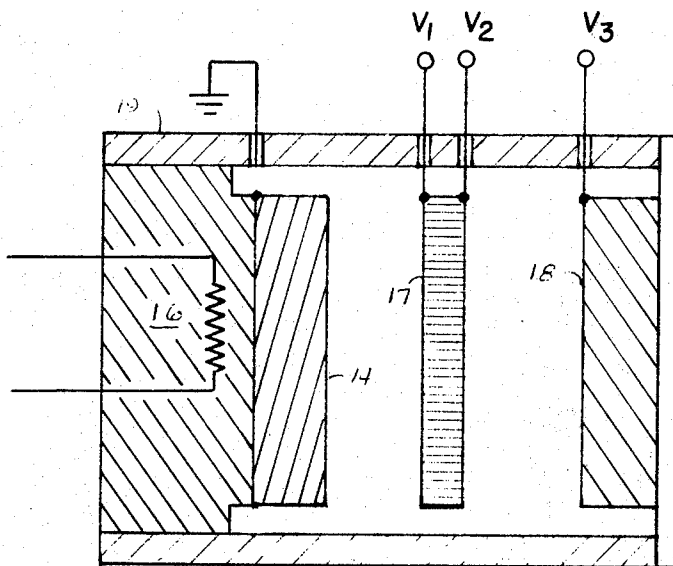


[54] **STIMULATED EXOELECTRON EMISSION
DOSIMETER HAVING HIGH SPATIAL
RESOLUTION**[75] Inventor: **Peter F. Braunlich**, Bloomfield Hills,
Mich.[73] Assignee: **The Bendix Corporation**, Southfield,
Mich.[22] Filed: **Sept. 27, 1971**[21] Appl. No.: **184,153**[52] U.S. Cl. **250/459, 250/484, 340/173 CR**[51] Int. Cl. **G01t 1/02**[58] Field of Search **250/83, 83.3, 316, 330, 484,
250/459, 312; 340/173 CR**[56] **References Cited****UNITED STATES PATENTS**

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Primary Examiner—Harold A. Dixon
Attorney, Agent, or Firm—Lester L. Hallacher[57] **ABSTRACT**

A dosimeter having high spatial resolution is described. The inventive dosimeter includes a sample of a material which exhibits exoelectron emission during optical, thermal or radiation stimulation after having been exposed to the type of radiation the detection of which is desired. Exoelectrons emanating from the sample are detected by a microchannel plate (MCP) which releases a large number of electrons for each electron it receives. The electrons emanating from the output surface of the microchannel plate impact a detection surface which yields a visual indication in response to the impacting electrons. Because microchannel plates multiply electrons in well defined channels the spatial distribution of electrons leaving the surface of the sample is preserved at the output surface of the MCP. The spatial distribution of electrons impacting the detection surface is thus identical to that of the electrons emanating from the surface of the sample material. Accordingly, the spatial distribution of the radiation to which the sample was originally exposed is duplicated across the detection surface, thereby making it possible to determine both the intensity and spatial distribution of the radiation to which the sample was subjected.

10 Claims, 2 Drawing Figures

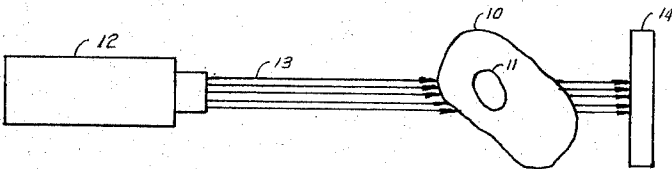


FIG 1

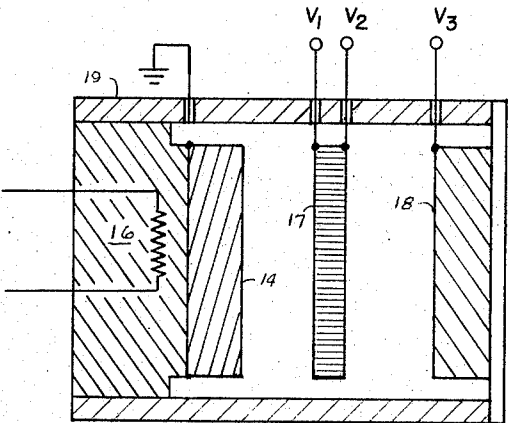


FIG 2

INVENTOR.
PETER F. BRAUNLICH
BY *Luigi L. H. Wachter*

STIMULATED EXOELECTRON EMISSION DOSIMETER HAVING HIGH SPATIAL RESOLUTION

BACKGROUND OF THE INVENTION

A brief explanation of some of the principles upon which the invention relies is useful in understanding the invention. Although the exact nature of the phenomenon of exoelectron emission is not fully understood, the existence of the phenomenon is well known in the art. Exoelectrons are emitted from surfaces of many dielectric compounds and metals are heated or when optically stimulated with light after having been exposed to various forms of radiation. Exoelectron emission also occurs when a substance is distorted by the application of a force, such as bending, twisting, or impacting. The emission occurs while the distortion is taking place and continues thereafter, although it decays with time. Cutting, milling, grinding, and all other processes which remove material also enhance exoelectron emission.

