MOLYBDENUM ALLOY TARGET FOR MAMMOGRAPHIC USAGE IN X-RAY TUBES

Inventors: Robert E. Hueschen, Hales Corners; Frank Bernstein, Milwaukee, both of Wis.

Assignee: General Electric Company, Milwaukee, Wis.

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References Cited

UNITED STATES PATENTS

3,328,626 6/1967 Natter et al.

Primary Examiner—Roy Lake
Assistant Examiner—Darwin R. Hostetter
Attorney—James E. Espe et al.

ABSTRACT

Low temperature ductility and high temperature strength of a molybdenum target for X-ray tubes employed in mammographic applications is achieved by alloying molybdenum with tungsten. The alloy target provides the necessary characteristic radiation of molybdenum while maintaining exceptional resistance to surface fracture and radiation output degradation under the required exposure condition for mammography.

9 Claims, 2 Drawing Figures
TUBE OUTPUT,
RELATIVE UNITS

THOUSANDS OF EXPOSURES

FIG. 2
MOLYBDENUM ALLOY TARGET FOR MAMMOGRAPHIC USAGE IN X-RAY TUBES

BACKGROUND OF THE INVENTION

This invention relates to mammography. More specifically, this invention relates to the X-ray tube and the anode therein employed in mammography.

The amount of tissue through which X-rays pass is generally much smaller with respect to the female breast compared to other parts of the body. Since there is no bone in the breast, it is not required, nor is it desirable to employ as high an energy beam to penetrate the breast as compared with the energy requirements for bone tissue. Therefore, in the area of diagnostic mammography, it is generally desirable to employ lower kilovoltages as compared to ordinary diagnostic X-ray techniques. The use of lower energy provides for greater contrast between fat and soft tissue and it is such contrast that is needed in order to obtain an optimum mammogram.

Most medical diagnostic X-ray techniques utilize large amounts of "hard" radiation, i.e., X-radiation having greater penetrating power than "soft" X-rays. For these applications, tungsten is an ideal anode target primarily because of its high atomic number and melting point. However, to obtain this hard radiation and excite the characteristic Kα and Kβ lines for tungsten requires a minimum of 70 kilovolts.

Mammography, however, as a special medical diagnostic technique, requires special techniques in exposure, exposure time and exceptional X-ray film quality and detail. The employment of lower kilovoltages is one means of achieving the fine film quality and details required in mammography. By employing hard X-radiation the diagnostic quality of exposed film is seriously reduced because of a costly reduction in contrast.

The continuous and characteristic X-ray spectra for most metals and materials is well known. The characteristic lines of a target material are excited at some minimum kilovoltage. The kilovoltage required to produce the characteristic spectra changes regularly with the atomic number of the metal. As compared with the characteristic tungsten Kα line, the characteristic molybdenum Kα line is excited at a minimum of 20 kilovolts.

It can readily be realized therefore that there is a decided advantage in using molybdenum instead of tungsten with reference to mammography, since at lower kilovoltages one obtains the intense characteristic molybdenum radiation which is not obtainable with tungsten.

In accordance with mammographic techniques, it is generally required to employ a relatively high number of milliamperes-seconds (mas) per exposure. Depending on the breast size, the mas employed can vary from about several hundred mas to over 1,000 mas. In consideration of the high milliamperes-second values, it is generally most desirable to operate the X-ray tube at maximum current in order to maintain the exposure times to the patient as low as possible.

Because of the high mas which is employed in mammography, severe mechanical stresses are imposed on the electron track surface of a molybdenum target. These mechanical stresses result in surface fractures in the focal track of the target area. Distortion of the target surface caused by the fracturing results in a marked decrease of X-radiation output intensity because the probability of an X-ray photon escaping from the target is markedly less for a rough target surface than for a smooth surface. The susceptibility of a molybdenum target to surface fracturing in the focal track area is greater than that of tungsten.

Metallurgists have been trying to solve the surface fracturing problem for X-ray targets and the like by various means. In U.S. Pat. No. 3,650,846 of Holland and Hueschen, a process is described for reconstituting the grain structure of refractory metals whereby the ductile-to-brittle transition temperature is reduced thereby reducing the tendency of the surface fractures under mechanical stresses as caused by the use of high mas and the like.

Because of the benefits obtained through the employment of a molybdenum target with respect to mammography, the art would be greatly advanced if additional techniques are discovered for expanding the useful lifetime of molybdenum targets.

SUMMARY OF THE INVENTION

A primary object of the present invention is to provide an X-ray target substantially comprising molybdenum, this target having superior properties with respect to withstanding mechanical stress from high energy impinging electrons. More specifically, it is an object to provide an X-ray anode which is an alloy of molybdenum and tungsten. Upon being subjected to low voltage techniques, the alloy will yield the continuous and characteristic X-ray spectra for molybdenum. The alloy unexpectedly and advantageously has improved properties with respect to low temperature ductility, resistance to thermal fatigue and increased high temperature strength as compared to a pure molybdenum target.

It is a further object to provide an X-ray anode comprising an alloy of molybdenum and tungsten. The alloy is a solid solution having superior strength compared to molybdenum at room temperatures and at elevated temperatures. The grain size is smaller as compared to pure molybdenum and the atoms of the alloy are in clusters in the solid solution rather than in short range atom order.

