Feb. 14, 1950 L. K. FREVEL 2,497,543

DEFLECTING AND FOCUSING MEANS FOR X-RAYS

Filed Sept. 19, 1946

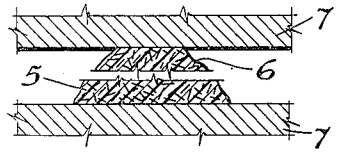


Fig. 1

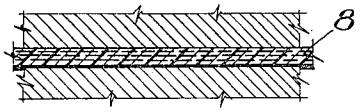


Fig. 2

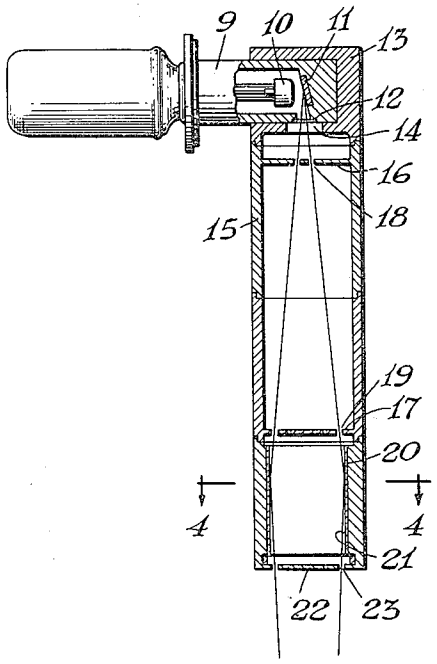


Fig. 3

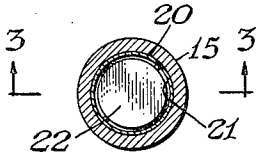


Fig. 4

INVENTOR.
Ludo K. Frevel
BY
Griswold & Burdick
ATTORNEYS

Patented Feb. 14, 1950 2,497,543

UNITED STATES PATENT OFFICE

2,497,543

DEFLECTING AND FOCUSING MEANS FOR X-RAYS

Ludo K. Frevel, Midland, Mich., assignor to The Dow Chemical Company, Midland, Mich., a corporation of Delaware

Application September 19, 1946, Serial No. 697,934

6 Claims. (Cl. 250—105)

1

This invention relates to a medium for deflecting X-rays and to a condenser for focusing X-rays using the medium.

It has long been realized that efficient means for deflecting and focusing X-rays would be desirable, both in X-ray therapy and X-ray spectroscopy. Thus, a convergent X-ray beam, such as would be produced by a condensing lens, should be highly advantageous in deep-therapy work. Likewise, a focusing device, by concentrating X-rays which would otherwise be lost, should materially increase sensitivity in X-ray spectroscopy.

Simple deflection of X-rays may, of course, be accomplished by means of plane single crystals, such as those of sodium chloride. X-ray focusing has been attempted by means of bent single crystals, but the amount of bending which can be achieved is quite limited. Consequently, only a small solid angle of a divergent X-ray beam can be subtended by the bent crystal and hence only a minute fraction of the beam brought to a focus. In addition, defects in the crystal induced by bending frequently cause troublesome diffraction "ghosts."

In view of these considerations, it is an object of the present invention to provide an inexpensive medium for deflecting X-rays which may be simply prepared from readily available materials. Another object is to provide a deflection medium which may be easily shaped to any desired curve, including a full cylinder, so as to subtend a large part of a divergent X-ray beam and thus form an efficient X-ray "lens." A further object is to provide a simple apparatus for producing a hollow convergent beam of monochromatic X-rays.

According to the invention, an X-ray deflection medium is prepared by forming a smooth-surfaced body of amorphous material having embedded therein thin flakes of a crystalline substance, such flakes being oriented parallel to the surface of the body. Conveniently, the medium is produced in the form of a thin flexible sheet which may be curved in any desired manner.

So far as known, there may be used any amorphous material which can be formed into a compact body, the term "amorphous" referring to the fact that the material shows practically no diffraction pattern to X-rays. Amorphous organic plastics, particularly synthetic resinous thermoplastics such as polystyrene and ethyl cellulose, are preferred because of the ease with which they may be shaped by molding.

The crystalline material employed in the invention should, of course, be one which can readily be converted to the form of thin flakes. In general, flakes of inorganic crystalline substances characterized by micaceous cleavage are preferred because they are most easily oriented parallel to the surface of the amorphous material by a simple molding operation. The term "micaceous cleavage" refers to the nearly perfect basal cleavage exhibited by the micas and other minerals, by virtue of which these substances are separable into very thin leaves. Typical of such substances are mica, talc, mercurous chloride, mercurous iodide, cadmium iodide, molybdenite, yellow lead monoxide, and graphite.