The phenomenon of thermally stimulated exoelectron emission is different from thermionic emission because it occurs at a much lower temperature; and the phenomenon of optically stimulated exoelectron emission is different from photoemission, inasmuch as the wavelengths of the stimulating light are longer than the threshold wavelengths for photoemission. It is believed that exoelectron emission occurs because the exposing of the substance to radiation such as ultraviolet, X-ray, alpha or beta particles, or other similar types of ionizing radiation causes electrons within the material to be raised above the Fermi escape level and be trapped along a thin surface layer of the substance. Upon heating to temperatures which are in excess of ambient, which are less than the higher temperatures required for thermionic emission, the trapped electrons escape across the potential barrier at the surface of the material into the gas or vacuum atmosphere adjacent the substance surface. A detailed description of the emission of exoelectrons is presented in an article by K. Becker entitled "Principles of Thermally Stimulated Exoelectron Emission (TSEE) Dosimetry."

Studies of exoelectron emission of various substances indicate that peak emission occurs at specific temperatures. For example, maximum exoelectron emission for lithium fluoride occurs at a temperature of approximately 150° centigrade. Accordingly, by elevating a sample of lithium fluoride to 150° centigrade the emission of exoelectrons can be maximized.

A microchannel plate is a thin wafer of nonconductive material which contains a large number of parallel channels passing completely through the wafer. The interior walls of the channels are coated with an electron emissive material so that electrons impinging upon the input surface of the MCP enter the channel striking the electron emissive material, thereby releasing a plurality of electrons for each impacting electron. The emitted electrons, commonly called secondary emission electrons, in turn impact the electron emissive material to release another plurality of electrons for each impacting electron. As a consequence, the number of electrons emanating from the output surface of the MCP greatly exceeds the number which impacted the input surface. Furthermore, because the multiplication occurs in the well defined channels, the spatial distribu-

tion of impacting electrons across the input surface of the MCP is preserved at the output surface of the MCP. It is therefore possible to retain any image information contained within the pattern of electrons across the input surface of the MCP. When the electrons which serve as the input electrons to an MCP are exoelectrons which emanated from a sample, the surface characteristics of the sample or the radiation pattern to which the sample was exposed is contained within the pattern of electrons striking the input surface and thus is preserved at the output surface of the MCP. A visual image of the electrons emanating from the MCP can be obtained simply by placing a fluorescent screen in the proximity of the output surface of the MCP.

Exoelectron emission has been used for high sensitivity dosimetry of ionizing radiation such as alpha, beta, gamma, X-rays, neutrons, etc., and some types of exodosimeters are commercially available. In the presently available devices a known exoelectron emitter such as a mixture of sintered Beryllium-Oxide and graphite powder, or Lithium-Fluoride powder and occasionally ionic single crystals, are exposed to radiation the detection of which is desired. The sample is then stimulated, such as by the use of optical or thermal stimulation to induce the emission of exoelectrons. The total number of emitted electrons is then used as a measure of the radiation dose received by the sample. Although these devices are useful in measuring the total dosage of radiation to which the sample was exposed, they do not yield any information relating to the spatial distribution of the radiation dosage across the surface of the dosimeter.

In some types of radiation research, such as medical radiation treatment, it is advantageous to know the spatial distribution of the radiation across the treated area. An example is the cobalt radiation treatment of cancerous organs. In this type of treatment, the radiation sensitive dosimeter element is inserted behind the affected organ which is subsequently exposed to the treating radiation. After the radiation treatment has been completed, the radiation sensitive dosimeter element is removed and heated or otherwise stimulated to cause the release of exoelectrons from the dosimeter element. The total number of electrons released is then a measure of the radiation which was received by the afflicted organ.

It would be highly advantageous for medical purposes to be able to detect the spatial distribution of radiation across the treated organ. This is so because in many instances some portions of the organ are intended to receive higher dosages of the radiation than other portions, and also because it is desirable to be able to detect the radiation which passes the edges of the organ and which thus does not serve in treating the afflicted organ.

Even though the existing dosimeters are incapable of yielding spatial distribution information, segmented distribution information can be obtained by utilizing a plurality of smaller dosimeters in the form of a mosaic pattern in lieu of a single dosimeter. The spatial resolution is thus roughly obtained by the variation in the total radiation dosage received by the various dosimeters. Obviously, this technique is disadvantageous because the resolution of the spatial distribution is dependent upon the size and number of dosimeters placed behind the organ and also because the exact location

of each dosimeter must be recorded and accurately located with respect to the organ.

