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Description

Background of the Invention

This invention relates to microfocus X-ray tubes such as are used to take medical X-rays. In such X-ray tubes, the electron beam is focused on an extremely small point on the target, which has the medical advantage that the X-ray silhouette is very clear and crisp. However, the highly dense, small spot of electrons quickly melts the target no matter what kind of cooling device is used, and therefore either the X-ray target is consumed in one use or fewer electrons are used in the beam than would otherwise be desirable. In particular, it is highly desirable in medical X-ray work to use an extremely short exposure time so that the motion of the patient or of the patient's inside organs does not smear the picture. However, with prior-art microfocus tubes, the exposure time must be relatively long to get enough X-rays to form the picture because the rate of X-ray production is so small.

The problems suggested in the preceding paragraph are not intended to be exhaustive, but rather are among many which tend to reduce the effectiveness of prior-art microfocus X-ray tubes. Other noteworthy problems may also exist; however, those presented above should be sufficient to demonstrate that microfocus X-ray tubes appearing in the prior-art have not been altogether satisfactory.

Objects of the Invention

It is, therefore, a general object of the invention to provide a microfocus X-ray tube which will obviate or minimize problems of the type previously described.

It is a particular object of the invention to provide such a device which is reusable, yet which generates a relatively large number of X-rays in a relatively short period of time using a narrowly focused electron beam.

It is a further object of the invention to provide a microfocus X-ray tube wherein the X-ray tube comprises means for moving the target anode so that it is stationary during production of X-rays but a fresh portion of the surface of the target anode is presented to the electron beam each time the X-ray tube is used.

The target anode may be in the form of a ribbon.

Other objects and advantages of the present invention will become apparent from the detailed description of a preferred embodiment given hereinafter taken in conjunction with the accompanying drawings.

Description of the Prior Art

Many X-ray tubes of the type used in taking medical X-rays are known which employ more or less elaborate devices to move the target anode *during* impingement of the electron beam, thereby distributing the heat generated by the electron beam over a portion of the surface of the target anode far in excess of the cross-sectional area of

the electron beam. Representative of the awkward designs others skilled in the art have resorted to remove and deconcentrate the heat generated by the action of the electron beam on the target material is the device disclosed in U.S. patent no. 3,825,786.

Many other X-ray tubes of the type used in taking medical X-rays are known in which similarly elaborate devices are employed to bring a cooling fluid into thermal contact with the target anode during impingement of the electron beam. The cooling fluid may, for example, be water or air.

Other types of X-ray tubes not suitable for use in taking medical X-rays, but suitable for use in X-ray crystallography, are known in which the target anode can be moved *between* impingements of the electron beam. Typical of these are the devices shown in U.S. patent no. 2,298,335 and U.S. patent no. 3,753,020. Such devices, however, include a plurality of separate target anodes made of different materials, and the devices permit the operator to alternate from one target anode to another to obtain different readings from the different types of anodes. However, they do not cause the automatic substitution of one target anode for another after each use, and the operator could (and in many cases would) use the same segment of the same target anode many times before switching to a different target anode. Moreover, devices such as are disclosed in these patents do not cause a different portion of each target anode to be used each time the user returns to a given target anode. If a fresh portion of the target anode is presented to the electron beam when a given target anode is used on a subsequent occasion, it would be accidental or incidental, not caused deliberately and consistently.

Finally, U.S. patent no. 3,290,540 discloses an electron discharge tube having a movable *cathode* tape. The tape serves as an *emissive* element, and the tape can be incremented after it has become pitted from use. However, the pitting of an emissive cathode from use is very different, both physically and conceptually, from the melting of a portion of a target anode due to the impingement of an electron beam.

The Drawings

Figure 1 is a perspective view of the presently preferred embodiment of an X-ray tube according to the invention.

Figure 2 is a schematic diagram of control means for the X-ray tube shown in Figure 1.

Detailed Description of the Presently Preferred Embodiment

The presently preferred embodiment of the subject invention comprises a conventional evacuated glass envelope 10 and a high voltage line 12, filament current wires 14, a heater cathode 16, and an electron beam collimator 18 which together constitute means for producing a dense, narrow electron beam 20. Instead of the conventional conical target anode, however, the

subject X-ray tube preferably has a target anode in the form of a ribbon 22 trained around two spools 24 mounted within the X-ray tube on bracket 26. The ribbon 22 is preferably made of tungsten, but in any event the working surface of the ribbon 22 is made of a single anode material.

Also mounted within the X-ray tube is a stepping motor 28 which is operatively connected to the spools 24 via a drive belt 30. Power for the motor 28 is supplied by motor wires 32, and the motor 28 and the target anode 22 are grounded by ground wire 34.

