Abstract: The present invention relates broadly to a radiation dosimeter which measures ionising radiation distribution in three dimensions (3D). The phantom material of the dosimeter is elastic and strong and can be moulded in an anthropomorphic shape. The phantom comprises a transparent silicone elastomer in which an indicator in the form of a leucodye and chloroform are dissolved.
An Anthropomorphic Radiation Dosimeter

Technical Field

[0001] The present invention relates broadly to an anthropomorphic radiation dosimeter. The invention also relates generally to a method of detecting spatial dose distributions in an anthropomorphic radiation dosimeter.

Background of Invention

[0002] Technological progress in the area of medical imaging and information technology led to the development of conformal radiotherapy in the 1990’s. Conformal radiotherapy is an advanced form of external beam radiation therapy where by the aid of computers, the treatment is optimized to deliver as much radiation dose as possible to the tumour (target) while sparing the healthy tissue from radiation doses considered to be higher than can be tolerated. Intensity modulated radiation therapy (IMRT) evolved out of the inability of 3D conformal radiation therapy to irradiate tumours that are concave in shape and surrounded by healthy tissue, or that are in very close proximity to critical organs. IMRT and succeeding dynamic treatments can be used to escalate dose to the tumour volume without increasing normal tissue toxicity. Alternatively, these advanced treatment modalities can be used to deliver conventional doses to the tumour, accompanied by a lower dose to normal tissues, which leads to a reduced toxicity. Rapid dose fall off around the tumour can be achieved together with low doses to adjacent organs at risk which offers a therapeutic gain.

[0003] High-precision conformal radiation treatments such as IMRT and dynamic treatment deliveries such as static field (IMRT) or rotational (IMAT) modulated radiation therapy and tomotherapy are now standard of care in many Australian radiation oncology departments. New technologies have also been introduced to track and compensate for tumour motion during the treatment. Despite the obvious benefit of targeting cancers with more precise radiation treatments, from a safety point-of-view, there is concern that errors in planning or treatment delivery may not be detected. With a new era of real time image guided high precision radiotherapy there
is a need for three dimensional (3D) dosimetric quality assurance (QA) of the whole treatment chain to ensure all patients are receiving the planned dose to the delineated targets. The combination of very small radiation fields moving dynamically with moving targets as a result of respiration or changes in bladder filling and bowel motion makes this challenging.

[0004] For conventional radiotherapy of head-and-neck cancer, the long term complications include xerostomia, dysphagia, loss of taste, decreased tongue mobility, dental decay and neck fibrosis. For head-and-neck tumours, the advantages of IMRT lie in the organ sparing of the salivary glands and optic nerves hence improving the quality of life in head-and-neck cancer patients. Head-and-neck tumours represent an attractive site for IMRT treatment because of the absence of organ motion so that only uncertainties of the setup need to be addressed. However the treatment planning is very complex and in principle, a thorough QA check should be carried out in 3D. In practice, however, only a 2D QA check is typically performed. In the case of prostate cancer, IMRT is superior over conventional radiation therapy allowing dose escalation to achieve higher cure rates with lower side effects. IMRT plans provide steep dose gradients at the edges of the target volume and improved avoidance of adjacent organs at risk such as the rectum, bowel and bladder. A problem with the tighter margins is the uncertainty that exists in daily reproducible positioning of the prostate and the target within. This can be followed on a daily basis through image guidance using ultrasound, electronic portal imaging, cone beam computed tomography (CT) or megavoltage CT. For breast cancer, IMRT has been shown to reduce the frequency of skin complications in comparison with conventional radiotherapy treatment for patients with large breasts.

[0005] Although there are proven benefits of IMRT in terms of tumour control and reduction of complications, implementing IMRT in a clinical setting requires several steps and potential barriers can be identified:

1. The target (tumour) and tissues at risk have to be delineated carefully by a clinician. Because of the sharp geometrical dose delivery in IMRT, the delineation is less forgiving for the clinician than with conventional external radiotherapy.
2. An optimization strategy of treatment plans has to be developed that adheres to the dose requirements for the target, as well as the dose constraints of the surrounding critical structures. Nowadays, several treatment planning software packages are commercially available to do this.

