal at any optional position of the specimen along any crystal axis. It is not possible to make precise observations of a crystalline specimen if the angle of the specimen to the incident electron beam is effected by chance. Conventional electron microscope specimen holding devices frequently incorporate specimen tilting means, however, with such means it is possible to tilt the specimen only with respect to the optical axis and there is no choice of the azimuthal angle of the specimen in respect to the optical axis because no means are provided to rotate and/or shift such specimen. Consequently, once a specimen is set in the conventional tiltable specimen holder, only that portion of the specimen which happens to coincide with the tilting axis can be tilted without drift. The other parts of the specimen which do not coincide with the tilting axis will escape from the visual field when the holding device is tilted since they will be tilted out of the axis. Accordingly, the conventional specimen holding devices are not suitable for continual observation of a specimen.

Other devices and methods heretofore employed to position specimens on tiltable holding devices while maintaining the visual field on a predetermined part of a specimen are complicated and it is exceedingly difficult by employing these means to vary the tilting angle of the specimen continually and gradually. Consequently, the prior art tiltable specimen holders and aforesaid devices for maintaining the visual field of a predetermined part of a specimen while tilting the specimen are not suitable for the observation of crystalline specimens.

By means of the apparatus of the present invention, it is possible to tilt, rotate or shift a specimen (substantially horizontally) with respect to the electron beam so that continual observation of any part of the specimen for any desired angle may be satisfactorily made.

The present invention is a tiltable specimen holding device that is provided with means for effecting independent rotation of the specimen and additionally means for effecting independent shifting of the specimen, such combination of means making it possible to rotate and shift the specimen in a substantially horizontal plane at any optionally selected tilting angle without being confined to that part of the specimen that happens to fall under the electron beam when such specimen is inclined. By means of the apparatus of the present invention, it is possible to align the tilting axis and the rotational axis of that part of the specimen to be observed with the optical axis of the microscope. The specimen can then be optionally tilted and/or rotated for continual observation of any optionally selected part of the sample. In other words, the apparatus of the present invention permits a device such as an electron

2

microscope to effect a microscopic image or an electron diffraction pattern of an optionally selected portion of a specimen as tilted or rotated to any desired angle with respect to the electron beam.

Such advantages are possible because of the unique mechanical structure of the present apparatus which consists of a stage, a tiltable cartridge supported by the stage, a circular rotary mount fixed on the tiltable cartridge in a manner to permit free rotation, a mobile specimen cartridge inserted into the rotary mount and gears arranged adjacent to the rotary mount that effect shifting position control of the mobile specimen cartridge. In the present apparatus the specimen cartridge is seated on the rotary mount in a manner to permit horizontal adjustment.

By means of the apparatus in the present invention, a tilting axis of the specimen containing cartridge may be adjusted to cross the optical axis (electron beam) by means of the specimen shifting mechanism and then the specimen which is seated in the specimen cartridge may be rotated by means of the rotary mount without disturbing the above mentioned axis configuration. Accordingly, the axis of the crystalline specimen may be adjusted in the specimen plane so that it is parallel to the tilting axis, additionally, the specimen cartridge can be shifted so that any optionally selected crystal axis may be made to coincide with the tilting axis. It will be appreciated that where an optionally selected crystal axis completely coincides with the tilting axis, the image may be observed from any angle of incidence of the electron beam by effecting any degree of tilting of the holder without being subjected to specimen drift. The rotative shifting and tilting adjustments may be made independently of one another so that any position from any azimuthal angle of the specimen may be readily examined.

Another feature of this invention is that the tiltable specimen holder permits the specimen to be inserted deeply in the electron microscope or near the center of the objective lens pole piece which enables one to obtain a high resolution. Hence, the specimen holding device of the present invention may be said to provide improved means for observing tilted specimens and, additionally, effects an apparatus that enables the obtaining of high resolution.

Other advantageous features of the present invention will be obvious from the following description and the drawings wherein:

FIGURE 1 is a plan view of an electron microscope specimen holding device that embodies features of the present invention;

FIGURE 2 is a cross-sectional view of the apparatus in FIGURE 1 as seen from along the line II—II thereof; and

FIGURE 3 is a perspective view of the apparatus of FIGURES 1 and 2.

In the apparatus of FIGURE 1 and as illustrated in FIGURES 1 through 3, a stage 1 is shown to be fixed to a conventional specimen shifting mount 3. Mount 3 is the type of a mounting conventionally employed in conjunction with the ordinary transmission type electron microscope. A collar and hold down bolts 2 are associated with the conventional means and will not be described in detail in the present specification.

