Aug. 15, 1967 SHINICHI NAGASHIMA ET AL 3,336,494

X-RAY TUBE WITH ALLOY TARGET

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FIG. 1

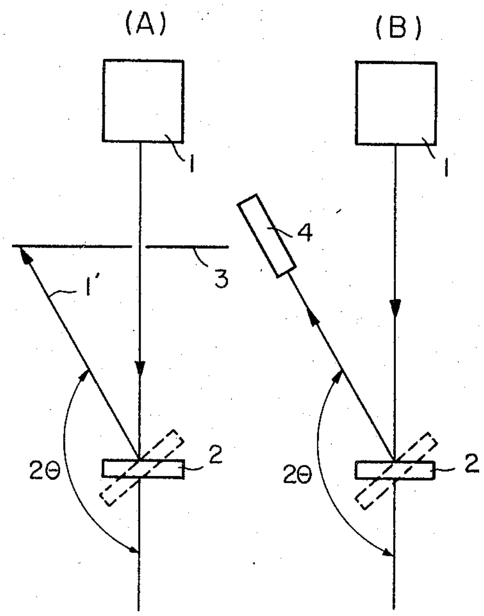


FIG. 3

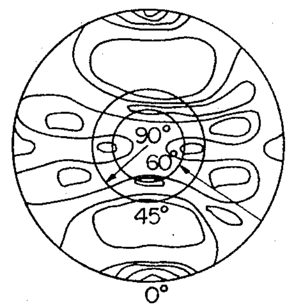


FIG. 4

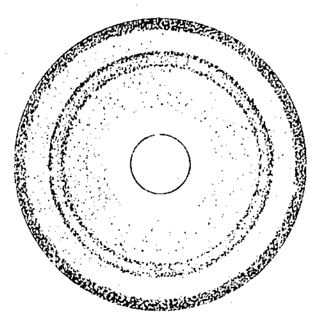
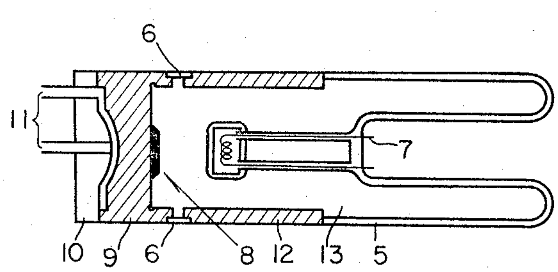


FIG. 2



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X-RAY TUBE WITH ALLOY TARGET

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This invention relates in general to an X-ray tube and more particularly to an X-ray with a target made of an alloy which can be used in X-ray diffraction analysis.

The conventional target in an X-ray tube used for the above-described analysis and measurement is made of pure metal but this type of X-ray tube requires very complicated procedures by the X-ray operator for analytical measurement using two or more kinds of characteristic X-ray radiations. This invention seeks to provide an excellent solution to the problem of eliminating the difficulty arising from the operation of the X-ray tube, by replacing the conventional pure metal target with a new target composed of two or more metallic elements.

An object of the present invention is to provide an X-ray tube which assures successful analysis of metallurgical structure and the making of pole figure diagrams by applying characteristic X-rays by means of a common simple tube with extreme ease and at a high speed, without the necessity of following such troublesome procedures as changing tubes or readjustment of the relative position of the tube and the specimen to be tested.

Another object of this invention is to provide an X-ray tube for diffraction analysis with a new target, made of an alloy composed of two or more metallic elements, in place of the conventional target, made of pure metal, the latter target being much more difficult to manufacture.

Other objects and a fuller understanding of this invention may be had by referring to the following description, taken in conjunction with the accompanying drawings, in which;

FIGS. 1A and 1B are diagrams of an arrangement for an X-ray method of stress measurement using X-ray diffraction analysis;

FIG. 2 is a longitudinal cross-sectional view of an X-ray tube according to the invention;

FIG. 3 is a representation of a pole figure diagram for mild steel; and

FIG. 4 is a representation of a photographic back reflection pattern of pure iron taken with an X-ray tube in accordance with this invention.