3. Patient positioning and localization of the target organ becomes more important with IMRT. From the early stage in the treatment planning until the patient is actually irradiated, the position of the target can change. This is especially the case for prostate tumours, where the filling of the bladder and the colon are important. Also immobilization of the breast can pose serious difficulties in terms of the reproducibility of the tumour position.

4. For radiotherapy treatments of abdominal and lung tumours, organ motion related to breathing is problematic. Research on the effects of radiation therapy on moving tumours is one of the challenges of this innovation, especially for lung, prostate and breast tumours.

[0006] Throughout the whole process starting with spatial delineation of the target and critical organs until treatment delivery, careful quality assurance is necessary to achieve the aimed dose distribution at the correct location. The possibility that patient safety will be compromised with the fast pace at which new technologies are introduced is of great concern to the community. Traditional radiotherapy in which a few static fields were given, was verified by use of point (0D) and planar (2D) measurements of beam fluency. Dosimetric QA should assure the radiation oncologist that the dose distribution given to the patient matches the aimed dose distribution and should not be restricted to machine QA.

[0007] Currently, all radiotherapy centres use a combination of point (0D) and planar (2D) methods for dosimetric QA. Although more sophisticated computer planning simulation software are becoming commercially available, it may give a false feeling of security and clinical implementation of these systems still presents a challenge because more accurate treatment planning calculations require longer computation time. The lack of good 3D quality assurance that verifies the whole treatment chain (scanning the patient, transfer of scans to treatment planning computer, treatment optimization, positioning the patient, transfer of treatment
protocol to the treatment machine, treatment delivery) can be seen as a flaw in the safeguarding of patients.

**Summary of Invention**

[0008] According to a first aspect of the present invention there is provided an anthropomorphic radiation dosimeter comprising a silicone elastomer in combination with an indicator which under the influence of ionizing radiation provides a colour change in the dosimeter from which the spatial dose distribution of the ionizing radiation is derived.

[0009] According to a second aspect of the invention there is provided an anthropomorphic radiation dosimeter comprising a silicone elastomer in combination with an indicator which under the influence of ionizing radiation provides a colour change in the dosimeter from which spatial dose distribution of the ionizing radiation is derived with an optical scanner operative at selective wavelengths.

[0010] Preferably the dosimeter is resiliently deformable.

[0011] Preferably the indicator includes a leucodye. More preferably the indicator also includes chloroform to be combined with the leucodye. Even more preferably the dosimeter also comprises a curing agent to be combined with the leucodye and the chloroform.

[0012] According to a third aspect of the invention there is provided a method of detecting spatial dose distribution in an anthropomorphic radiation dosimeter, said method comprising the steps of:

- applying ionizing radiation to the dosimeter which comprises a silicone elastomer in combination with an indicator which under the influence of the ionizing radiation provides a colour change in the dosimeter;
- detecting the colour change in the irradiated dosimeter with an optical scanner operative at selective wavelengths to derive the spatial dose distribution of the ionizing radiation.

[0013] Preferably the method also comprises the step of deforming the dosimeter whilst applying the ionizing radiation.
[0014] Preferably the step of detecting the colour change in the dosimeter involves selective wavelength scanning of the irradiated dosimeter using the optical scanner. More preferably the selective wavelength scanning of the irradiated dosimeter is performed using a dual wavelength CT scanner.

[0015] According to a fourth aspect of the invention there is provided use of an anthropomorphic radiation dosimeter to detect spatial dose distribution in the dosimeter which comprises a silicone elastomer in combination with an indicator which under influence of ionizing radiation provides a colour change in the dosimeter from which the spatial dose distribution of the ionizing radiation is derived.

[0016] According to a fifth aspect of the invention there is provided use of an anthropomorphic radiation dosimeter to detect spatial dose distribution in the dosimeter which comprises a silicone elastomer in combination with an indicator which under influence of ionizing radiation provides a colour change in the dosimeter from which the spatial dose distribution of the ionizing radiation is derived with an optical scanner operative at selective wavelengths.

