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Zingaro

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[54] **MULTI-ANODE X-RAY TUBE**

[75] Inventor: **William P. Zingaro**, Hartsdale, N.Y.

[73] Assignee: **Philips Electronics and Pharmaceutical Industries**, New York, N.Y.

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[52] **U.S. Cl.** **313/60,** 313/56, 313/149

[51] **Int. Cl.** **H01j 35/10**

[58] **Field of Search** 313/57, 60

[56] **References Cited**

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Primary Examiner—Roy Lake

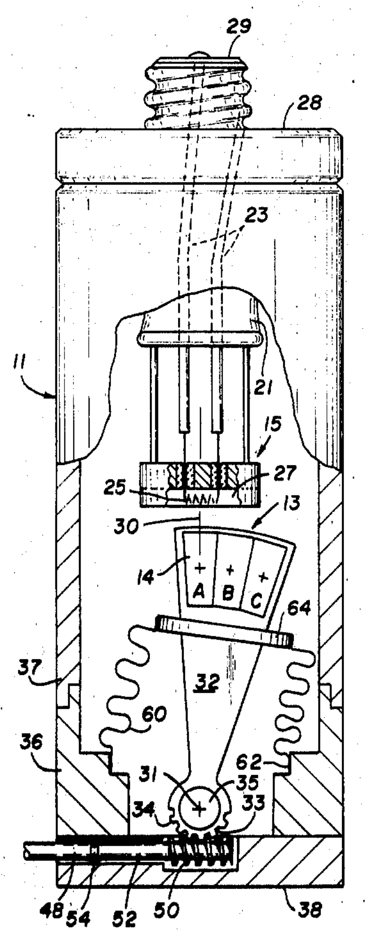
Assistant Examiner—Darwin R. Hostetter

Attorney—Frank R. Trifari

[57] **ABSTRACT**

A plurality of anodes in an X-ray tube are each disposed at the circumferential portion of adjacent sectors having a common center which is concentric with a gear nonmovable fitted to the sectors. The gear is in mating arrangement with a worm screw for permitting selection of one of the anodes to be in line with a stream of electrons from the cathode.

