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R. M. FISHER ET AL

3,033,984

APPARATUS FOR INCREASING THE ENERGY OF X-RAYS

Filed Feb. 17, 1959

2 Sheets-Sheet 1

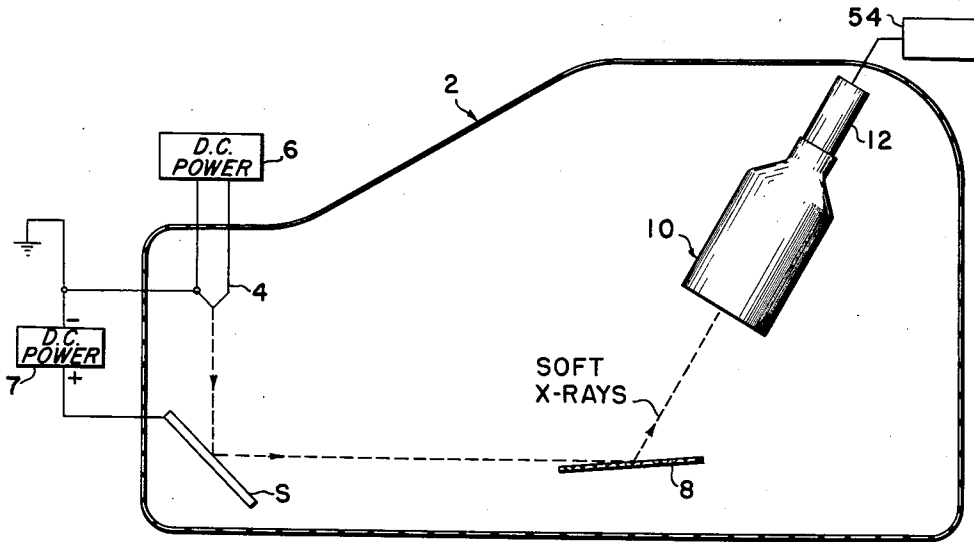


FIG. 1

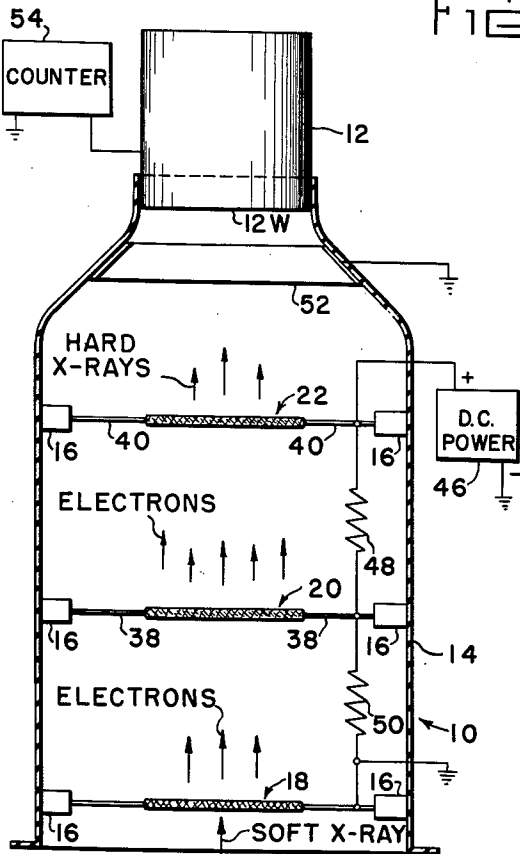


FIG. 2

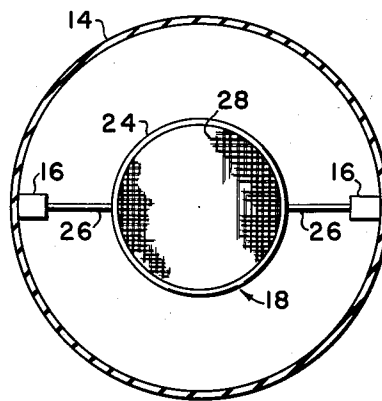


FIG. 3

INVENTORS:
ROBERT M. FISHER &
JEROME E. HOLLIDAY
by *Donald H. Dalton*
attorney

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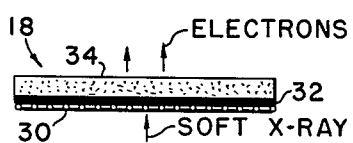