SUMMARY OF THE INVENTION

The invention overcomes the disadvantages of the prior art dosimeters in that it provides an output from which both the intensity and spatial distribution of the radiation to which the sample was exposed can be determined. The distribution capability is achieved by placing the exposed sample in the proximity of a microchannel plate and subsequently stimulating the emission of exoelectrons from the sample. The stimulation can be effected by exposing the sample to optical energy, electromagnetic energy, or by heating the sample so that the exoelectrons emanate from the surface of the sample in a pattern determined by the pattern of the radiation to which the sample was originally exposed. Exoelectrons emanating from the surface of the sample then impact the input surface of the microchannel plate. Because of the point-to-point electron multiplication characteristics of the microchannel plate, the distributional information contained within the pattern of electrons impinging upon the input surface of the MCP is preserved and is simplified at the output surface of the MCP. The electrons emanating from the output surface of the MCP are then detected by an appropriate detector, such as by a phosphor screen, which yields a visual pattern indicative of the spatial distribution of the radiation to which the sample was originally exposed.

Because of the spatial distribution characteristics of the invention, the invention has usages in such areas as microdosimetry of radiation fields at interfaces, in measuring dose distributions of small beams with high accuracy, and in medical applications as explained hereinabove. Furthermore, the invention can be useful in space applications simply by remotely controlling the elements which stimulate the emission of exoelectrons and by transmitting the output information to the ground station by use of telemetry such as television transmission.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a simplified diagram showing one possible usage of the inventive system.

FIG. 2 is a preferred embodiment of the invention.

DETAILED DESCRIPTION

FIG. 1 is useful in explaining how the inventive concept is utilized in the medical radiation treatment of diseased or tumorous organs. In FIG. 1 a Human Organ 10, such as a lung or liver, is shown containing a tumor or other deformity 11, the treatment of which is desired by means of radiation. Because radiation treatment has detrimental effects on healthy tissue, it is preferable to confine the radiation to the affected area rather than the entire organ. With the prior art dosimeters it is difficult to determine that the radiation was so confined while simultaneously precisely determining that the entire afflicted area was exposed to radiation.

In the inventive system a Source of Radiation 12 which emits a form of therapeutic radiation, such as cobalt radiation, which is used to direct the Radiation Rays 13 to the Tumorous Area 11 of the Afflicted Organ 10. The Radiation 13 can be directed to the organ either by a scanning technique, or by simulta-

neously exposing the entire Afflicted Area 11 to a wide beam of the radiation.

A Sample 14 of a known exoelectron emitter, such as sintered BeO-graphite or LiF-powder is positioned behind Organ 10 so that Radiation 13 passes through the organ and impacts with the Sample 14. After the treatment is completed Sample 14 is removed and placed in the inventive dosimeter as illustrated in FIG. 2. Exoelectron emission from a material is dependent upon the surface characteristics of the sample as well as the spatial distribution of the inductive to which the sample is exposed. For this reason the surface of Sample 14 must be free of faults and smooth. Also, the sample must be homogeneous. Sample 14 must therefore be carefully prepared and care must be taken in its use. However, the manner of preparation is no more difficult than that of other types of materials having special usages and therefore is within the purview of those skilled in the art. As an example, etching techniques can be used to achieve the required smoothness and homogeneity.

Sample 14 is placed against a Heating Mechanism 16 in the proximity of a Microchannel Plate 17. Microchannel Plate 17 is also positioned in the proximity of a Fluorescent Screen 18. The entire arrangement including Sample 14, Microchannel Plate 17, and Fluorescent Screen 18 is enclosed in an evacuable Casing 19 so that the atmosphere can be removed from the casing to thereby enhance the operation of the system. Heater 16 is then energized to raise the temperature of Sample 14 to that temperature at which emission is maximized. This is a known temperature and is different for each material from which Sample 14 can be made. The exoelectrons emanating from the output surface of Sample 14 then impact Microchannel Plate 14. Flow of electrons from Sample 14 to Screen 18 is enhanced by the application of biasing voltages V_1 , V_2 , and V_3 which are selected to attract electrons. Accordingly, the voltages are all positive and are selected so that $V_3 > V_2 > V_1$. Because of the application of biasing voltages, V_1 , V_2 , and V_3 , the electrons travel in virtually straight lines from the surface of Sample 14 to the input surface of Microchannel Plate 17. A straight travel path is also caused by very closely spacing Sample 14, MCP 17 and Screen 18 so that only very small spaces remain between these elements. Because of the straight travel of electrons through the dosimeters the spatial distribution of electrons emanating from Sample 14 is maintained across the input surface of MCP 17. Because of the point-to-point multiplication of the input electrons by MCP 17 the pattern of the output electrons emanating from the output surface of MCP 17 is very nearly identical to the pattern of electrons emanating from Sample 14. Furthermore, as explained hereinabove, the emission of exoelectrons from Sample 14 is dependent upon the pattern of radiation to which the sample was exposed while in the proximity of the Organ 10 of FIG. 1. Hence, the pattern of radiation exposure of the organ is indicated by the pattern of exoelectrons emanating from Sample 14. This pattern is retained across MCP 17 and exists in the pattern of electrons emanating from output MCP 17.