6 Claims, 2 Drawing Figures



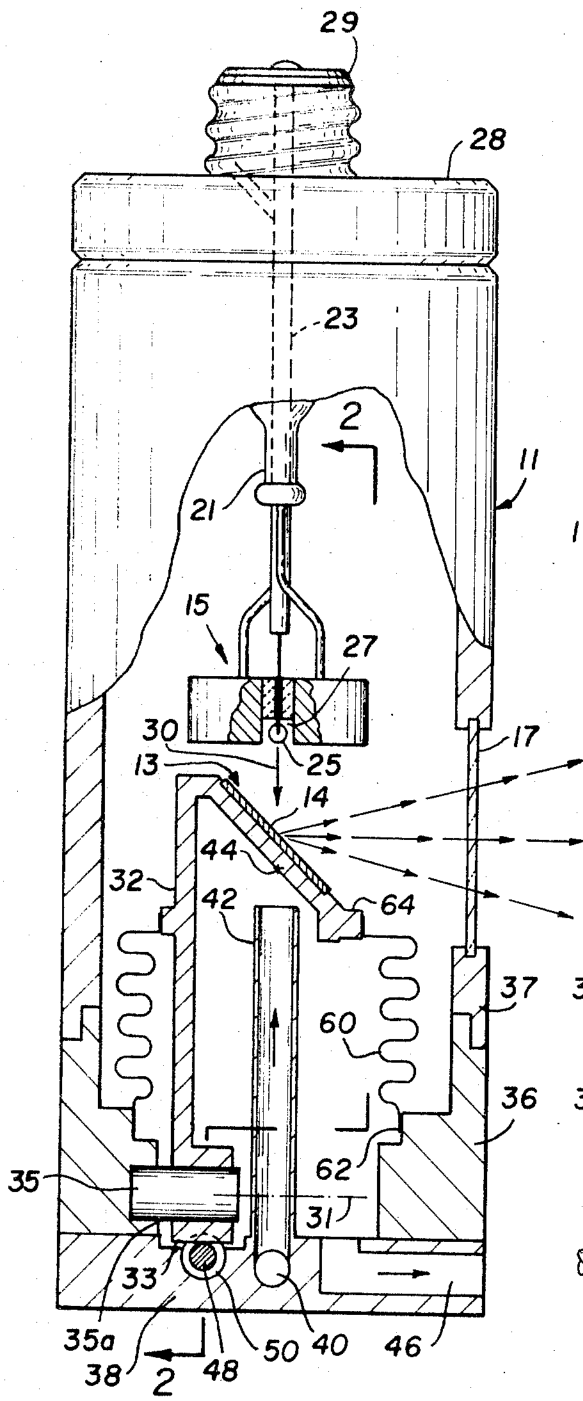

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FIG. 1

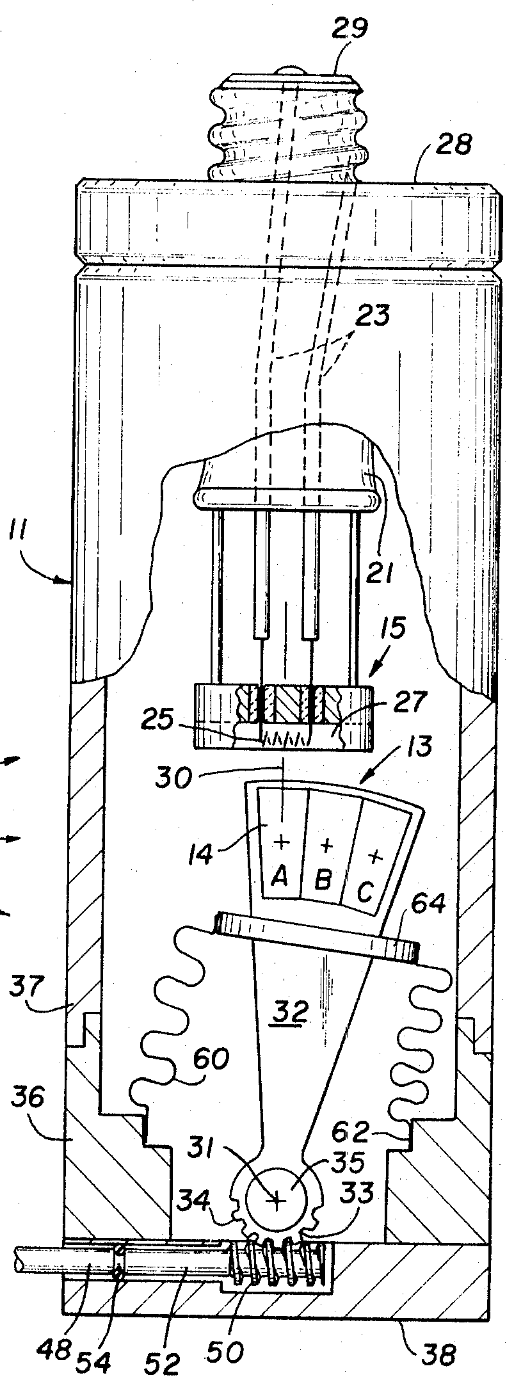
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FIG. 2

MULTI-ANODE X-RAY TUBE

This invention relates to X-ray apparatus, and more particularly to X-ray diffraction and spectrometric apparatus designed for continuous operation.

As is well known to those skilled in the art, X-ray diffraction and spectrometric work necessitates frequent exchanges of the tubes so as to provide the required target material for each particular investigation being performed.

The need for multiple anodes is to produce exciting secondary lines having a characteristic radiation which is preferable to white radiation. The characteristic radiation produced should not be much harder than the secondary radiation excited. Thus, the characteristic radiation is affected more than the continuous radiation in producing secondary lines, in spite of the fact that the total energy of the characteristic radiation is much smaller than that of the white radiation. It is not sufficient that the secondary rays be produced within the sample since they must also emerge from the sample without being absorbed by the material through which they must pass. Considering now only that portion of the continuous radiation whose wave-lengths are shorter than that of the absorption edge of the element to be investigated, since the softer components of the white radiation are ineffective in producing the secondary line, the part of the exciting continuous spectrum having appreciably shorter wave-lengths than are required to excite the secondary lines will then be to a large extent, only absorbed in a deeper layer of the sample. The secondary radiation emitted by the sample will have in the latter case an appreciably longer wavelength than the primary rays, and thus the secondary rays will be unable to penetrate the layer in question and further will not be available for the purpose of analysis by X-ray means. In short, the secondary rays produced by the target material should be of a quality that is just slightly harder than the material being analyzed to get the best result, and this requires a multiplicity of anodes having different characteristic radiation. In the past, these replacements of tubes necessitated, in each instance, a complete realignment of the camera or cameras and other accessories employed in conjunction with the source of X-ray radiation, a procedure which not only rendered the work time-consuming and costly but in addition, failed to yield fully reproducible or comparable results in view of the differences in adjustment involved.