The roughened portions of the ribbon 22 caused by impingement of the electron beam 20 are, of course, greatly exaggerated in size for clarity. In fact, the roughened portions are approximately 50 microns in diameter, and their center-to-center distance (i.e., the amount by which the stepping motor 28 increments the ribbon 22 each time it is actuated) is approximately 100 microns.

In use, activation of the heater cathode 16 and the motor 28 is coordinated so that the ribbon 22 is stationary during production of X-rays 36, but a fresh portion of the surface of the ribbon 22 is presented to the electron beam 20 each time the X-ray tube is used. Each use of the X-ray tube therefore melts at least the surface portion of the spot on the ribbon 22 on which the electron beam 20 is focused, but the ribbon 22 is then moved on by a short distance, much in the fashion of a typewriter ribbon, before the X-ray tube is used again.

Figure 2 shows in schematic form exemplary means for coordinating the electron producing means and the ribbon advancing means. Such means comprises three ganged switches 38, 40, and 42 and three circuits, one of which is controlled by each of the switches. The ganged switches may be operated simultaneously by a single push button (not shown). One of the three circuits comprises a voltage source 44, the switch 42, and the filament current wires 14. Another of the three circuits comprises a high voltage generator 46 grounded at 48, the switch 40, and the high voltage line 12. Since these circuits are conventional, they will not be described further. The third circuit, however, is not conventional, for it is the circuit which coordinates the first two circuits and the stepping motor 28. It comprises the switch 38, a battery 50 (which may be the same as battery 44), a timer 52, which may for instance be a two second timer, a pulse generator 54, a driver card 56, and motor wires 32.

Activation of the ganged switches 40 and 42 causes generation of an electron beam lasting less than 1/10 of a second in the conventional manner. Simultaneously actuation of the switch 38 actuates the two-second timer 52. After elapse of the two seconds, the pulse generator 54 emits a pulse which actuates the driver card 56, and the driver card 56 causes the stepping motor 28 to increment. The increment of the stepping motor 28 may, for instance, be 1.8°, and the spools 24 and the take-off spool connected to the stepping motor 28 are sized so that a 1.8° increment of the

stepping motor causes the ribbon 22 to advance by approximately 100 microns. Since the time elapse between X-rays is much more than two seconds, the illustrated apparatus insures that a fresh portion of the surface of the ribbon 22 is presented to the electron beam upon each actuation of the beam.

Although not illustrated, it is within the scope of the invention for the target anode to take on shapes other than the illustrated ribbon shape. It may, for instance, be in the shape of a wheel or a cone. No matter what its shape, however, the common feature of the invention is that the target is moved intermittently to present a new target area for each shot, but remains stationary during each shot.

Advantages of the Invention

From the foregoing description of a microfocus X-ray tube in accordance with a preferred embodiment of the invention, those skilled in the art will recognize several advantages which singularly distinguish the subject invention from previously known devices. Some of those advantages are set forth below. However, while the following list of advantages is believed to be both accurate and representative, it does not purport to be exhaustive.

A particular advantage of the subject invention is that it is reusable, yet it generates a relatively large number of X-rays in a relatively short period of time from a narrowly focused electron beam.

Another advantage of the subject invention is that it produces X-ray silhouettes which are very clear and crisp. In particular, since the X-ray silhouettes are made in a short time exposure, motion of the patient's organs does not smear the picture.

While the present invention has been illustrated by a detailed description of a preferred embodiment thereof, it will be obvious to those skilled in the art that various changes in form and detail can be made therein without departing from the true scope of the invention.

Claims

1. A microfocus X-ray tube comprising:

(a) apparatus (16, 18) for producing a dense, narrow electron beam and

(b) a target anode (22), wherein

the X-ray tube further comprises apparatus (24, 28) for moving said target anode (22) so that it is stationary during production of X-rays but a fresh portion of the surface of said target anode is presented to the electron beam each time the X-ray tube is used, such that

a relatively large number of X-rays can be generated in a relatively short period of time using a narrowly focused electron beam without destroying the X-ray tube.

2. A microfocus X-ray tube as recited in Claim 1 wherein said target anode is in the form of a ribbon (22).

3. A microfocus X-ray tube as recited in Claim 2

wherein said target anode is made of tungsten.

4. A microfocus X-ray tube as recited in Claim 2 wherein said target anode is trained around two spools (24) mounted within the X-ray tube.

5. A microfocus X-ray tube as recited in Claim 4 wherein the apparatus for moving comprises a motor (28) mounted within the X-ray tube and operatively connected to at least one of said spools (24) to drive the spool and advance the anode ribbon.