Generally, for X-ray diffraction analysis, the continuous spectrum of X-rays and characteristic X-rays are applied to a specimen. Namely, the continuous spectrum of X-rays is applied primarily to save photography in the Laue method using a single crystal, while characteristic X-rays are used for such various roentgenographies or measurements as the powder method or the rotating crystal method etc., applicable to analysis of the structure of a specimen.

The present invention is designed for easy and quick X-ray diffraction measurement, for which different characteristic X-rays are preferably applied for the diffraction analysis of the structure of a substance or the making of a pole figure diagram, by employing only a common single X-ray tube which contains a metallic alloy target composed of two or more metallic elements and from which two or more kinds of characteristic X-rays can be generated. By the use of this X-ray tube, one can eliminate the troublesome procedures of changing X-ray tubes and readjustment of the relative position of the

specimen and the tube, which steps are indispensable for diffraction analysis with a conventional X-ray tube.

One of the other advantages of having the target composed of an alloy metal is the extreme ease of fabrication into the target of, for example, a manganese bronze alloy, as compared to a conventional target of pure metal such as manganese which is quite difficult to fabricate.

Generally, for diffraction analysis of the structure of a substance, a Geiger-Müller counter may be employed, but for another analysis by means of a pole figure or the like, the combined use of a scintillation counter tube or a proportional counter tube and a pulse height analyzer is desirable.

The target of the conventional X-ray tube is made of a single pure metal. Examples of such metals usually used as the material of the conventional target are tungsten for continuous spectrum X-ray methods, and chromium, iron, cobalt, nickel, copper, and molybdenum for characteristic X-ray methods. In a method of X-ray diffraction analysis, other than the Laue method, the characteristic X-ray of a certain wave length is applied, but it contains a continuous spectrum of X-rays and some other rays with undesired wave lengths. It is desirable to eliminate such unwanted components by employing a suitable filter or crystal monochrometer, even when a pure metal target is used. For this reason, it is the usual practice to employ high purity metal for the target material of an X-ray tube.

The target, made of such high purity metal, is sealed in an X-ray tube to which high tension is applied to cause generation of X-rays, which in turn are applied to the X-ray camera or X-ray diffractometer to be combined for photography or measurement. Generally, most of the measurements can be successfully performed by applying a single characteristic X-ray, but some of them should preferably be conducted twice for each specimen with two different characteristic X-rays for a particular type of measurement. For example, to measure residual stress in iron or steel, first, residual stress in plane **211** is measured by applying thereto a characteristic X-ray generated from the chromium target (Cr–Kα), and then similar stress in another plane **310** is measured at the same position of the same specimen by applying another characteristic radiation, generated from another target of cobalt (Co–Kα). For a fuller understanding, a further description is given in the following with reference to the drawing;

In FIG. 1, which is a diagram of an arrangement which is the same as that which can be used according to this invention, an X-ray tube is positioned to beam X-rays on a specimen **2** to be tested. A roentgenographical film **3** and a counter **4** are provided in the positions shown. For roentgenographical measurement, carried out by the arrangement of FIG. 1A, the specimen **2** is placed in a position normal to a direction (represented by solid line) corresponding to the direction of incidence of X-rays directed therein for taking a roentgenogram on the film **3** on which a circular diffraction pattern is formed by X-rays, diffracted in the direction indicated by the arrow. Then, the specimen is inclined to an angle of 45° relative to the direction of incidence of the X-rays, as illustrated by the broken lines, to form a similar image on the film, thus enabling the tester to calculate stress on a certain crystal plane from the angular positions of a pair of diffraction lines for two different positions of the specimen, i.e. at 90° and 45°. Finally, the X-ray tube is replaced by another tube with the target of different metal, and the position of the camera is readjusted accordingly to obtain two additional roentgenograms at the same two different positions of the specimen, 90° and 45° relative to the line of incidence of the X-rays, to find the stress in a second crystal plane, which is deemed to be the residual stress.

The method described above can also be followed in the same manner for another measurement with a Geiger counter tube as illustrated in FIG. 1B, in which the Geiger counter is moved an angle of 2θ from 158° to 164°, and the angle of the diffraction lines, $2\theta_\beta$ are measured.