In making the X-ray deflection medium, the amorphous material, conveniently an organic thermoplastic, e. g. polystyrene, and the crystalline material, e. g. flake molybdenite or graphite, are ground separately and then mixed together thoroughly. The proportion of crystalline material is not critical, but should be as high as is consistent with maintaining good molding qualities. The mixture is then molded under heat and pressure in such manner as to cause a high degree of lateral flow in order to orient the flakes parallel to the surface of the molding. The resulting product, after removal from the cooled mold, is ready to be used.

Since all flakes in the molded piece are oriented parallel to the surface, the piece acts, when exposed to X-rays, like a single crystal with respect to the crystal plane parallel to the surface of the molding. A part of the beam of X-rays falling obliquely on the surface is diffracted in accordance with Bragg's law. By curving the surface of the piece concavely, convergence of part of the incident X-ray beam may be produced in a manner quite analogous to the concentration of light by a concave mirror.

The invention may be further explained with reference to the accompanying drawing, in which

Fig. 1 is a fragmentary view of a molding press in which a polystyrene-graphite mixture has been placed, the body of the mixture being shown in broken line to indicate that it has considerable height.

Fig. 2 is a view of the press after molding;

Fig. 3 is a vertical view, partly in section, of apparatus for producing a convergent monochromatic X-ray beam using a cylindrical X-ray condenser according to the invention, the section being taken along the line 3—3 of Fig. 4; and

Fig. 4 is a horizontal section of the same apparatus, taken along the line 4—4 in Fig. 3.

In the procedure illustrated in Fig. 1, a mixture of equal parts by weight of ground polystyrene 5 and finely-divided flake molybdenite 6 is loaded between opposing flat plates 7 of a compression molding press in the form of a loose mass in which the molybdenite flakes are in random orientation (Fig. 1). The plates are heated to a temperature of 80° to 125° C. and forced together to mold the mixture between them. Under the applied pressure, the material flows laterally, the action of the flowing plastic serving to turn the molybdenite flakes in the direction of flow. When compression is completed (Fig. 2), there is obtained a thin sheet 8 of material in which all the flakes are oriented parallel to the surface of the sheet. In general, it is desirable, in making a sheet of 0.010 inch in thickness, to start with a mass at least 0.5 inch in height.

If the flakes 6 are not perfectly oriented in the first molding, the sheet 8 may be cut into strips, which can then be superposed and remolded.

The final molded sheet, after trimming, may be rolled into cylindrical form and used as a focusing medium to produce a convergent monochromatic X-ray beam in the apparatus of Figs. 3 and 4.

In this apparatus, X-rays of a whole band of wave-lengths are generated in a conventional high-vacuum X-ray tube 9, such as a type AEG-50, having a heated cathode 10, grounded target 11, and beryllium window 12 through which the rays issue as a divergent beam. The lower end of the tube 9 fits into a cylindrical adapter 13 in one side of which is an opening 14 concentric with and larger than the X-ray window 12.

Mounted on the adapter is an elongated cylindrical lead-alloy tube 15 co-axial with the window 12 and opening 14, the tube being made in three interfitting sections, as shown, for convenience in manufacture. In the upper portion of the tube 15 are two transverse lead-alloy shields 16 and 17 spaced from the window 12 and from each other. Narrow annular slits 18 and 19 are cut in the shields co-axial with the window 12. The slits are of such diameters as to fall in the surface of a divergent cone including the window 12 and having its apex at the target 11. Below the lower slit 19, the wall of the tube 15 is thickened inwardly to provide a cylindrical surface 20 which is co-axial with and intercepts the surface of the cone defined by the slits 18 and 19.

A polystyrene-oriented-molybdenite-flake flexible X-ray deflecting sheet 21, prepared as previously described, is rolled into a cylinder and secured into the tube 15 so as to fit snugly against the cylindrical surface 20. The tube 15 is closed at its lower end by a lead-alloy shield 22 in which is cut a narrow annular slit 23 of diameter substantially equal to that of the slit 19.

In operation, a divergent beam of X-rays issues from the window 12. Much of the radiation is absorbed by the shields 16 and 17, but a part passes through the slits 18 and 19 which serve to define a hollow divergent conical beam. This X-ray beam, which includes rays of a band of wavelengths, falls on the cylindrical deflecting surface 21. Part of the rays are scattered and absorbed in the tube 15 and shield 22, but a portion is diffracted or reflected in the form of a convergent conical beam, which is sharpened by the slit 23. This diffracted portion is of essentially monochromatic X-rays, the wavelength of which is fixed by the conical angle of the divergent beam and the lattice constants of the flake molybdenite in the medium 21.