Two downwardly depending legs of the stage 1 identified in FIGURE 2 as 1a and 1b project into the interior of the objective lens pole piece 4. At the lower edge of the legs 1a and 1b, holes are provided to receive pins 4 which form tilting axle 5a and 5b of an elongated hollow tiltable cartridge 6. The tiltable cartridge 6 is provided

with a rim 6a such as shown in FIGURE 2. The tiltable cartridge 6 is also provided with pillow blocks 7a and 7b upon which the pins 5 are pivotally mounted to form the tilting axle 5a and 5b. The axle 5a and 5b is aligned on a plane which coincides with the tilting axis R—R so that the specimen which is mounted in the lower portion of the holder for the specimen, the specimen holding cartridge 11 may be tilted with respect to the optical axis A—A. The exact means in which the tilting mechanism functions will be described in fuller detail herebelow.

On the rim 6a of the tiltable cartridge 6, there is positioned a rotatable mount or first mounting plate 8. The rotatable mount 8 is loop-shaped and is disposed to be rotated freely on the rim 6a of the tiltable cartridge 6. The central axis of the rotatable mount 8 may be adjusted to intersect the optical axis A—A and the tilting axis R—R of the specimen surface (see FIGURE 2) and the specimen is preferably seated at the junction or cross-point of these three axes.

A helical worm drive 9 is appropriately mounted to the rim 6a of the tiltable cartridge 6. Worm drive 9 meshes with gears formed in the periphery of the rotatable mount 8. The axle 9a of worm gear 9 is driven through a universal joint (not shown) by a shaft projecting externally of the electron microscope. Hence, worm gear 9 may be caused to rotate to transmit rotative movement to the rotary mount 8 by manipulating a universal joint from outside of the electron microscope and as will be shown herebelow, such rotative motion is transmitted to the specimen holding cartridge 11 to effect rotation of the specimen.

It is understood that the specimen holder of the present invention as shown by the embodiments of FIGURES 1 through 3 is conventionally mounted within the housing of an electron microscope and that such housing must be of sufficient continuity to permit a vacuum to be created in the vicinity of the specimen to allow observation of the specimen through electron bombardment.

The worm drive 9 must be freely operable from the outside of the housing of the electron microscope without interfering with the vacuum within.

Positioned as seated within the central opening of the rotatable mount or second mounting plate 8 is a loop-rimmed horizontal shiftable mount 10. The specimen cartridge 11 projects through the central opening of the shiftable mount 10 so as to be supported within the rotatable mount 8. The specimen cartridge may be removed and replaced by lifting it from its seat within the shiftable mount 10. In effect, the specimen cartridge 11 is inserted into the interior of the rotatable mount 8 and is merely supported within the surface of the rotatable mount 8 by the shiftable mount 10.

The horizontal shiftable mount 10 fits loosely within the central opening of the rotatable mount 8 so that it is susceptible to horizontal positioning within such mount.

The mount 10 is caused to shift in its position on rotatable mount 8 by means of an interlocking mechanism that includes the spring 12, bolts 13 and 14, gears 15 and 16, and pinions 17 and 18 all of which are concentrically arranged around the rotatable mount 8. The shifting mechanism is clearly illustrated in FIGURES 2 and 3. Pinions 17 and 18 mesh with the crawl gears 15 and 16. Central openings within pinions 17 and 18 are threaded so that the bolts 13 and 14 are threadably engaged with the respective central openings of the pinions 17 and 18. Bolt 13 is formed with a pointed edge that takes the shape of a knife blade and as shown in particular by FIGURE 1, such edge bears upon a specifically hardened insert positioned within shiftable mount 10. The end of bolt 14 is rounded or hemispherical in shape and bears upon a flat area formed on the shifting mount 10. A spring 12 is appropriately attached at one end to the rotatable mount 8 and at the other end to shiftable mount 10. The spring 12 is maintained under tension so as to urge the shiftable mount 10 against the edge of bolt 13

and the rounded end of bolt 14. The shiftable mount 10 is consequently controlled in its horizontal position by the horizontal position of the bolts 13 and 14 within the pinions 17 and 18. When pinions 17 and 18 are caused to rotate, the bolts 13 and 14 will be advanced or retracted in accordance with the direction of their rotation. In the present embodiment, the rotation of the pinions 17 and 18 is effected by rotation or circular movement of the crawl gears 15 and 16. Rotation of the gears 15 and 16 is effected through gears 27 and 28 which are appropriately connected to universal joints and shafts projecting outside the housing of the electron microscope so that gears 27 and 28 are caused to rotate when shafts 25 and 26 are caused to rotate by such exterior means (not shown).

