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Terasawa

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[45] **March 20, 1973**

[54] **APPARATUS FOR PRODUCING X-RAYS FROM AN ELECTRIC INSULATOR**

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[22] Filed: **Nov. 1, 1971**

[21] Appl. No.: **194,379**

[52] **U.S. Cl.**.....**313/55,** 313/330

[51] **Int. Cl.**.....**H01j 35/08**

[58] **Field of Search**.....313/55, 330

Primary Examiner—Roy Lake
Assistant Examiner—Darwin R. Hostetter
Attorney—Solon B. Kemon et al.

[57] **ABSTRACT**

Apparatus for producing X-rays from an electric insulator. Two electrodes are disposed to contact the electric insulator. One electrode has a larger contact area with the insulator than that of the other. When a high D.C. or A.C. voltage is applied across the electrodes, the electric field becomes stronger in the portion of the insulator near the contact section with the small electrode, resulting in the production of X-rays from the vicinity of the contact section of the insulator with the small electrode.

14 Claims, 13 Drawing Figures

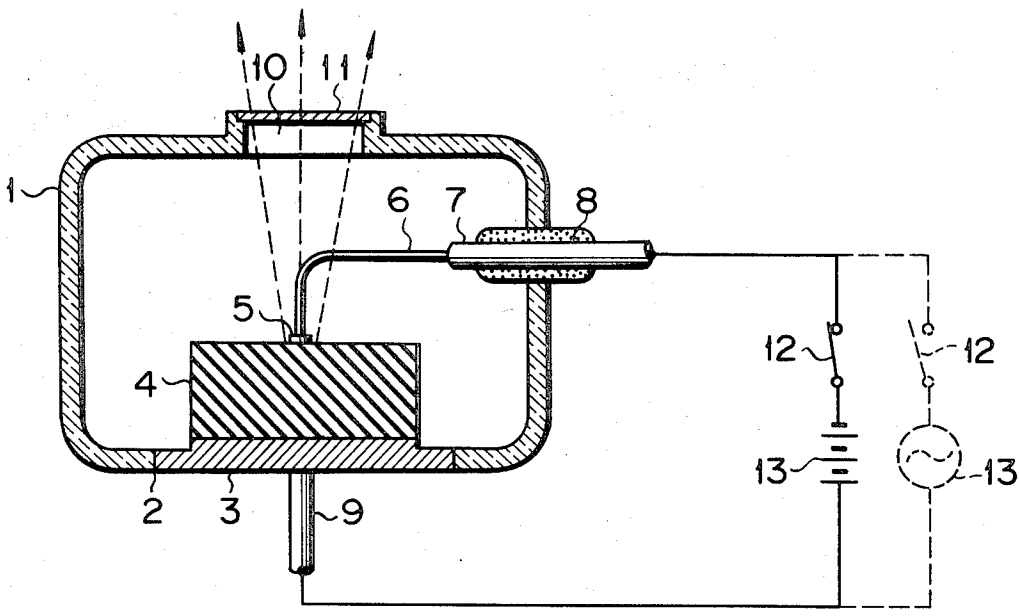


FIG. 1

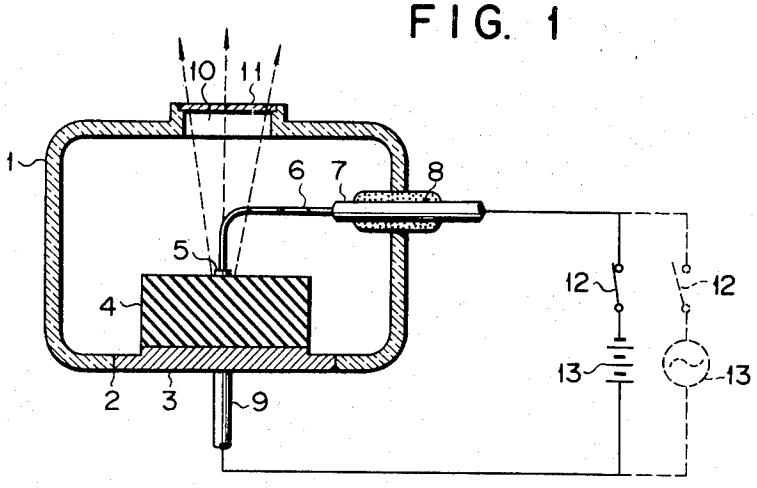


FIG. 2

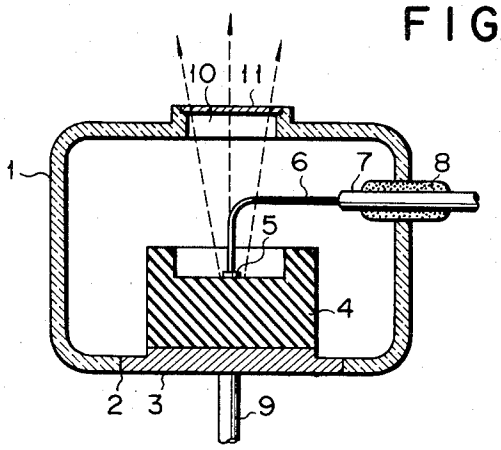


FIG. 3

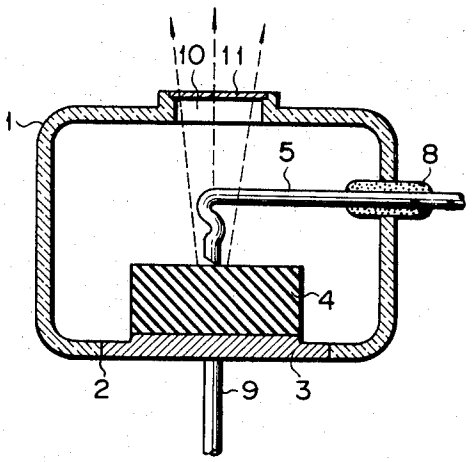