In view of the drawbacks outlined above inherent in prior art devices of this kind, X-ray diffraction and spectrometric apparatus permitting replacement of tubes without the need for any realignment of cameras and other accessories has long been a desideratum in the X-ray art.

One way of accomplishing this is by furnishing the anode end of the envelope with a yoke structure which carries diametrically opposed adjusting screws in position outwardly of the yoke. The adjusting screws permit tilting of the anode in the direction of the axes of the screws so as to position any one of a plurality of different anode targets in line with the electrons from the cathode. The anode is flexibly mounted by a bellows to maintain a seal on the anode. However, the bellows which provides the flexible mounting, is disposed between the interior of the anode and the atmosphere and is thus susceptible to inaccurate positioning with atmospheric pressure changes.

Furthermore the screws which provide the tiltable feature have the disadvantage that the anode is hollow and has a blind path in the interior of the anode passageway which provides for the passage of cooling fluid. Thus there is constantly present the distinct disadvantage during operation of the development of a vapor pocket in the blind path which will block the flow of the cooling fluid therethrough and thus impair the cooling efficiency of the X-ray tube.

Another disadvantage in the prior art is the difficulty in positioning the desired anode in the target position viz. the adjustment of two separate screws simultaneously or intermittently one and then the other, to tilt the desired anode into the target position.

Accordingly, the present invention includes an X-ray tube comprising a cathode and a plurality of anodes with the cathode having an elongated electron-emitting filament positioned to emit an electron beam toward a selected one of the plurality of anodes and each of the plurality of anodes containing either a different target material or the same material for use as a substitute when one anode becomes too pitted for further use. The plurality of anodes are disposed to move with respect to the filament and about a central point in an arc, to cause impingement of the electron beam upon the desired target material in the selected one of the anodes which is in position diametrically opposite the filament. The plurality of anodes are supported on a sector shaped anode mount which at its narrow portion forms a gear means which is cooperatively coupled to a drive means, the drive means being operable to position the desired anode diametrically opposite the filament to produce resulting X-rays of a desired character corresponding with the target material of the selected one of the plurality of anodes.

It is therefore an object of the present invention to provide an X-ray tube having a plurality of anodes each of which has a different target material and when energized, produces corresponding X-rays having characteristics different from the X-rays produced at the other anodes.

It is another object of the present invention to provide an X-ray tube particularly well adapted for analysis of materials by X-ray diffraction or spectrometry.

It is another object of the present invention to provide an X-ray tube having a plurality of anodes and an accurately positionable adjustable mounting for the anodes, whereby a selected anode may be positioned in focal operating position with respect to the cathode of the tube, so that the tube may be conditioned to emit X-rays generated by electron impingement upon any selected one of a plurality of anodes.

It is a further object of the present invention to provide an X-ray tube having a plurality of anodes which are efficiently cooled by cooling fluid directed through an open passageway.

It is still another object of the present invention to provide an X-ray tube having a plurality of anodes which are easily and accurately adjustable.

The foregoing and numerous other important objects, advantages and inherent functions of the invention will become apparent as the same is more fully understood from the following description, which, taken in connection with the accompanying drawing, discloses a preferred embodiment of the invention, in which;

FIG. 1 is a side view, partially sectionalized, of a multi-anode X-ray tube embodying my present invention; and

FIG. 2 is a partially sectionalized view taken along 2—2 of FIG. 1.

Analysis of materials may be accomplished by exposing the material to be analyzed to X-rays and observing the X-ray diffraction characteristics of the material as by recording the same on a sensitive film or other well known energy detection devices.

The choice of a proper target material for X-ray diffraction analysis depends to a great extent upon the type of speciment being examined, the particular technique to be used, and the kind of information sought.