6. A microfocus X-ray tube for taking medical X-rays comprising:

(a) apparatus (16, 18) for producing a dense, narrow electron beam; and

(b) a target anode (22); and wherein apparatus (24, 28) for moving the target anode (22) within the X-ray tube and including:

apparatus (52, 54, 56) for coordinating the first apparatus for producing the electron beam and the apparatus for moving the target so that said target anode (22) is stationary during production of X-rays and a fresh portion of the surface of said target anode is presented to the electron beam in each instance the X-ray tube is used,

such that a relatively large number of X-rays can be generated in a relatively short period of time using a narrowly focused electron beam without destroying the usefulness of the X-ray tube.

7. A microfocus X-ray tube as recited in Claim 6 wherein the target anode is in the form of a ribbon wound on spools.

8. A microfocus X-ray tube as recited in Claim 7 wherein said target anode is made of tungsten.

9. A method of generating a relatively large number of X-rays in a relatively short period of time using a re-usable microfocus X-ray tube comprising apparatus (16, 18) for producing a dense, narrow electron beam and a target anode (22),

the method including the step of:

moving the target anode (22) so that it is stationary during production of an X-ray but a fresh portion of the surface of the target anode is presented to the electron beam each time the X-ray tube is used.

10. A method as recited in Claim 9 wherein the target anode is moved by a short distance between uses of the X-ray tube, such that the used portions of the target anode are closely spaced.

Patentansprüche

1. Eine Mikrofokus-Röntgenröhre mit:

(a) einem Apparat (16, 18) zum Erzeugen eines dichten, schmalen Elektronenstrahls und

(b) einer Auftreffanode (22), wobei die Röntgenröhre außerdem einen Apparat (22, 28) aufweist, um die Auftreffanode (22) so zu bewegen, daß diese während der Erzeugung von Röntgenstrahlen still steht, daß aber ein frischer Abschnitt der Oberfläche der Auftreffanode dem Elektronenstrahl jedesmal dargeboten wird, sooft die Röntgenröhre benutzt wird, so daß

eine verhältnismäßig große Anzahl von Rönt-

genstrahlen in einer verhältnismäßig kurzen Zeitperiode unter Verwendung eines schmal fokussierten Elektronenstrahls erzeugt werden kann, ohne die Röntgenröhre zu zerstören.

2. Mikrofokus-Röntgenröhre nach Anspruch 1, bei der die Auftreffanode in der Form eines Bandes (22) ausgebildet ist.

3. Mikrofokus-Röntgenröhre nach Anspruch 2, bei der die Auftreffanode aus Wolfram gefertigt ist.

4. Mikrofokus-Röntgenröhre nach Anspruch 2, bei der die Auftreffanode um zwei Rollen (24) geführt ist, die innerhalb der Röntgenröhre angeordnet sind.

5. Mikrofokus-Röntgenröhre nach Anspruch 4, bei der der Apparat (22, 28) einen Motor (28) aufweist, der innerhalb der Röntgenröhre angeordnet und wirkungsmäßig mit zumindest einer der Rollen (24) verbunden ist, um die Rolle anzutreiben und das Anodenband zu bewegen.

6. Mikrofokus-Röntgenröhre für medizinische Röntgenaufnahmen mit:

(a) einem Apparat (16, 18) zum Erzeugen eines dichten, schmalen Elektronenstrahls und

(b) einer Auftreffanode (22); wobei ein Apparat (24, 28) zum Bewegen der Auftreffanode (22) innerhalb der Röntgenröhre angeordnet ist; und wobei

ein Apparat (52, 54, 56) zum Koordinieren des ersten Apparats zum Erzeugen des Elektronenstrahls und des Apparates zum Bewegen des Auftreffzieles vorhanden ist, derart, daß die Auftreffanode (22) während der Erzeugung von Röntgenstrahlen im Stillstand ist und ein frischer Abschnitt der Oberfläche der Auftreffanode dem Elektronenstrahl jedesmal dargeboten wird, wenn die Röntgenröhre benutzt wird,

so daß eine verhältnismäßig große Anzahl von Röntgenstrahlen in einer verhältnismäßig kurzen Zeitperiode erzeugt werden kann unter Benutzung eines schmal fokussierten Elektronenstrahls, ohne die Brauchbarkeit der Röntgenröhre zu zerstören.

7. Mikrofokus-Röntgenröhre nach Anspruch 6, bei der die Auftreffanode die Form eines Bandes hat, das auf Rollen gewickelt ist.