FIG. 4

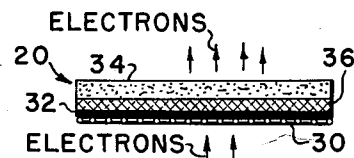


FIG. 5

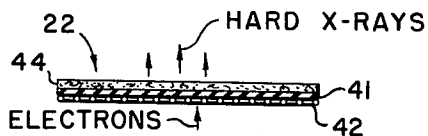


FIG. 6

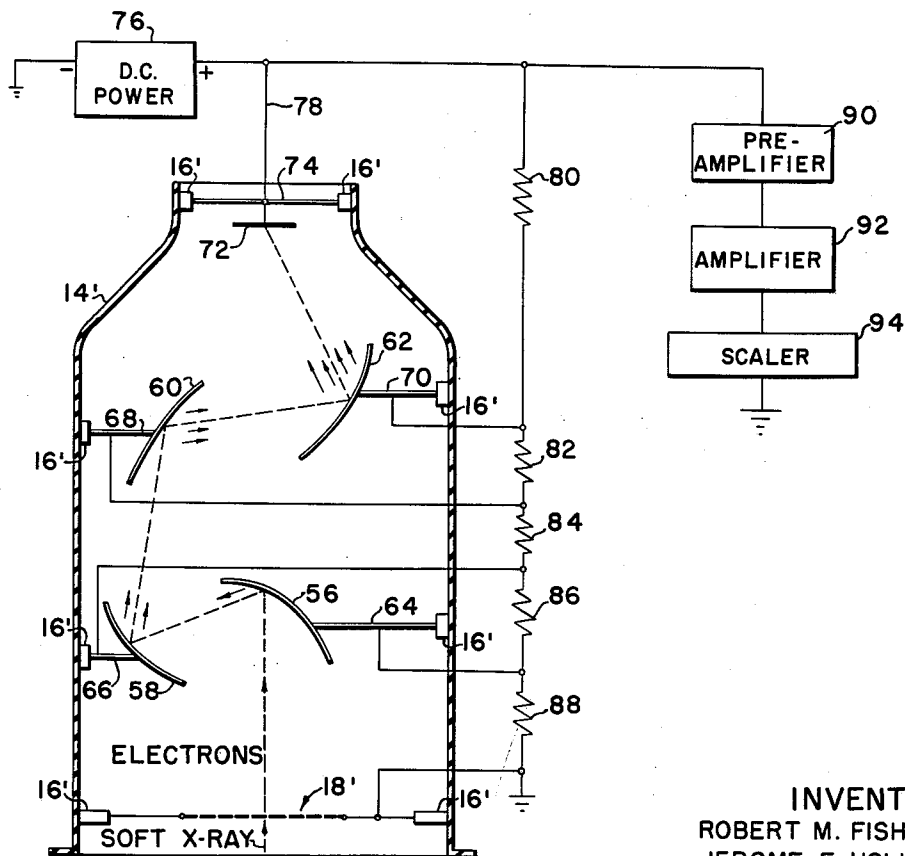


FIG. 7

INVENTORS:
ROBERT M. FISHER &
JEROME E. HOLLIDAY
by *Donald H. Dalton*
attorney

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APPARATUS FOR INCREASING THE ENERGY OF X-RAYS

Robert M. Fisher, Wilkins Township, Allegheny County, and Jerome E. Holliday, Monroeville, Pa., assignors to United States Steel Corporation, a corporation of New Jersey

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This invention relates to apparatus for increasing the energy of X-rays and more particularly for increasing the energy of X-rays having a wavelength of between 10 and 100 Å. (soft X-rays) so that conventional X-ray spectroscopic techniques may be used to detect elements whose characteristic K X-rays are in this range of wavelengths. At the present time X-ray spectroscopic analysis of very low atomic numbered elements such as carbon, oxygen and nitrogen is difficult because of the lack of a suitable detector for the "soft" (low energy) X-ray wavelengths emitted by these elements. The characteristic K X-rays from carbon, for example, have a wavelength of 43.64 (284 electron volts) as compared to 8.5 Å. (1559 electron volts) for aluminum which is the present limit for X-ray fluorescence methods of analysis. Standard X-ray detectors such as Geiger, proportional or scintillation counters cannot be used because these units have windows of plastic or metal foil which are completely opaque to X-rays having a wavelength above 10 Å. (Angstrom units).