FIG. 4

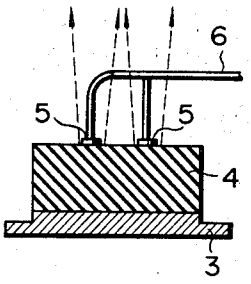


FIG. 5

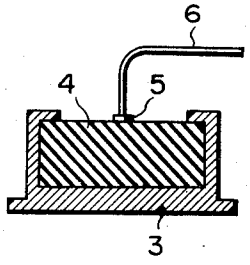


FIG. 6A

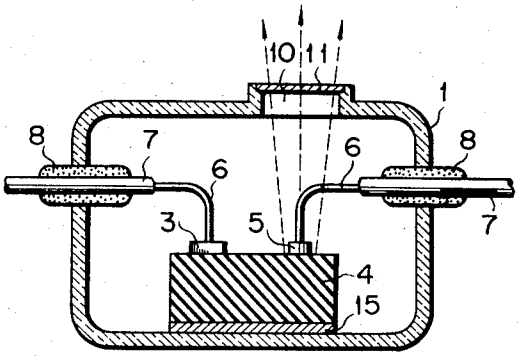


FIG. 6B

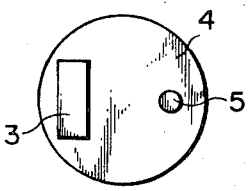


FIG. 7

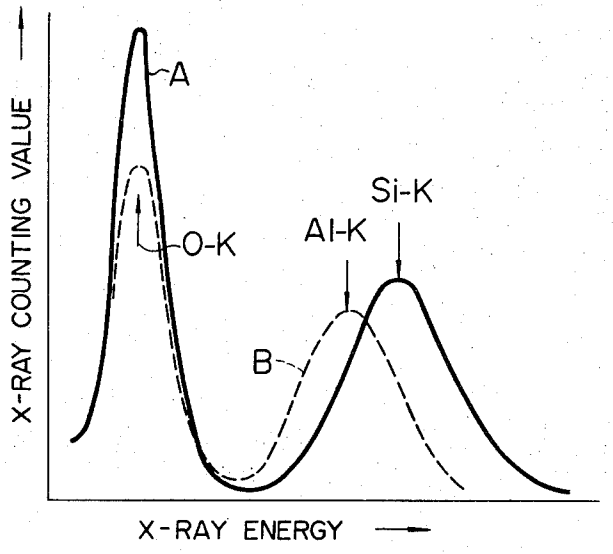

X-RAY COUNTING VALUE
A
O-K
Al-K
Si-K
B
X-RAY ENERGY

FIG. 8

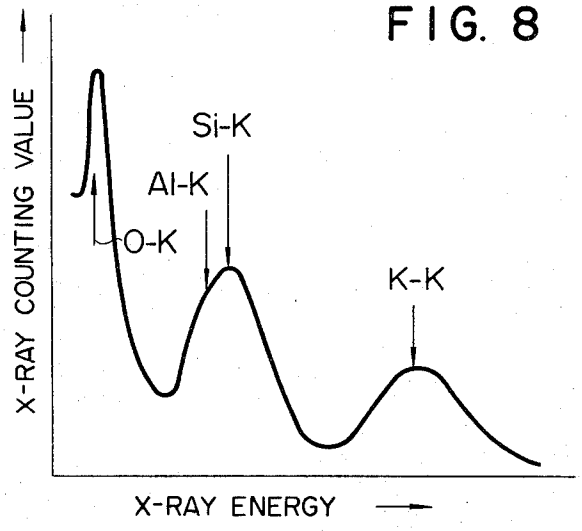

X-RAY COUNTING VALUE
Si-K
Al-K
O-K
K-K
X-RAY ENERGY

FIG. 9

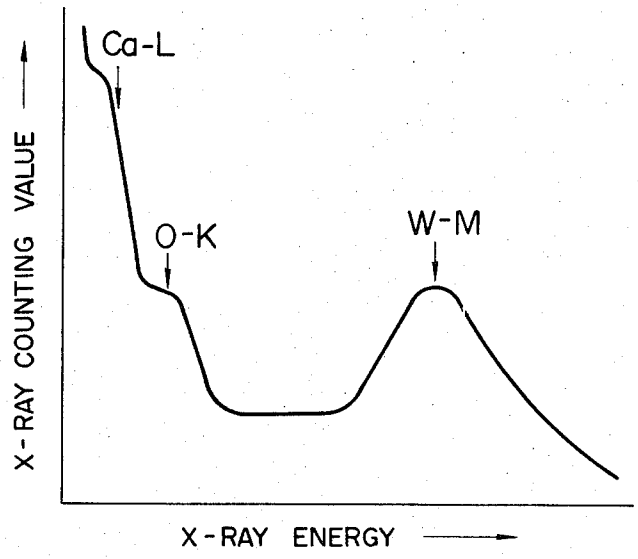

Ca-L
O-K
W-M
X-RAY COUNTING VALUE
X-RAY ENERGY

FIG. 10

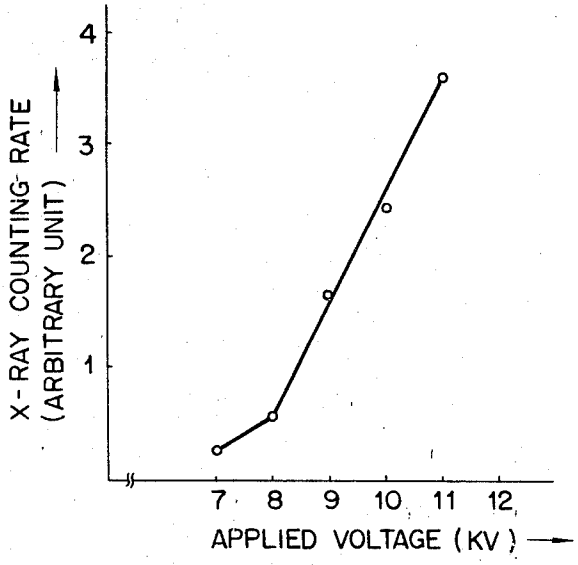

4
3
2
1
X-RAY COUNTING RATE
(ARBITRARY UNIT)
7
8
9
10
11
12
APPLIED VOLTAGE (KV)