The radiation from an X-ray tube consists of a continuous, or "white," spectrum, the wave-length and intensity distribution of which depends largely upon the potential employed, and a characteristic sharp "line" spectrum comprising a relatively few lines, each of which has a specific wave-length, depending only upon the type of X-ray target material employed in producing the X-rays. This "line" spectrum is entirely independent of the operating potential above a minimum voltage, which minimum voltage also is characteristic of the target material. Any suitable target material may, of course, be employed for X-ray analysis, provided, of course, the material of the target and hence its "line" spectrum is known. Otherwise the lines caused by the target material in the spectrograph of the material being examined may be mistaken for lines supposedly caused by the material being examined. It will be obvious also that various materials to be examined by diffraction or spectrometric analysis may best be examined by using different targets.

The same is true in the elemental analysis of materials by X-ray spectrometry. The specimen to be analyzed becomes a source of X-rays upon bombardment by the X-rays from the tube. The wave-lengths of the radiations originating in the sample are uniquely characteristic of the elements present and the intensities of these radiations are a measure of the concentrations of these elements.

The choice of a proper target material in the X-ray tube for analysis of the sample serves a dual purpose, viz: to optimize the production of elemental characteristic radiation from the specimen thereby permitting the detection of elements present in low concentrations in the sample and to introduce a tube target material different from the element in the sample so as to avoid superimposing the characteristic line originating in the specimen. It is almost impossible, for example, to quantitatively determine low concentrations of cromium or tungsten in a sample using a cromium or tungsten target respectively.

Referring to the Figures, to facilitate examination of materials by X-rays, there is provided an X-ray tube **11** having a plurality of anodes **13** each containing target material **14** which is different so that, by aligning either of the anodes **13** in operating position with respect to a cathode **15**, X-rays having the "line" spectrum corresponding with the target material of any of the anodes may be produced at will and projected through window **17** for application in X-ray analysis.

The anodes **13** may comprise any preferred target material such as tungsten, molybdenum, copper, nickel, cobalt, iron, chromium, or other desired target material, and, as shown, the target material **14** comprises rectangular buttons A, B, and C set in the end of a target support comprising the anode **13**. These anodes, preferably comprise hollow copper cylinders which are closed at the target end; and if it is desired to produce X-rays having the "line" spectrum characteristic of a copper target, the anode may be aligned to receive electron impingement directly upon the cupreous material of the anode **13** at the end adjacent the target material **14**.

The cathode **15** is of typically well known design and preferably comprises a suitable head which may be supported and sealed upon a re-entrant envelope portion comprising a hollow stem **21**. Conductors **23** for energizing the electron producing filament **25** may extend through the stem **21**. The cathode end of the tube may be fitted with a ferrule **28** carrying a base **29** for connecting the conductors **23** with a suitable external source of power for energizing the filament **25** for electron emission.

It will be noted that the filament **25** is of elongated character and is supported in a groove **27** formed in the head of the cathode **15** whereby electrons emitted by the filament **25**, when energized, will be focused substantially along a line **30** parallel to the longitudinal axis of the filament **25** on the target end of the anode **13** which is diametrically opposite the filament **25**. This line focus of electrons makes it possible to bring any of the anodes **13** into focal position or to position one of the anodes **13** so that the copper material thereof, extending about the target material **14**, is positioned to receive focused electrons impinging thereon. To this end, the anodes **13** are mounted for movement in the tube envelope lateral to the filament **25** in an arc motion about a pivot **31** so that the desired target material **14** may be aligned with the filament **25** so that it is diametrically opposite the filament **25** and in electron receiving position. In FIG. 2, button A is shown in position to receive the electron emission from the filament **25**.

The anodes **13** are mounted adjacent each other on a support sector **32** having an annulus portion rotatably mounted for movement about the pivot **31** on a cylindrical bearing **35**. The support sector **32** forms a follower means at a portion of a gear wheel at **33** having teeth **34**.

The bearing **35** is conventionally secured at one end in a bore **35a** in the interior of a cap section **36** of the anode **13** as shown in FIG. 1. The cap section **36** is press fit into a cylindrical section **37** at one end and is conventionally enclosed at its other end with a cap **38** for ease of construction of the components within the X-ray envelope (unnumbered) of the X-ray tube **11**. However, it is obvious that the cap section **36** and the cylindrical section **37** could be formed in one piece.