It is therefore an object of our invention to provide apparatus for increasing the energy of X-rays to permit detection thereof with standard equipment.

Another object is to provide apparatus for use in the spectroscopic analysis of materials containing elements whose characteristic K X-rays have long wavelengths and low energy.

These and other objects will be more apparent after referring to the following specification and attached drawings, in which:

FIGURE 1 is a schematic diagram of a conventional X-ray spectrometer with the energy amplifier of our invention incorporated therein;

FIGURE 2 is a cross-section of the preferred embodiment of our energy amplifier fitted upon a Geiger tube;

FIGURE 3 is a plan view of a typical grid within the amplifier;

FIGURE 4 is a cross-section of the first grid;

FIGURE 5 is a cross-section of an intermediate grid;

FIGURE 6 is a cross-section of the final grid; and

FIGURE 7 is a cross-section of another embodiment of our invention.

Referring more particularly to FIGURES 1 to 6 of the drawings, reference numeral 2 indicates the airtight chamber of an X-ray spectrometer. A specimen S is mounted within the chamber 2 adjacent a filament 4. Power is supplied to the filament 4 from D.C. power source 6. The filament 4 and specimen S are connected through a D.C. power source 7. The specimen S is excited by cathode rays from filament 4 so that the specimen S emits characteristic K X-rays. The X-rays from the specimen S are diffracted by grating 8 into an energy amplifier 10 which is physically attached to a Geiger counter 12 so that the two move as a unit. The chamber 2 is evacuated when the analysis is being made to a pressure preferably of about 10^{-5} mm. of mercury. The parts so far described, except for the energy amplifier 10, make up a conventional X-ray spectrometer similar to that described on pages 348–356 of Proceedings of Physical Society, volume 67B, 1954. The amplifier 10 includes a glass envelope or shell 14 and porcelain insulators 16 which support grid assemblies 18, 20, 22 within the envelope 14.

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Grid 18 (FIGS. 3 and 4) includes a ring 24 connected by means of supports 26 to the insulators 16. The ring 24 is made of a metal having high electrical conductivity such as copper or brass. Mesh 28, preferably copper mesh of size 200, is fixed to the ring 24. Upon the wires 30 making up the mesh 28 is deposited approximately 20 Å. of carbon 32 upon which is evaporated 2500 Å. of potassium chloride 34. Sodium chloride or lithium chloride may be used in place of the potassium chloride. Grid 20 is constructed in the same manner as grid 18 except that there is only 600 Å. of potassium chloride and a layer of aluminum 36 approximately 100 Å. thick is evaporated on top of the carbon 32 and the potassium chloride 34 is evaporated on top of the aluminum as shown in FIGURE 5. The grid 20 is fastened to insulator 16 by means of supports 38. Grid 22 is fastened to insulator 16 by means of supports 40. The grid 22 is constructed in the same manner as grids 18 and 20 except that a supporting film 41 is provided on its mesh 42 with a layer of gold 44 between approximately 200 and 400 Å. thick being evaporated on the film 41. The sole purpose of the film 41 is to support the gold and it may be made of carbon, cellulose nitrate or any suitable plastic material. Copper, platinum, chromium or aluminum may be used in place of the gold. A D.C. power source 46 has its positive terminal connected to grid 22 which in turn is connected through resistor 48 to grid 20 and through resistor 50 to grid 18. Grid 18 is also connected to ground. The preferred value of resistor 48 is 30 megohms and that of resistor 50 is 10 megohms. Power supply 46 is preferably capable of maintaining a potential of approximately 10,000 volts on grid 22. A metallic grid 52 made of conducting material, such as nickel, is provided on the end of envelope 14 adjacent grid 22. Grid 52 is grounded and isolates the Geiger counter 12 from the electrical charge. The end of envelope 14 adjacent grid 52 is shaped to receive the Geiger counter 12 which is so positioned that its window 12W is exposed to the interior of envelope 14. The Geiger counter 12 is connected to a conventional counting device 54.