FIG. 11

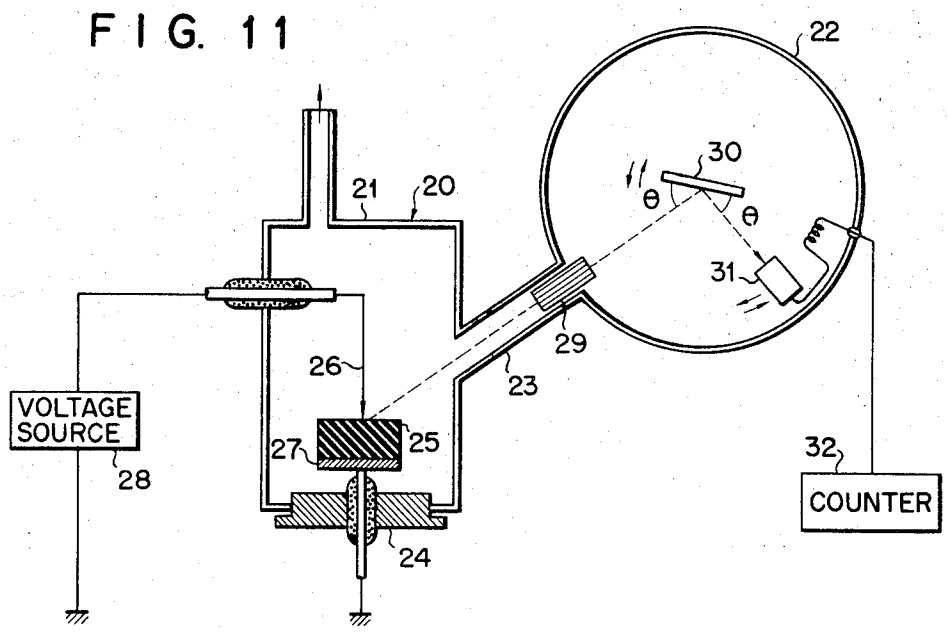
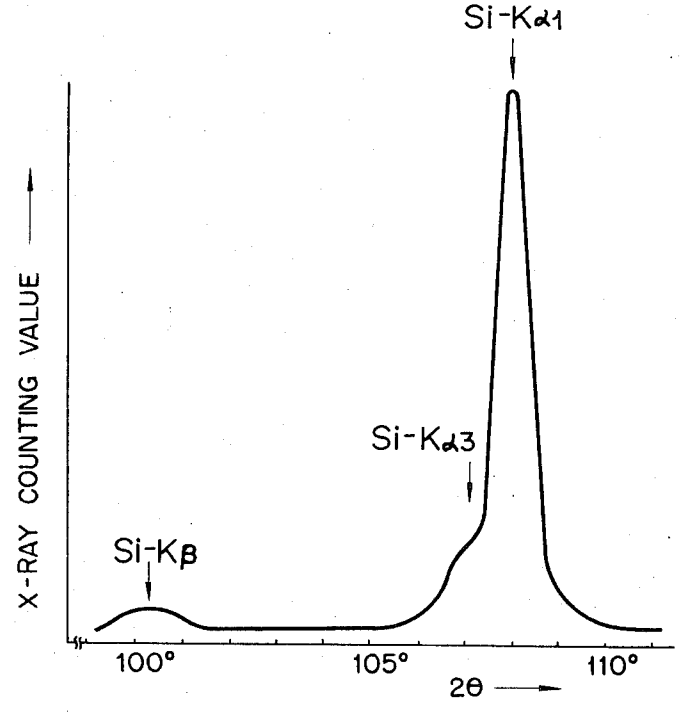

22
30
θ
θ
21
20
31
29
26
23
VOLTAGE SOURCE
28
27
25
32
COUNTER
24

FIG. 12


Si-Kα1
Si-Kα3
Si-Kβ
X-RAY COUNTING VALUE
100°
105°
110°
2θ

APPARATUS FOR PRODUCING X-RAYS FROM AN ELECTRIC INSULATOR

This invention relates to apparatus for the production of X-rays and particularly to apparatus for producing X-rays from an electric insulator.

Among the conventional apparatus for the production of X-rays is known an X-ray tube to emit X-rays by accelerating electrons emitted from a heated filament at a high voltage so as to allow the electrons to collide with an anticathode or a target formed of a conductor such as copper, chrome, tungsten or the like, and by exciting atoms constituting the anticathode.

X-ray tube of this type has, however, the serious disadvantages as mentioned below. Parts such as filament, target and vacuum vessel to seal these parts are required, resulting in the difficult manufacture of the tube and in the relatively large size of the entire assembly. A high power source is needed for the filament. The X-ray tube was difficult to maintain and inspect.