8. Mikrofokus-Röntgenröhre nach Anspruch 7, bei der die Auftreffanode aus Wolfram gefertigt ist.

9. Verfahren zum Erzeugen einer verhältnismäßig großen Anzahl von Röntgenstrahlen in einer verhältnismäßig kurzen Zeitperiode unter Verwendung einer mehrmals benutzbaren Mikrofokus-Röntgenröhre mit einem Apparat (16, 18) zum Erzeugen eines dichten, schmalen Elektronenstrahls und einer Auftreffanode (22), einschließlich des folgenden Verfahrensschrittes:

Bewegen der Auftreffanode (22) derart, daß sie während des Erzeugens eines Röntgenstrahls still steht, daß jedoch eine frischer Abschnitt der Oberfläche der Auftreffanode dem Elektronenstrahl jedesmal dargeboten wird, sooft die Röntgenröhre benutzt wird.

10. Verfahren nach Anspruch 9, bei dem die

Auftreffanode zwischen den Benutzungen der Röntgenröhre eine kurze Strecke bewegt wird, so daß die benutzten Abschnitte der Auftreffanode einander eng benachbart sind.

Revendications

1. Tube à rayons X à micro-foyer comprenant
(a) un dispositif (16, 18) pour produire un faisceau d'électrons dense et étroit, et
(b) une anode-cible (22).

caractérisé en ce que le tube à rayons X comprend en outre un dispositif (24, 28) destiné à mouvoir ladite anode-cible (22) de manière qu'elle soit fixe pendant la production des rayons X mais qu'une nouvelle partie de la surface de ladite anode-cible soit présentée au faisceau d'électrons chaque fois que l'on utilise le tube à rayons X,

de manière qu'un nombre relativement important de rayons X puisse être engendré pendant une période de temps relativement courte en utilisant un faisceau d'électrons étroitement concentré et sans détruire le tube à rayons X.

2. Tube à rayons X à micro-foyer selon la revendication 1, caractérisé en ce que ladite anode-cible se présente sous la forme d'un ruban (22).

3. Tube à rayons X à micro-foyer selon la revendication 2, caractérisé en ce que ladite anode-cible est réalisée en tungstène.

4. Tube à rayons X à micro-foyer selon la revendication 2, caractérisé en ce que ladite anode-cible est entraînée autour de deux bobines 24 montées à l'intérieur du tube à rayons X.

5. Tube à rayons X à micro-foyer selon la revendication 4, caractérisé en ce que le dispositif destiné au mouvement comprend un moteur (28) monté à l'intérieur du tube à rayons X et relié fonctionnellement à au moins l'une desdites bobines (24) pour entraîner la bobine et faire avancer le ruban constituant l'anode.

6. Tube à rayons X à micro-foyer destiné à réaliser des radiographies médicales, comprenant:

(a) un dispositif (16, 18) pour produire un faisceau d'électrons dense et étroit, et

(b) une anode-cible (22), et dans lequel le dispositif (24, 28) destiné à déplacer l'anode-cible (22) à l'intérieur du tube à rayons X comprend:

un dispositif (52, 54, 56) pour coordonner le premier dispositif permettant de produire le faisceau d'électrons et le dispositif pour mouvoir la cible de manière que ladite anode-cible (22) soit fixe pendant la production des rayons X et qu'une nouvelle partie de la surface de l'anode-cible soit présentée au faisceau d'électrons chaque fois que le tube à rayons X est utilisé,

de manière qu'un nombre relativement important de rayons X puisse être engendré pendant une période de temps relativement courte en utilisant un faisceau d'électrons étroitement concentré sans détruire la possibilité d'utilisation du tube à rayons X.

7. Tube à rayons X à micro-foyer selon la revendication 6, caractérisé en ce que l'anode-cible se présente sous la forme d'un ruban enroulé autour de bobines.

8. Tube à rayons X à micro-foyer selon la revendication 7, caractérisé en ce que ladite anode-cible est réalisée en tungstène.

9. Procédé pour engendrer un nombre relativement important de rayons X pendant une période de temps relativement courte en utilisant un tube à rayons X à micro-foyer réutilisable, comprenant un dispositif (16, 18) pour produire un faisceau d'électrons étroit et dense sur une anode-cible (22),

le procédé comprenant l'étape consistant à:

mouvoir l'anode-cible (22) de manière qu'elle soit fixe pendant la production des rayons X mais qu'une nouvelle partie de la surface de l'anode-cible soit présentée au faisceau d'électrons chaque fois que l'on utilise le tube à rayons X.

10. Procédé selon la revendication 9, caractérisé en ce que l'anode-cible est mue sur une courte distance entre les utilisations du tube à rayons X, de manière que les parties utilisées de l'anode-cible soient étroitement espacées.