As may be seen, particularly in FIGURES 2 and 3, bolts 13 and 14 project through openings within appropriate mounting members that are rigidly attached to the rotatable mount 8. L-shaped members 19 are rigidly attached to the mounting members and projected into elongated grooves formed in bolts 13 and 14 to prevent the rotation of bolts 13 and 14 along with the pinions 17 and 18 so that they will advance or retract whenever the pinions 17 and 18 are caused to rotate, such mounting means also being positioned to prevent the pinions 17 and 18 from becoming disengaged with the crawl gears 15 and 16.

The bolts 13 and 14 are orthogonally positioned as shown in FIGURE 1 and the specimen shiftable mount 10 is pulled by the spring 12 diagonally towards and against the tips of the bolts. Consequently, the specimen can be moved towards the center of rotative movement of the rotatable mount 8 by appropriate rotation of the axle 25 and the gear 27 so that the crawl gear 16 causes the pinion 18 to rotate in a manner to cause bolt 14 to push the shiftable mount 10. Similar mechanical adjustment of axle 26, gear 28, crawl gear 15, pinion 17 and bolt 13 will urge shifting mount 10 in another direction. Obviously, if it is required, the appropriate axles 25 or 26 may be rotated in a reverse direction which will cause bolts 14 and 13 to retreat from shiftable mount 10 so that spring 12 will appropriately urge the mount 10 in the desired direction.

As previously described, cartridge 6 is pivotally mounted to stage 1 by a means of pins projecting into receptacles of the legs 1a and 1b of stage 1, such pins being mounted to pillow blocks 7a and 7b which in turn are mounted to the cartridge 6. Consequently, the specimen cartridge 11 mounted within rotatable mount 8 in shiftable mount 10 may be shifted in position in respect to the optical axis A—A, and may be tilted along the axis R—R.

A lever 21 is pivotally mounted about a fulcrum 24 that is attached to the upper surface of stage 1. The lever 21 is attached at one end to the rotatable mount 8 and is urged to push against the mount 8 so as to tilt mount 8 and consequently cartridge 6 by springs 22 and 23 which are appropriately mounted to stage 1 and attached to the lever 21. A bolt 20 which is connected to a universal joint disposed to the operated exterior of the housing is threadably engaged with a nut 29 that is rigidly attached to stage 1 so that the bolt 20 bears on one end of the lever 21. By rotation of the bolt 20 in a manner to cause it to bear upon lever 21, the lever is caused to pivot about the fulcrum 24 so as to oppose the springs 22 and 23. Advancing the bolt 20 causes the rotatable mount 8 and consequently cartridge 6 to be tilted about the axis of axle 5a and 5b. If the bolt 20 is rotated in a reverse direction, obviously the lever 21 will be urged in a reverse direction by the springs 22 and 23 to cause cartridge 6 to tilt in the opposite direction. Hence, rotation of bolt 20 forward or backward makes the lever 21 push or pull on the rotary mount 8 to tilt a specimen within cartridge 6 about the tilting axis R—R.

As previously described, the apparatus of the present invention consists of a stage that is rigidly attached to a

5

conventional type shifting mount 3. The shifting mount 3 is caused to adjust the position of the apparatus in respect to the optical axis (electron beam) by means similar to the shifting means provided for such horizontal position consisting of the shifting mount 10. A spring similar to spring 12 urges the mount 3 in a direction diagonal to two elongated members which bear on the mount 3. The purpose of the shifting mount 3 is to adjust the apparatus prior to inserting the specimen. The apparatus of the present invention provides means for optionally rotating, tilting, and shifting the sample so that any desired view and angle may be observed after the initial alignment has been accomplished.

The above described rotational, tilting, and shifting mechanisms are positioned on stage 1 of the specimen shifting mount 3 and the tilting axis R—R may be made to mechanically intercept the rotational axis. By shifting the stage 1, the above described cross-point can be adjusted to meet with the optical axis so that the tilting axis, rotational axis and optical axis meet at one point.

As described above, the present apparatus is provided with the adjusting mechanisms 9, 12-18, 20, 21, etc. which consists of a variety of gears mounted on or near the rotatable mount 8 (including the upper part of the tiltable carriage 6) and through this adjusting mechanism horizontal shifting, rotation and tilting of the specimen, including the adjustment of the three aforementioned axes, is accomplished.