The object of this invention is to provide apparatus for producing X-rays, which has a relatively small size, a simple construction, a long lifetime, an easy treatment, and a low manufacturing cost.

In accordance with this invention there is provided apparatus for producing X-rays comprising an electric insulator; and first and second electrodes which contact the insulator and are spaced apart from each other; the contact area of the first electrode with the insulator being smaller than that of the second electrode, thereby emitting X-rays from portion of said insulator in the vicinity of said first electrode upon application of a voltage having a predetermined magnitude across the first and second electrodes.

This invention can be more fully understood from the following detailed description when taken in conjunction with reference to the appended drawings, in which:

FIG. 1 is a schematic sectional diagram of apparatus for the production of X-rays according to an embodiment of the invention;

FIG. 2 is a schematic sectional diagram of apparatus for the production of X-rays having an electric insulator of a shape different from that of FIG. 1;

FIGS. 3 to 5 illustrate modifications of electrodes of FIG. 1;

FIG. 6A shows apparatus according to another embodiment of this invention;

FIG. 6B indicates the top of the electric insulator of FIG. 6A;

FIGS. 7 to 9 represent the spectra of X-rays obtained from various electric insulators;

FIG. 10 is a characteristic curve for X-ray intensity vs. applied voltage;

FIG. 11 is a schematic diagram of an X-ray analyzer employing the apparatus of this invention; and

FIG. 12 indicates the spectrum of X-rays obtained from quartz glass according to the device of FIG. 11.

In FIG. 1 there is shown a vessel made of glass components and thickness of which are considered to substantially prevent the transmission of X-rays. Alternatively, the vessel may be made of a metal such as copper. A hole 2 of a predetermined diameter is formed in the bottom portion of vessel 1. A plate electrode of about 20 to 30 mm in diameter and made of copper, for example, is inserted into the hole 2 and

fixed to the glass by a suitable bonding agent. An electrical insulator 4 of about 20 to 30 mm in diameter, about 1 mm in thickness and made of quartz glass (SiO_2), for example, is disposed on the upper surface of the plate electrode 3 to electrically contact with the plate electrode 3. A spot electrode 5 is disposed substantially at the center of the upper surface of the insulator 4 in close contact therewith. The spot electrode 5 of about 1 mm in diameter may be formed on the insulator 4 by vapor deposition of gold, for example. A gold wire or internal conductor 6 is soldered to the spot electrode 5. The internal conductor is in turn connected to a first external electrode 7 secured to the vessel 1 with a sealing alloy containing iron, nickel and cobalt, for example. When the vessel 1 is made of metal, the external conductor 7 is secured to the vessel 1 by a suitable insulation material. A second external conductor 9 is attached to the lower surface of the plate electrode 3. A window 10 is formed in the top portion of the vessel 1 facing the spot electrode 5 on the insulator 4 to substantially transmit X-rays therethrough. To the window 10 there is fixed a relatively thin film of a material having a good transmissibility of X-rays such as beryllium, aluminum, mica, polypropylene, mylar or the like. Across the first and second external conductors 7 and 9 there are connected a power source 13 and a switch 12 in series. The power source 13 may be of either D.C. as shown by solid line or A.C. as shown by dashed line.

In such construction as mentioned above, when across the plate electrode 3 and the spot electrode 5 there is impressed a predetermined high A.C. or D.C. voltage, for example, a D.C. voltage of about 10 kilovolts in such a manner that the plate electrode 3 is positive while the spot electrode 5 is negative as shown, characteristic X-rays determined by constituent elements of the insulator 4 are emitted from a portion of the insulator 4 in the vicinity of the spot electrode 5 where a high electric field region is formed. The D.C. voltage may be applied across the two electrodes 3 and 5 with the polarity opposite to that shown in the figure. In this case, however, there is a slight decrease in the emitted X-rays. The applied voltage may be A.C. voltage of about 10 kilovolts.

FIGS. 7 to 9 show respectively the spectrum of the X-rays emitted from the insulator 4 by the apparatus of this invention. In FIG. 7, curve A represents the spectrum of quartz glass (SiO_2) and curve B the spectrum of alumina (Al_2O_3). The measurement of KX-rays in this case was made by a proportional counter. As shown in the figure, the Al-K, Si-K and O-K rays peculiar to the constituent elements of the insulator were respectively verified.