**Brief Description of Drawings**

[0017] In order to achieve a better understanding of the nature of the present invention a preferred embodiment of an anthropomorphic radiation dosimeter will now be described, by way of example only, with reference to the accompanying illustrations in which:

Figure 1(a) illustrates a silicone radiation dosimeter according an embodiment of to the present invention exposed to ionizing radiation;

Figure 1(b) is a corresponding light absorption spectrum for the radiation dosimeter of Figure 1(a) for different radiation exposure times;

Figures 2(a) to 2(d) schematically illustrate the principal of selective wavelength scanning applied to a silicone radiation dosimeter;

Figure 3 illustrates a grid pattern in a silicone radiation dosimeter together with associated scans;
Figures 4(a) shows longitudinal and axial sections through a cylindrical silicone dosimeter recorded at various times post-irradiation;

Figure 4(b) shows lateral profiles through the middle of the phantom of figure 4(a) at the respective times post-irradiation;

Figure 5 is a dose response sensitivity phase diagram for different compositions of silicone dosimeter according to embodiments of the invention;

Figure 6 is a graph showing the dose rate dependence for an exemplary silicone dosimeter;

Figures 7(a) shows the mass attenuation coefficients as a function of photon energies for an exemplary silicone radiation dosimeter,

Figure 7(b) shows the atom weight fractions for the silicone radiation dosimeter of figure 7(a);

Figures 8(a) to 8(f) illustrate various steps involved in the construction of a hollow anthropomorphic cardiac radiation dosimeter according to one embodiment of the invention;

Figures 9(a) to 9(e) illustrate various steps involved in the construction of another embodiment of an anthropomorphic radiation dosimeter according to the invention;

Figures 10(a) and 10(b) illustrate different kinds of optical scanners acting with multiple wavelengths and used in scanning radiation dosimeters to read out spatial dose distributions of the ionizing radiation.

**Detailed Description**

[0018] In one aspect of the invention there is provided a radiation dosimeter which measures ionizing radiation dose distributions in three dimensions (3D). The phantom material of the dosimeter is elastic and strong and can be moulded in an anthropomorphic shape. The phantom comprises a transparent silicone elastomer in which in this embodiment an indicator in the form of leucomalachite (LMG) and chloroform are dissolved. Upon irradiation, chloroform radicals will transform LMG into
malachite green (MG) that has a predominant optical absorption peak around 630 nm, see figure 1(b).

[0019] The dosimeter is preferably used to acquire radiation dose distributions delivered during radiotherapy where deformation of organs during treatment is taken into account. The dosimeter is shaped and deformed by a pneumatic, hydraulic or mechanical actuator. The dosimeter may also be folded around a patient, while serving as a bolus material and radiation dosimeter during patient treatment to measure skin dose.

[0020] In another aspect of the invention a scanning method is introduced that is capable of acquiring images of the flexible anthropomorphic shaped phantom. The optical scanning method relies on the principle of cone beam optical CT scanning at different wavelengths where only light in a specific range of wavelengths is absorbed by the indicator, in this example leucomalachite green. Images recorded with a light source with another wavelength outside the absorption bandwidth of the indicator are used as background 'blank' images. This selective wavelength scanning technique replaces the need for a blank measurement of the dosimeter phantom to be taken prior to irradiation. As a result, the scanning becomes more reliable in terms of repositioning the dosimeter or phantom in the optical scanner, which is considered as a critical step in previous systems and may lead to imaging artefacts and therefore uncertainties in the dose distribution.

[0021] The principle of selective wavelength scanning is shown in figures 2(a) to 2(d). While red light is absorbed by the leucodye at (a), the phantom remains nearly optical transparent for green light at (b). However, any aberrations of the light by other particles or optical non-uniformities present in the phantom that are not due to the leucodye will be present in both images. A stack of axial images of a cylindrical dosimeter phantom exposed to a square clinical photon beam are shown where scanning is performed with a red light source at (c) and with a green light source at (d) which demonstrate that the irradiated part is optically transparent for green light.