The operation of our device is as follows: Low energy X-ray photons (soft X-rays) from specimen S are directed by grating 8 into the mouth of amplifier 10 where they impinge upon grid 18. Each X-ray photon causes approximately one electron to be ejected from the KCL layer on grid 18. The electrons are accelerated toward grid 20 because grid 20 is at a positive voltage with respect to grid 18. The aluminum layer 36 changes the angle at which the electron is traveling so that its path of travel is lengthened through grid 20 and the number of secondary electrons is thereby increased. The aluminum also prevents charging of the KCL. Each electron striking grid 20 will cause from one to five additional electrons to be emitted by grid 20. The positive potential on grid 22 accelerates the electrons toward grid 22 and as the electrons strike the gold on grid 22 hard X-rays are emitted therefrom. These X-rays possess energy up to 7,500 electron volts (75% of the voltage of power source 46) and therefore readily penetrate window 12W in counter 12. The X-rays are then counted by counter 54. For simplicity only two KCL grids have been shown but, because only approximately one X-ray is produced for each ten electrons striking grid 22 and because of the necessity of having a large count above background, sufficient KCL grids should be provided so that on the average each soft X-ray entering the system will result in a count.

The above described embodiment of our invention may be modified by the omission of gold plated grid 22. In this case, the Geiger tube will count electrons rather than hard X-rays. An acceleration potential of approximately

15,000 volts must be provided to give the electrons sufficient energy to penetrate window 12W.

FIGURE 7 discloses another embodiment of our invention in which reference numeral 14' indicates a glass envelope having glass insulators 16' mounted thereon. A grid 18' is supported in the glass envelope 14' by insulators 16' and is identical to grid 18 in FIGURE 2. Dynodes 56, 58, 60 and 62 are connected to insulators 16' by means of supports 64, 66, 68 and 70, respectively. The dynodes are provided with a high secondary electron yield surface such as copper—4% beryllium or silver magnesium. An anode 72 is held in place in the end of the glass envelope 14' by means of support 74 and insulators 16'. A D.C. power source 76 has its negative terminal grounded and its positive terminal connected to anode 72 through wire 78, to dynode 62 through resistor 80, to dynode 60 through resistor 82, to dynode 58 through resistor 84, to dynode 56 through resistor 86, and to grid 18' through resistor 88. Grid 18' is also connected to ground. This provides a voltage dividing circuit in which an accelerating potential is maintained between successive electrodes. The D.C. voltage supply 76 preferably has a potential of 1000 volts with resistors 80, 82, 84, 86 and 88 so proportioned that the accelerating potential between successive electrodes is approximately 200 volts. Connected to anode 72 are conventional elements including a preamplifier 90, a high gain amplifier 92, and a scaler 94. The number of dynodes may be varied as required to obtain the proper correspondence between the number of soft X-rays entering the system and the output of the scaler 94.

The operation of this embodiment of our invention is as follows: X-ray photons produced as heretofore described are directed so as to impinge upon grid 18' and cause electrons to be ejected from the surface thereof. Because dynode 56 is at a positive potential with respect to grid 18', the electrons ejected from grid 18' will be accelerated toward dynode 56. Each electron impinging upon dynode 56 causes from one to five secondary electrons to be emitted by dynode 56. These electrons are accelerated toward dynode 58 by positive potential on dynode 58 and when the electrons strike dynode 58 secondary emission again occurs. This process continues until the electrons, now multiplied in number, impinge upon anode 72 where they are amplified by the preamplifier 90 and the amplifier 92 and measured by the scaler 94.

In the alternative the electrons emitted by dynode 62 may be accelerated by a high potential and directed at the window of a Geiger tube in which case anode 72 would be omitted.

While several embodiments of our invention have been shown and described it will be apparent that other adaptations and modifications may be made without departing from the scope of the following claims.

We claim:

1. Apparatus for increasing the energy of X-rays and counting the same comprising a shell, means for directing X-ray photons into the entry end of said shell, means in said shell for converting said photons to electrons, means for increasing the energy of said electrons, means for converting said electrons to X-ray photons, and means for counting said last named X-ray photons.