The apparatus of Figs. 3 and 4 thus effectively deflects a portion of a divergent X-ray beam and focuses it into a hollow convergent beam of monochromatic rays which reaches a focus at a point below the tube 15. Different wavelengths of the convergent beam may be secured by increasing or decreasing the length of the tube 15 from the window 12 to the deflecting cylinder 21 and correspondingly changing the diameters of the slits 18, 19, and 23 to alter the conical angle of the X-ray beam. Alternatively, the deflecting sheet 21 can be removed and a new sheet containing a different crystalline flake material substituted.

The apparatus shown may be used as a source of a convergent X-ray beam in deep therapy, in which use it has the advantage that, by suitably choosing the wavelength of the convergent beam, the softer X-rays, which produce serious erythema, can be eliminated.

The foregoing description is illustrative rather than strictly limitative, the invention being coextensive in scope with the following claims.

What is claimed is:

1. In combination with a source of a divergent X-ray beam, a hollow cylinder formed of an amorphous organic plastic having embedded therein thin flakes of an inorganic crystalline substance characterized by micaceous cleavage, such flakes being oriented parallel to the surface of the cylinder, and a support for the cylinder disposed to maintain the axis of the cylinder in line with the X-ray source.

2. Apparatus for providing a hollow convergent beam of monochromatic X-rays comprising: a source of a divergent X-ray beam; a shield spaced from the source and having therein an annular slit co-axial with the divergent beam, such shield acting to restrict the beam to the form of a hollow divergent cone; and an X-ray condenser comprising a hollow cylindrical formed of an amorphous organic plastic having molded therein thin flakes of an inorganic crystalline substance characterized by micaceous cleavage, such flakes being oriented parallel to the surface of the cylinder, and a support for the cylinder disposed to maintain the cylinder with its axis co-axial with the hollow divergent cone of X-rays and so spaced from the shield that the inside cylindrical surface intercepts the conical X-ray beam.

3. Apparatus for providing a convergent X-ray beam comprising: a source of a divergent X-ray beam, a mounting having thereon a hollow right-circular cylindrical X-ray deflector support with its axis in line with the X-ray source and so spaced from the source that the inside surface of the support intercepts the X-ray beam, and an X-ray deflector element lining the support and comprising a thin flexible sheet of an amorphous organic plastic having embedded therein thin flakes of an inorganic crystalline substance characterized by micaceous cleavage, such flakes being oriented parallel to the surface of the sheet.

4. Apparatus for providing a hollow convergent beam of mono-chromatic X-rays comprising: a source of a hollow divergent conical X-ray beam, a mounting having thereon a hollow right-circular cylindrical X-ray deflector support co-axial with the source and so spaced from the latter that the inside surface of the support intercepts the hollow conical X-ray beam, and

an X-ray deflector element comprising a thin flexible sheet molded of an amorphous organic plastic having embedded therein thin flakes of an inorganic crystalline substance characterized by micaceous cleavage, such flakes being oriented parallel to the surface of the sheet, the said element being curved to cylindrical form and removably lining the deflector support.

5. Apparatus according to claim 4 wherein the organic plastic is polystyrene and the inorganic substance is graphite.

6. Apparatus for providing a convergent X-ray beam comprising: an X-ray tube having an X-ray transparent window therein; a hollow cylindrical X-ray opaque tube mounted on the X-ray tube co-axial with the window thereof, a pair of X-ray opaque shields mounted transversely in the tube spaced from the window and from each other, each shield having therein an annular slit co-axial with the tube, the slits being of such diameters as to restrict the X-ray beam issuing from the window to the form of a hollow divergent cone, a cylindrical X-ray deflector support surface formed in the tube co-axial therewith and at a point more remote from the window than the shields in position to intercept the cone defined by the slits, and an X-ray deflector element comprising a thin flexible sheet molded of an amorphous organic plastic having embedded therein thin flakes of an inorganic crystalline substance characterized by micaceous cleavage, such flakes being oriented parallel to the surface of the sheet, the said element being curved to cylindrical form and removably lining the deflector support.

LUDO K. FREVEL.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,208,474	Caldwell	Dec. 12, 1916
1,556,990	Henry	Oct. 13, 1925
1,865,441	Mutscheller	July 5, 1932
1,993,058	Hahn	Mar. 5, 1935
2,265,226	Clewell et al.	Dec. 9, 1941
2,279,762	Scott et al.	Apr. 14, 1942

FOREIGN PATENTS

Number	Country	Date
382,518	Great Britain	Oct. 27, 1932
506,022	Great Britain	May 22, 1939
601,545	France	Dec. 1, 1925

OTHER REFERENCES

"A Variable Temperature X-Ray Powder Camera," by W. H. Barnes and W. F. Hampton, Review of Scientific Instruments, vol. 6, November 1935, pp. 342–344.