The secondary emission electrons emanating from MCP 17 impact with a Fluorescent Screen 18 which thereby yields a visual indication of the radiation distribution pattern across Organ 10. It is therefore possible to determine the precise pattern of radiation to which Organ 10 was exposed, thus making it possible to very

precisely determine that only afflicted Area 11 of the Infected Organ 10 was exposed to radiation as desired.

If desired, a compound MCP can be used as the channel electron multiplier which amplifies the electrons. In such a multiplier two MCP's are arranged so that the output surface of the input MCP is juxtaposed the input surface of the output MCP. Both MCP's are fabricated so that the channels are disposed at a small angle with respect to the input and output surfaces. Also, the channels of the two MCP's slop in opposite directions. Several benefits are obtained from such an arrangement. Firstly, because two MCP's are used another electron multiplication is obtained. Secondly, because of the angularly disposed channels, and the nonalignment of the channels of the two MCP's, back scatter of positive particles from Screen 18 is eliminated. Compound MCP's are available and are known to multiply electrons on a point-to-point basis in much the same manner as single wafer MCP's.

The preferred embodiment of FIG. 2 stimulates exoelectron emission from Sample 14 by using Heater 16 to thermally stimulate the sample. It will be appreciated that other techniques of stimulating the sample can be employed. For example, electromagnetic energy, such as visible light, infrared, or ultraviolet can be used to illuminate Sample 14. Techniques for these types of stimulation are within the purview of those skilled in the art and accordingly need not be described in detail herein.

It will be appreciated that the intensity of the image present on Screen 18 will be a measure of the radiation exposure of Sample 14. Therefore, by appropriately calibrating the dosimeter using techniques known to those skilled in the art both the intensity and spatial distribution of the energy to which the sample was subjected can be determined.

What is claimed is:

1. A dosimeter having high spatial resolution comprising:

a sample of exoelectron emissive material having a smooth, homogenous surface for receiving radiation, the spatial distribution and intensity of which is to be determined, said exoelectron emissive material characterized by the property, wherein electrons are stored in an excited state along the surface of said material upon receiving said radiation and said stored electrons are emitted as exoelectrons when said material is stimulated by energy substantially less than the energy required to cause thermionic emission or photoemission;

a electron multiplier in the proximity of said sample, for receiving exoelectrons emanating from said sample and multiplying said exoelectrons on a point-to-point basis so that pattern information contained in said exoelectrons is preserved in said

multiplier;

detector means in the proximity of said multiplier for receiving said multiplied electrons and yielding an output indicative of the spatial distribution of said radiation; and

means for stimulating the emission of exoelectrons from said sample after the exposure of said sample to said radiation.

2. The dosimeter of claim 1 wherein said electron multiplier is a microchannel plate.

3. The dosimeter of claim 2 wherein said detector is a phosphorous screen.

4. The dosimeter of claim 3 wherein said sample, said multipliers and said screen are contained in an evacuable casing; and

further including means for maintaining said sample at a reference voltage V_0 which may be ground, the input electrode of said multiplier at a voltage V_1 , the output electrode of said multiplier at a voltage V_2 , and said screen at a voltage V_3 , where:

$$V_0 < V_1 < V_2 < V_3.$$

5. The dosimeter of claim 3 wherein said means for stimulating includes heater means for raising said sample to a temperature at which maximum exoelectron emission occurs.

6. The dosimeter of claim 3 wherein said means for stimulating includes a source of electromagnetic radiation for illuminating said sample.

7. The dosimeter of claim 1 wherein said multiplier is a compound microchannel plate formed from at least two single microchannel plates, each having channels angularly disposed with respect to the input and output surfaces of said plates, said two microchannel plates being formed along a common plane and the slopes of said channels being opposite.

8. The dosimeter of claim 7 wherein said detector is a phosphorous screen:

said sample, said multiplier, and said screen are contained in an evacuable casing; and

further including means for maintaining said sample at a reference voltage V_0 , which may be ground, the input to said multiplier at a voltage V_1 , the output to said multiplier at a voltage V_2 , and said screen at a voltage V_3 where:

$$V_0 < V_1 < V_2 < V_3.$$

9. The dosimeter of claim 7 wherein said means for stimulating includes heater means for raising said sample to a temperature at which maximum exoelectron emission occurs.

10. The dosimeter of claim 7 wherein said means for stimulating includes a source of electromagnetic radiation for illuminating said sample.

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