Stress in the plane **310** is determined using a cobalt target from two different values of diffraction angle $2\theta_\beta$ as determined from two consecutive measurements, conducted at two different angular positions of the specimen, 90° and 45°, and another value of stress in the plane **211** is obtained by applying another characteristic X-ray, generated by a chromium target, substituted for the former X-ray tube with a cobalt target.

The method of stress measurement involving two consecutive X-ray applications requires highly complicated procedures, because two different characteristic X-rays must be applied to the same specimen, in addition to the required change of the target and readjustment of relative position of the camera and the X-ray apparatus for every change of the target.

Another example of a similar measurement which requires troublesome frequent changes of the target before completion of testing is the making of an X-ray pole figure, which is designed to enable determination of the preferred orientation of a metal sheet. For this measurement, a perfect pole figure can be realized only by two different and consecutive measurements of transmission and reflection. To test, for example, sheets of mild steel and silicon steel, first the pole figure is determined in the range from 0° to 60° of by measuring primary diffraction of the plane **110**, employing an X-ray tube with a molybdenum target, and the diagram is made for the positions from 0° (starting at the periphery of a circle) to 60° as illustrated in FIG. 3, and then the same pole figure is made in the range from 40° to 90° (center) by measuring secondary diffraction of plane **110**, employing an iron target, and the diagram is made for the positions from 40° to 90° on the same chart of the pole figure as illustrated in FIG. 3. Readjustment of the X-ray tube is necessary for every target change for this method also.

The present invention has as a primary object removal of the described drawback of the troublesome operation necessary in conventional practice, and assures successful consecutive measurements, described hereinafter, with a common single X-ray tube in a very short time and without reduction in the accuracy of the result obtained.

The combination of metallic elements for the target may vary according to the object of the particular measurement; for example, for measurement of residual stress of iron and steel, a Cr-Co alloy target is employed, and for X-ray pole figure measurement, an Ag-Fe or Mo-Fe target is used. In addition to the two-elements alloy target, described above, the alloy target can have more

than two elements according to this invention. For example, for an X-ray tube with a target made of more than two metallic elements, different characteristic X-rays, corresponding to all individual metallic elements, can be irradiated at one time, and can be selectively applied to the specimen to be inspected by joint use of a scintillation counter or a proportional counter and a pulse height analyzer.

An embodiment of this invention is as described hereunder.

FIG. 2 is a longitudinal cross-sectional view of the X-ray tube comprised of a sealing glass tube **5**, an X-ray beam aperture **6**, heater leads **7** extending through the glass tube **5**, a target **8** on an anode **9**, which in turn is on an anode base **10** having an inlet and outlet **11** for anode cooling water, and a shield **12** over the heater and target. The space **12** inside the X-ray tube, is kept under a vacuum.

FIG. 4 shows a roentgenogram on the same film on which are represented diffractions at two different crystal planes **310** and **211** of pure iron, caused by the application of X-rays generated by an X-ray tube wherein an alloy target made of Cr-Co elements (ratio of the mixture 1:1) is employed. The outer pair of dark and light diffraction rings and the inner pair of such rings represent the double rings **211** and **310** caused by chromium $K\alpha_1$ and $K\alpha_2$ characteristic X-rays and by cobalt-$K\alpha_1$ and $K\alpha_2$ characteristic X-rays respectively.

Other than the above described example, an alloy target of Mo-Fe and Co-Fe, etc. of the two-element type can be used, and for a three-element type target, a combination of Co-Cu-Fe is recommended as an embodiment of this invention.

What is claimed is:

1. In a system for making an X-ray analysis of a specimen by means of at least two characteristic X-rays and having a specimen which can be analyzed by the characteristic X-rays from at least two metals and positioned at one position in said system for movement about that position, the improvement comprising a sealed reflection type X-ray tube fixed at a second position in said system for emitting a beam of X-rays in a fixed direction toward said one position, said X-ray tube having a target of an alloy taken from the group consisting of Mo-Fe, Cr-Co, Fe-Ag and Co-Cu-Fe.

2. The improvement as claimed in claim **1** in which the target is an alloy of Cr-Co in a ratio of 1:1.

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