FIG. 8 indicates the spectrum of mica ($KAl_2(AlSi_3O_{10})(OH)_2$). The O-K, Al-K, Si-K and K-K rays peculiar to the constituent elements of the insulator 4 were respectively verified.

FIG. 9 designates the spectrum of calcium tungstate ($CaWO_4$). As seen from the figure, the Ca-L, O-K and W-M rays were respectively verified.

FIG. 10 is a curve for X-ray intensity (the intensity of the Si-K ray of quartz glass) vs. applied voltage. It will be understood that the intensity of the X-rays emitted from the insulator is increased with the applied voltage.

As described above, X-rays are emitted from the electric insulator by applying a high voltage across the large and small electrodes in close contact with the insulator. However, a principle for the X-rays generation from the insulators still remains unknown. Presumably, electrons are accelerated and multiplied by a strong electric field generated in the vicinity of the spot electrode so that the electrons move toward the plate electrode in the interior and on the surface of the insulator.

Experiment shows that only the low-energy X-rays are produced with low applied voltage and that the high-energy X-rays tend to emit as the applied voltage increases. To excite the high-energy X-rays, a higher applied voltage is required. It seems that the theoretical elucidation of the production of X-rays is merely a question of time.

The conditions of producing X-rays according to this invention on the basis of various experiments will be described below.

1. Insulator: The insulator should be either one of electric insulators such as quartz glass, ruby, alumina, yttrium garnet, lithium niobate, calcium tungstate, mica and the like, electric insulator consisting of a mixture of powders of insulating material and conducting material, or electric insulator consisting of a metal such as aluminum or iron and an electrically insulating oxidizing film formed thereon.

2. Electrodes: One electrode **5** should be formed into a single spot electrode as shown in FIG. **1**, plural spot electrodes as shown in FIG. **4**, or a needle-shaped electrode as shown in FIG. **3**. Alternatively, the electrode may be in a line or mesh form. Another electrode **3** should have a larger contact area with the insulator than that of the spot or needle-shaped electrode **5**. That is, it is required that a steep gradient region of electric potential be formed in the surface of the insulator to produce X-rays. The large electrode **3** contacting the lower surface of the insulator may extend onto the upper surface thereof on which the small electrode **5** is disposed through the sides thereof or at least the sides thereof. Unlike the above-mentioned embodiment, it is not always necessary to sandwich the insulator **4** between the small electrode **5** and the large electrode **3**. for example, both the small electrode **5** and the large electrode **3** may be disposed on the upper surface of the insulator **4**, as shown in FIGS. **6A** and **6B**. In this case, too, a high-electric-field region is formed in a portion of the insulator in the vicinity of the small electrode **5**, thereby emitting X-rays from the portion of the insulator **4** near the small electrode **5**. In this embodiment, the insulator **4** may be fixed to the bottom of the vessel **1** with solder **15**. The large electrode **3**, like the small electrode **5**, is connected to the internal conductor **6** and the external conductor **7**. In disposing the spot or needle-shaped electrode on the insulator **4** the electrode is required to be sufficiently in close contact with the surface of the insulator **4**.

3. Applied voltage: Voltage to be applied across the large and small electrodes may be either A.C. or D.C. voltage. Its value varies with the component of the insulator and also with the gap between the two electrodes. The intensity of X-rays emitted tends to depend on the value of applied voltage. When a high voltage is applied to generate high-energy X-rays, for example, some measure is needed to eliminate the surface leakage of the insulator **4** or the conduction between the first and second electrodes **5** and **3**. To this end, for example, it is effective to increase the surface distance of the insulator **4** by projecting an outer peripheral portion of the upper surface of the insulator **4** as shown in FIG. **2**.

4. The environment in which the insulator is disposed: The environment may be either vacuum or air. To produce low energy X-rays, however, vacuum is preferred to prevent the attenuation of amount of the emitted X-rays.