Solid solution strengthening is important, particularly at elevated temperatures since the exposures required for mammography are relatively long. This strengthening causes the anode to be more resistant to high thermal fatigue while being subjected to the impinging of high energy electrons.

The reduction of grain size results in reduced ductile-to-brittle transition temperature thereby providing greater ductility at and above room temperature when the electron beam first strikes the cold anode target. For an explanation of ductile-to-brittle transition temperature, see U.S. Pat. No. 3,650,846 issued Mar. 21, 1972. The reduction in ductile-to-brittle transition temperature results in a significant decrease in surface fracturing of the anode and more particularly at the target area. The inhibition of brittle fracture is highly desirable since such fractures cause a marked decrease in X-radiation output intensity.

Clustering of atoms is more desirable than short range order since the alloy will evidence increased strength at high temperatures by solute strengthening and by providing improved dislocation mobility, and hence increased ductility at lower temperatures since solute clustering causes removal of interstitial elements.
from the matrix. That is, the increased ductility is a direct result of decreased interstitial elements within the grains (notably carbon and oxygen) which are known to drastically increase the ductile-to-brittle transition temperature.

A further object of this invention is to provide an X-ray tube adapted for mammographic application having a rotary metallic anode body with an exposed target area and electron beam means for producing electrons for impingement on the target area of the anode thereby producing X-ray emission, the anode comprising the alloy described herein.

It is a further object to provide the above improvements in an inexpensive and economical manner.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In accordance with this invention, the above and other objects are attained by providing an X-ray anode comprising an alloy of from about 95 to about 65 percent molybdenum and from about 5 to about 35 percent tungsten. In an especially preferred embodiment of the invention, the alloy employed in accordance with the invention consists essentially of about 70 percent molybdenum and 30 percent tungsten. The preparation of the alloy is according to standard and art recognized procedures and as such does not constitute a part of the invention.

The entire anode need not be made of the molybdenum-tungsten alloy. For example, as in rotating anodes, at least the target area or the focal track can consist essentially of the alloy whereas the base can comprise other suitable materials such as tungsten, molybdenum and the like. The procedures for making X-ray anodes are well known in the art and need no full elaboration.

In accordance with another embodiment of the invention, there is provided an X-ray tube adopted for mammography comprising a metallic anode body with an exposed target area and electron beam means such as a cathode for producing an electron beam for impingement upon the target area thereby producing suitable X-rays for diagnostic mammography. In accordance with the invention, the anode body or at least the target area of the anode body comprises an alloy of molybdenum and about from 5 to about 35 percent tungsten. In a preferred embodiment, the alloy consists essentially of about 70 percent molybdenum and about 30 percent tungsten.

FIG. 1 is a plot of X-ray tube output in terms of relative units versus thousands of exposures.

FIG. 2 is also a plot of X-ray tube output in terms of relative units versus thousands of exposures.

EXAMPLES

1. A pure molybdenum target is continuously exposed to an electron beam so as to provide X-radiation for mammographic applications under the following conditions: 40 peak kilovolts, 300 milliamperes, 2.5 second exposures. Two exposures are made per minute thereby providing 60,000 heat units per minute inputs. Heat units per minute (H) is defined as the product of the peak kilovoltage applied across the anode and cathode (kvp), the milliamperes (ma), the exposure time (s), and the number of exposures per minute (n) during a life test; \( H = (kvp) \cdot (ma) \cdot (s) \cdot (n) \).
constant rate of deterioration of the former is apparently the results of being subjected to greater stresses because of the longer cooling time between exposures. The alloy target subjected to 30,000 heat units per minute initially deteriorated more rapidly than the alloy exposed to 60,000 heat units per minute, however, the rate of deterioration of the former leveled out at a higher percentage output level.

The foregoing description and the accompanying drawings pertain to the presently preferred embodiment of the invention heretofore disclosed. It is not intended that the invention be limited to either that which has been shown in the accompanying drawings or described in the specification since it will be obvious to those skilled in the art that various changes and modifications may be made after benefit of this disclosure. It is therefore intended that the appended claims cover all changes and modifications embraced within the true spirit and scope of the invention.

We claim:

1. An X-ray tube anode wherein at least the target of said anode comprises an alloy of molybdenum and from about 5 to about 35 percent of tungsten.

2. An X-ray tube anode as in claim 1 wherein the alloy comprises about 70 percent molybdenum and about 30 percent tungsten.

3. An X-ray tube anode as in claim 1 wherein said anode is a rotating anode.

4. An X-ray tube anode as in claim 3 wherein said rotating anode consists essentially of an alloy of molybdenum with from about 5 to about 35 percent of tungsten.

5. An X-ray tube anode of claim 4 wherein said anode consists essentially of about 70 percent molybdenum and 30 percent tungsten.

6. In an X-ray tube adopted for mammographic applications having a rotary metallic anode body with an exposed target area and electron beam means for producing an electron beam impinging on said target area thereby producing X-ray emission, the improvement comprising said anode body having at least the target area comprising an alloy of molybdenum and from about 5 to about 35 percent tungsten.

7. In an X-ray tube as in claim 6 wherein the alloy comprises about 70 percent molybdenum and about 30 percent tungsten.

8. In an X-ray tube as in claim 6 wherein the anode consists essentially of an alloy of molybdenum with from about 5 to about 35 percent of tungsten.

9. In an X-ray tube as in claim 8 wherein said alloy consists essentially of about 70 percent molybdenum and 30 percent tungsten.

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