[0022] In order to check the reliability of scanning a non-cylindrical phantom, a spherical phantom and other non-cylindrical test phantoms were scanned. Figure 3 shows a grid pattern created in these phantoms by use of syringes arranged in a
regular pattern. After removal of the syringes, the cavities were filled with a coloured leucodye gel. A grid pattern created in a demi-spherical phantom is preserved in the scans. The scans were obtained with the laser scanner but comparable results were obtained with the cone beam scanner and in a non-spherical prostate shaped phantom.

[0023] Figure 4(a) shows reconstructed longitudinal and axial slices through a silicone radiation dosimeter or phantom after exposure with a square photon beam obtained by dual wavelength scanning at several times post irradiation. From left to right in figure 4(a) the post irradiation times are 3h, 3h30min, 4h30min and 6h. Figure 4(b) shows cross-profiles perpendicular to the beam direction, demonstrating good spatial integrity in the phantom.

[0024] The dosimeter phantom of this embodiment comprises four chemical components: (1) a silicone polymer in the form of polydimethylsiloxane (PDMS), (2) a curing agent, (3) chloroform which serves as a source of radiation induced radicals and (4) an indicator in the form of a dye (LMG) that is transformed upon irradiation by the radicals. In this example the proportions of each component are 87.5% (w/w) PDMS, 10% (w/w) curing agent, 2.5% (w/w) chloroform and 0.04% (w/w) (LMG). In an alternative embodiment the leucodye is leucocrystal violet.

[0025] In formulating the composition of the dosimeter, several requirements need to be satisfied for the radiation sensitive material to serve as a reliable deformable 3D radiation dosimeter. The dosimeter phantom is formulated to have favourable radiation properties which depend on the following parameters.

**Sensitive to clinical radiation doses**

[0026] Clinical doses range from tens of centi-Gray (cGy) to tens of Grays (Gy) depending on the application. In that range, the optical absorption coefficient should optimally vary between 0 cm⁻¹ and 1 cm⁻¹. The current dosimeter formulation has a dose sensitivity (change in optical absorption coefficient per unit of radiation) of around 0.01 cm⁻¹.Gy⁻¹. Figure 5 shows a phase diagram of dose-sensitivity for different concentrations of chloroform and different concentrations of LMG. In this embodiment, the optimum composition of the silicone dosimeter in terms of dose sensitivity is around 0.025% (w/w) LMG and 5% (w/w) chloroform. For LMG
concentrations higher than 0.5% (w/w) the dosimeter became turbid. For the optimum composition (0.025% (w/w) LMG and 5% (w/w) chloroform), the dose sensitivity for high energetic photon beams (6 MV) was around 0.01 cm⁻¹.Gy⁻¹.

Dose rate dependence

[0027] The change in optical absorption coefficient with dose should be invariant to the rate at which the radiation dose is delivered for a dose rate up to around 8 Gy/min which is a maximum dose rate that can be achieved with contemporary clinical linear accelerators. The dose rate dependence of the preferred dosimeter is shown in figure 6 for dose rates between 200 cGy/min and 400 cGy/min. It can be seen that the dose rate dependence is more pronounced at higher dose levels and that the dose response is non-linear. The non-linearity in dose response increases with decreasing dose rate. For dose values between 0 Gy and 20 Gy, the dose rate dependence of the dose sensitivity amounts to 12%, while in the dose range 20 Gy to 40 Gy the dose sensitivity varies to up to 32% for dose rates between 200 cGy/min and 600 cGy/min.

Spatial integrity and temporal stability

[0028] The radiation dose distribution captured in the dosimeter phantom should be preserved for a sufficiently long time (in the order of a week). An excellent preservation of the dose distribution has been found for the preferred dosimeter for prolonged periods of time (months). An offset in optical absorption coefficient may occur as a result of auto-oxidation (i.e. not induced by ionizing radiation) of the leucodye. This offset may be extracted through calibration to reduce negative impact on the accuracy.