FIG. **11** is a schematic diagram of an X-ray analyzer as an application of this invention. In the figure there is shown a glass vessel **20** capable of being evacuated. This glass vessel **20** consists of a specimen chamber **21**, an analysis chamber **22**, and a portion **23** connecting these two chambers. At the top of a lid **24** within the specimen chamber **21** is disposed a insulator specimen **25** to be analyzed which is sandwiched between a small electrode **26** and a large electrode **27**. the small electrode **26** is connected to a power supply **28** and the large electrode **27** is grounded.

A collimator **29** is disposed at a predetermined portion of the connecting portion **23** to collimate X-rays emitted from the insulator **25**. An X-ray spectrometer **30** mounting a crystal for X-ray spectral analysis is located at a portion within the analysis chamber **22**, facing the collimator **29**, so as to allow its angle to be varied. Within the analysis chamber **22** is disposed a movable X-ray detector **31** to detect X-rays of a prescribed spectrum reflected from the spectrometer **30**. The output from this X-ray detector **31** is connected to a counter **32**.

When a predetermined voltage is applied across the small electrode **26** and the large electrode **27** which sandwich the specimen **25** in the construction described above, X-rays peculiar to the constituent elements of the sample are emitted. Part of the X-rays travels in the direction shown by the dashed line arrow in the figure and are collimated by the collimator **29** to enter the spectrometer **30**. In the spectrometer **30** only the spectram satisfying Bragg's condition are reflected. The reflected X-rays are detected by the detector **31**. The outputs from the detector **31** are counted by the counter **32**. The counting value are used for the quantitative analysis of the constituent elements of the specimen.

FIG. **12** shows the spectrum obtained by the device of FIG. **11** from the same specimen (quartz glass) as curve A in FIG. **7**. In this case, a disk of about 1 mm in thickness and about 25 mm in diameter was used. And EDDT (Ethylene Diamine-d-Tartrate) was employed as a spectral crystal. The degree of vacuum in the vessel **20** was about 10^{-3} torr. The applied voltage was D.C. voltage in the range of 5 to 13 kilovolts. It will be understood from the figure that a spectrum preciser than the result of measurement by the proportional counter in curve A of FIG. **7** can be obtained.

What is claimed is:

1. Apparatus for producing X-rays comprising:

an electric insulator; and first and second electrodes which contact said insulator and are spaced apart from each other;

the contact area of said first electrode with said insulator being smaller than that of said second electrode, thereby emitting X-rays from said insulator

upon application of a voltage across said first and second electrodes.

2. Apparatus according to claim 1 wherein said first and second electrodes are disposed so as to sandwich said insulator therebetween.

3. Apparatus according to claim 1 wherein said first and second electrodes are disposed on the identical surface of said insulator.

4. Apparatus according to claim 1 wherein said first electrode is at least one spot electrode and said second electrode is a plate electrode.

5. Apparatus according to claim 1 wherein said first electrode is a needle-shaped electrode and said second electrode is a plate electrode.

6. Apparatus according to claim 1 wherein said first and second electrodes contact the upper and lower surfaces of said insulator so as to sandwich said insulator and said second electrode is extended to at least the sides of said insulator.

7. Apparatus according to claim 2 wherein the surface of said insulator contacting said first electrode has a protruding peripheral portion and said first electrode contacts said insulator substantially at the center of said surface.

8. Apparatus according to claim 1 wherein said insulator is one selected from a group consisting of quartz glass, ruby, alumina, yttrium garnet, lithium niobate, calcium tungstate, and mica.

9. Apparatus according to claim 1 wherein said insulator is a mixture of powders of insulating material and conducting material.

10. Apparatus according to claim 1 wherein said insulator is either aluminum or iron on a surface of which an electrically insulating oxidizing layer is formed.

11. Apparatus for the production of X-rays comprising:

a vessel capable of substantially preventing the transmission of X-rays;

a window mounted on part of said vessel to substantially transmit X-rays therethrough;

an electric insulator disposed within said vessel;

a first electrode and a second electrode each contacting said insulator, the contact area of said first electrode with said insulator being larger than that of said second electrode; and

first and second conductors respectively connected to said first and second electrodes and extending to the outside of said vessel.

12. Apparatus according to claim 11 wherein there is further provided a voltage source connected across said first and second conductors.

13. Apparatus according to claim 12 wherein said voltage source is D.C. voltage source.

14. Apparatus according to claim 12 wherein said voltage source is A.C. voltage source.

* * * * *