The high power required in the X-ray tubes for diffraction and spectrometry demand an effective cooling system. The cap **38** comprises a cooling fluid inlet port **40** coupled to a cooling fluid feed conduit **42** for directing the cooling fluid entering the inlet port **40** directly under the spot being bombarded by the electrons to the operating anode **13** at **44**. This provides localized cooling of the spot on the anodes **13** which is being bombarded with electrons from the filament **25**. A cooling fluid outlet port **46** is also provided in the cap **38** to remove cooling fluid from the interior of the anode **13**.

A shaft **48** is formed in the cap **38** for housing a drive means or worm gear **50** and a spindle **52** which is non-rotatably fixed to the end of the worm gear **50** and extends outside the shaft **48** to provide means for turning the worm gear **50** inside the X-ray tube **11** by an operator on the outside of the X-ray tube **11**. The spindle **52** is fitted with an O-ring **54** to prevent the loss of cooling fluid from the cap **38**.

In operation, the spindle **52** is manually rotated to place the desired one of the anodes **13** in position to receive the electron beam from the filament **25** since the spindle **52** turns the worm gear **50** which drives the gear wheel **33** thereby rotating the support sector **32**. Thus any one of the plurality of anodes **13** can be placed in position to receive electron emission from the filament **25**.

Conventional means are provided but are not shown exterior to the X-ray tube **11** which will actuate the spindle **52** and thereby accurately position any one A, B, or C of the buttons of the plurality of anodes **13**.

To maintain a relative vacuum within the interior of the anode **13**, a bellows **60** is provided to permit pivotal motion of the support sector **32**. The ends of the bellows **60** nearer the cap **38** is welded to an interior stepped in portion **62** of the cap section **36** and the opposite end of the bellows **60** is welded about the flange **64** of the support sector **32**.

As may be seen, the instant multi-anode X-ray tube is simple and reliable and can include many embodiments without departing from the scope of the invention and it is thus intended that this described embodiment be considered as exemplary only and that the invention not be limited except as warranted by the following claims.

I claim:

1. An X-ray tube having a cathode and a plurality of anodes, said plurality of anodes including mount means for supporting said plurality of anodes, follower means for pivoting said mount means about a pivot point and moving said plurality of anodes with respect to said cathode, drive means engaging said follower means for moving said follower means to position a selected one of said plurality of anodes diametrically opposite the filament of said cathode, means for moving said drive means, bearing means for supporting said mount means, said mount means including sector having said plurality of anodes mounted on the circumferential portion thereof and the narrow section of said sector forming an annulus which is fitted on said bearing means for rotatable motion thereabout, and follower means including a spur gear mounted on said bearing means and non-rotatably linked with said annulus, whereby said mount means are rotated with said spur gear upon said drive means moving said spur gear.

2. An X-ray tube as described in claim **1**, wherein said spur gear and said annulus are integral.

3. An X-ray tube as described in claim **1**, wherein a portion of said annulus forms said spur gear by a portion of said annulus having said spur gear teeth formed thereon.

4. An X-ray tube as described in claim **1**, wherein said drive means is a worm gear in meshing engagement with said spur gear.

5. An X-ray tube as described in claim **4**, wherein said X-ray tube includes a cap attached to the end of said X-ray tube adjacent said plurality of anodes and having at least one chamber formed therein to house said worm gear and a bellows sealed vacuum-tight to said sector at one end and sealed vacuum-tight to the inner face of said X-ray tube, said means for moving said drive means is a spindle non-rotatably connected to one end of said worm gear and extending from said worm gear through an extension of said chamber to the exterior of said cap, to provide means for rotating said worm gear from outside said X-ray tube and maintaining a vacuum within said X-ray tube.

6. An X-ray tube as described in claim **5**, wherein said cap has provided therein additional chambers to form an inlet port and outlet port for cooling fluid therein, said inlet port and said outlet port being separate and each extending integrally from the outside of said cap to the interior of said X-ray tube, and a feed conduit is connected at one end to said inlet port at the end opening into the interior of said X-ray tube and said feed conduit extends to the back of said plurality of anodes, whereby cooling fluid is introduced through said inlet port and said feed conduit to the back of the spot on said plurality of anodes being bombarded by electrons from said cathode and said cooling fluid is carried away from said X-ray tube through said outlet port in said cap for localized cooling of said plurality of anodes.

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