Tissue equivalence

[0029] The absorption of high energetic radiation energy by the material of the preferred dosimeter is similar to human tissue. Preliminary results show that the preferred dosimeter formulation has a tissue equivalence to all biological soft tissue for clinical high energetic photon radiation beams between 100kV and 100MV. The basic composition of the dosimeter in this embodiment is polydimethylsiloxane. Within the range of 100 kV to 20 MV, the dosimeter is highly tissue equivalent. The relative
electron density of the dosimeter as compared to the electron density of water is in the order of 1.0059 (for a chain length of 10). For higher chain lengths the electron density converges to that of water. Figure 7(a) shows mass attenuation coefficient as a function of photon energies for the preferred dosimeter (black) and water (blue) calculated using an online database. Figure 7(b) shows polydimethylsiloxone (PDMS) and the weight fraction of atoms is listed for different chain lengths.

*Insensitive to environmental conditions upon and after exposure to radiation*

[0030] The change in optical absorption coefficient for the preferred dosimeter predominantly depends on radiation dose and is independent of the temperature at which the dosimeter is irradiated in a temperature range of 5 degrees Celsius around normal room temperature. A temperature dependence of 0.8% per degree Celsius was observed for the preferred silicone dosimeter.

*Energy dependence*

[0031] The difference in dose sensitivity for the preferred dosimeters irradiated with photon beams of 6 MV and photon beams of 18 MV amounted to less than 5%. This difference was within the measurement uncertainty for these measurements.

[0032] The preferred formulation was synthesized on the basis of a sufficient dose sensitivity by varying the concentration of chloroform and LMG. It will be appreciated that the above mentioned characteristics and requirements will be different for other compositions. This will provide a phase space of radiation properties for different chemical compositions. The concentration and proportion of components may be varied to achieve application specific requirements in terms of required mechanical and radiation properties (e.g. to obtain elasto-mechanical properties that match those of the treated organ).

[0033] It will be appreciated that different anthropomorphic shaped phantoms may be constructed or fabricated using various techniques. For example a pumping heart shaped phantom is constructed with a single inner cavity that is created by use of a gelatine hydrogel which is easily removed after the polymer has cured, see figure 8. The heart phantom dosimeter is suspended in a thorax phantom and the pumping
action is achieved by use of a hydraulic actuator pumping the single cavity to simulate deformation of the myocardium.

[0034] In another example a radiation dosimeter in the shape of a prostate is constructed and suspended in a water filled pelvic phantom, see figure 9. The prostate phantom dosimeter is connected to a mechanical linear stage that moves in three dimensions. The motion is tracked using an RF tracking device that is used for organ motion tracking in patients. This enables the verification of dose delivery in image guided tracking radiotherapy (IGRT).

[0035] Exemplary anthropomorphic shaped phantoms may be obtained by fabricating a positive mould of the organ of interest by hand in Styrofoam and commercial casting materials. The negative mould for the phantom is then formed from the positive mould. Alternatively a 3D printer may be used to construct the negative moulds. Medical images obtained by MRI or CT serve as inputs to the 3D printer. Organs of interest are first contoured on the medical image data set using semi-automated software and the 3D contour set transferred to the 3D printer.

[0036] The construction of a heart shaped deformable radiation dosimeter is shown in figures 8(a) to 8(f) using handmade casts and first dose maps after exposure with a square beam of high energetic photons. Figures 8(a) to 8(f) show the handmade positive mould of the heart at (a), an inner cavity mould made from a hydrogel at (b), a first prototype of a heart shaped phantom at (c), a thorax phantom in which the heart phantom is suspended at (d) a phantom on a 4D CT scanner with hydraulic actuator to simulate pumping at (e), and dose maps after irradiation with a square photon beam generated with a clinical linear accelerator at (f). Figures 9(a) to 9(e) show the construction of a prostate shaped motion phantom at (a) and (b), suspended in a pelvic cast at (c), that filled with water is attached to a motion device at (d) and (e) to simulate movement of the prostate during radiation treatment. The 3D prostate dosimeter can be moved to simulate physiological motion for quality assurance of for example IGRT.