2. Apparatus for increasing the energy of X-rays and counting the same comprising a shell, means for directing X-ray photons into the entry end of said shell, a first means in said shell for converting said photons to electrons, means for increasing the energy of said electrons, means for multiplying said electrons, means for increasing the energy of said multiplied electrons, means for converting said last named electrons to X-ray photons, and means for counting said last named X-ray photons.

3. Apparatus for increasing the energy of X-rays comprising a shell, means for directing X-ray photons into the entry end of said shell, a plurality of electron emissive grids in said shell having a coating thereon of a salt of

the class consisting of potassium chloride, sodium chloride and lithium chloride, a direct current power source having its positive terminal connected to the last of said grids, and a voltage dividing circuit electrically connecting the last of said grids to the first of said grids.

4. Apparatus for increasing the energy of X-rays comprising a shell, means for directing X-ray photons into the entry end of said shell, a plurality of electron emissive grids in said shell having a coating thereon of a salt of the class consisting of potassium chloride, sodium chloride and lithium chloride, an X-ray emissive last grid in said shell having a coating thereon of a metal of the class consisting of chromium, copper, gold, iron, nickel, vanadium, platinum and aluminum, a direct current power source having its positive terminal connected to the last of said grids, and a voltage dividing circuit electrically connecting the last of said grids to the first of said grids.

5. Apparatus for increasing the energy of X-rays comprising a shell, means for directing X-ray photons into the entry end of said shell, a photo-electron emissive first grid in said shell adjacent said entry end, said grid including a wire mesh, a coating of carbon on said wire mesh and a coating of potassium chloride on said carbon, a secondary electron emissive second grid in said shell spaced from said first grid away from said entry end, said second grid including a wire mesh, a coating of carbon on said wire mesh, a coating of aluminum on said carbon and a coating of potassium chloride on said aluminum, a direct current power source having its positive terminal connected to said second grid, means including a resistor connecting said second grid to said first grid, and means connecting said first grid to ground.

6. Apparatus for increasing the energy of X-rays comprising a shell, means for directing X-ray photons into the entry end of said shell, a photo-electron emissive first grid in said shell adjacent said entry end, said grid including a wire mesh, a coating of carbon on said wire mesh and a coating of potassium chloride on said carbon, a secondary electron emissive second grid in said shell spaced from said first grid away from said entry end, said second grid including a wire mesh, a coating of carbon on said wire mesh, a coating of aluminum on said carbon and a coating of potassium chloride on said aluminum, an X-ray emissive third grid in said shell spaced from said second grid away from said entry end, said third grid including a wire mesh, said wire mesh having a coating thereon of a metal of the class consisting of chromium, copper, gold, iron, nickel, vanadium, platinum and aluminum, a direct current power source having its positive terminal connected to said third grid, means including a resistor connecting said third grid to said second grid, means including a resistor connecting said second grid to said first grid, and means connecting said first grid to ground.

7. Apparatus for increasing the energy of X-rays comprising a shell, means for directing X-ray photons into the entry end of said shell, a photo-electron emissive first grid in said shell adjacent said entry end, said grid including a wire mesh, said wire mesh having a coating of carbon thereon and a coating of potassium chloride on said carbon, a secondary electron emissive second grid in said shell spaced from said first grid away from said entry end, said second grid including a wire mesh, said wire mesh having a coating of carbon thereon, a coating of aluminum on said carbon and a coating of potassium chloride on said aluminum, an X-ray emissive third grid in said shell spaced from said second grid away from said entry end, said third grid including a wire mesh, said wire mesh having a coating thereon of a metal of the class consisting of chromium, copper, gold, iron, nickel, vanadium, platinum and aluminum, a metallic film on the outside of said shell adjacent the exit end thereof, a direct current power source having its positive terminal connected to said third grid, means including a resistor connecting said third grid to said second grid, means including a resistor connecting

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said second grid to said first grid, and means connecting said first grid to ground.

8. Apparatus for analyzing materials containing elements comprising means for exciting a specimen by cathode rays to emit characteristic X-ray photons therefrom, a shell, means for directing said X-ray photons into the entry end of said shell, means in said shell for converting said photons to electrons, means for increasing the energy of said electrons, means for multiplying said electrons, means for increasing the energy of said multiplied electrons, means for converting said last named electrons to X-ray photons, and means for counting said last named photons.

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