In the operation of the present apparatus (omitting the routine operational procedures employed in the use of an electron microscope) the cross-point of the rotational axis and the tilting axis are first adjusted to meet with the optical axis (electron path) by use of the specimen shifter 3 of the specimen chamber of the electron microscope. The specimen cartridge 11 holding the specimen is then inserted. The cartridge 11 is rotated by means of the worm drive 9 to make any optionally desired orientation of the specimen in parallel to or in the plane of the tilting axis R—R. Then any optional portion of the specimen one may desire to inspect is shifted to coincide with the point where the three axes meet. Finally, the specimen is tilted at any desired angle. These adjustments are accomplished by means of the various components of the present invention employed in the manner described above. Since any specific orientation at any portion of the specimen can be studied with the present device, a continuously successful three-dimensional observation of the specimen can be made.

It is to be understood that the term "cartridge" as it is used in the present specification and claims is inclusive of any suitable receptacle that may be employed in the manner described. For example, the term "tiltable cartridge" includes a funnel-shaped member such as shown at 6 in the accompanying drawing or any member that is suitable for such use. The term "specimen cartridge" encompasses in addition to member 11 of the drawings, any other suitable container or receptacle that will serve the purpose of holding specimens for electron microscopy.

We claim:

1. A specimen holding device for an electron beam apparatus having an optical axis comprising:

- (A) a stage having
 - (1) an opening through which electron beams pass along said optical axis, and
 - (2) portions extending downwardly from said opening in the direction of passage of said beams through the opening,
- (B) an elongated hollow cartridge through which electron beams pass
 - (1) extending through said opening and downwardly extending portions of the stage, and
 - (2) having pivots adjacent its lower end for mounting said cartridge on said downwardly extending portions of the stage for tilting about an axis transverse to said optical axis,

6

- (C) a first mounting plate,
 - (1) seated on the upper end of the cartridge,
 - (2) rotatable on the cartridge about a central axis parallel to the optical axis, and
 - (3) having a central opening through which electron beams pass,

- (D) a second mounting plate
 - (1) seated on said first mounting plate,
 - (2) having a central opening in line with the central opening in the first mounting plate through which electron beams pass,
 - (3) movable on said first plate transversely to the optical axis;

- (E) an elongated hollow specimen holder,
 - (1) mounted in the opening in said second mounting plate and extending downwardly through said hollow cartridge, and
 - (2) having means for mounting a specimen in the plane of the tilting axis of the cartridge,

- (F) adjustable means for rotating said first mounting plate,

- (G) adjustable means bearing against a portion of the cartridge outside the plane of the pivot axis for tilting the cartridge about said tilting axis, and

- (H) two adjustable mechanisms for moving the second mounting plate transversely of the first mounting plate, said adjustable mechanisms moving said second mounting plate in directions at right angles to each other.

2. A specimen holding device as described in claim 1 in which the means for moving the second mounting plate transversely of the first mounting plate comprises,

- (A) first and second crawl gears surrounding said second mounting plate and supported for rotation about said second mounting plate,
- (B) first and second pinion gears
 - (1) meshing respectively with said first and second crawl gears,
 - (2) spaced approximately 90° from each other about said first mounting plate, and
 - (3) each having an internally threaded opening extending radially of said first mounting plate,

- (C) first and second threaded bolts,
 - (1) threaded respectively in the threaded openings of said first and second pinions,
 - (2) restrained against rotations so that upon rotation of said pinions they will move towards and away from said second mounting plate,
 - (3) the ends of said bolts nearest the second mounting plate engaging the second mounting plate,

- (D) a spring tending to resiliently hold the second mounting plate against the ends of the bolts which engage the second mounting plate whereby rotation of the pinions moves the second mounting plate, and

- (E) means for adjustably rotating said crawl gears to rotate said pinions.

3. In electron beam apparatus having an optical axis and a holder for a specimen, the improvement comprising means for shifting the holder transversely of the optical axis, said shifting means comprising,

- (A) a mount for said holder,
- (B) first and second crawl gears surrounding said mount and supported for rotation about said mount,
- (C) first and second pinion gears
 - (1) meshing respectively with said first and second crawl gears,
 - (2) spaced approximately 90° from each other about said mount, and
 - (3) each having an internally threaded opening extending radially of said mount,
- (D) first and second threaded bolts,
 - (1) threaded respectively in the threaded openings of said first and second pinions,

7

- (2) and restrained against rotation so that upon rotation of said pinions they will move towards and away from said mount,
 (3) the ends of said bolts nearest the mount engaging the mount,
 (E) a spring tending to resiliently hold the mount against the ends of the bolts which engage the mount whereby rotation of the pinions moves the mount transversely of the optical axis, and
 (F) means for adjustably rotating said crawl gears to rotate said pinions.

5

10

8

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