[0037] In the preferred scanning method there is provided a dual wavelength laser CT scanner and a modified optical conebeam CT scanner to read out the radiation dosimeters. These scanners have a limited field-of-view (12 cm and 15 cm
respectively) and it is expected that in order to scan larger sized phantoms (e.g. a head and neck or human brain shaped dosimeter), a larger optical CT scanner with a larger field of view will be used. This will involve a larger water reservoir with larger windows, a CCD camera with larger dynamic range (14 bit minimal) and a large uniform diffuse light source with different wavelengths. Alternatively, a colour CCD camera can be used in combination with a white light source to acquire colour projection images of the phantom that can then be decomposed in their basic colour components. Figures 10(a) and (b) illustrate two different kinds of optical CT scanners with multiple wavelength. A laser scanning optical CT scanner using a green laser and red laser is shown at (a), and a cone beam optical CT scanner with CCD camera and diffuse light source at three different selectable colours is shown at (b).

[0038] The invention in its preferred form also involves the use of image processing software such as that developed using the Matlab platform. The developed software uses image reconstruction tools provided by the Matlab environment. Also to display the final dose distribution, the image processing toolbox of Matlab is used. Currently, the image reconstruction of a full 3D data set takes approximately 30 minutes on a personal computer (with a 1.6 GHz i7 CPU processor). The calculation time can be significantly reduced by using parallel GPU processing (e.g. by using a PC equipped with an NVidia multicore GPU card). The reconstruction and image processing software may be translated to C-programming language in combination with CUDA multi-thread programming. It is also expected that image quality can be improved by use of iterative reconstruction algorithms.

[0039] Now that a preferred embodiment of the invention has been described it will be apparent to those skilled in the art that the anthropomorphic radiation dosimeter has at least the following advantages over the admitted prior art:

1. The dosimeter can be shaped in anthropomorphic (human organ) shapes and scanned with an optical CT scanner operative at selective wavelengths;

2. The dual wavelength scanning method enables the spatial dose distribution of the ionizing radiation and the dosimeter to be derived without the need for a
pre-exposure blank scan and thus decreases uncertainties related to repositioning of the dosimeter phantom in the scanner;

3. The dosimeter and scanning method are particularly suited to non-cylindrical anthropomorphic and deformable dosimeter phantoms;

4. The anthropomorphic radiation dosimeter in its preferred form is non-toxic and relatively easy to handle;

5. The dosimeter and the optical scanner are relatively inexpensive and should be readily accessible;

6. It does not require a specialised chemistry laboratory to construct phantoms which are relatively easy to fabricate;

7. The dosimeters are formulated with relatively slow curing times and therefore reduced heat dissipation which gives relatively uniform densities in the material and homogenous optical uniformity;

8. The composition of deformable dosimeters can be changed to tune their mechanical properties.

[0040] Those skilled in the art will appreciate that the invention described herein is susceptible to variations and modifications other than those specifically described. For example, the composition of the dosimeter may vary from that described, provided it comprises a silicone elastomer in combination with an indicator which under the influence of ionizing radiation provides a colour change from which spatial dose distribution is derived. The optical scanner may vary from the examples described and illustrated, provided it is a scanner capable of deriving spatial dose distribution of the ionizing radiation within the irradiated dosimeter by use of light transmission scans acquired at different wavelengths.

[0041] All such variations and modifications are to be considered within the scope of the present invention the nature of which is to be determined from the foregoing description.
Claims

1. An anthropomorphic radiation dosimeter comprising a silicone elastomer in combination with an indicator which under the influence of ionizing radiation provides a colour change in the dosimeter from which the spatial dose distribution of the ionizing radiation is derived.

2. An anthropomorphic radiation dosimeter comprising a silicone elastomer in combination with an indicator which under the influence of ionizing radiation provides a colour change in the dosimeter from which spatial dose distribution of the ionizing radiation is derived with an optical scanner operative at selective wavelengths.

3. An anthropomorphic radiation dosimeter as defined in either of claims 1 or 2 wherein the dosimeter is resiliently deformable.

4. An anthropomorphic radiation dosimeter as defined in any one of the preceding claims wherein the indicator includes a leucodye.

5. An anthropomorphic radiation dosimeter as claimed in claim 4 wherein the indicator also includes chloroform to be combined with the leucodye.

6. An anthropomorphic radiation dosimeter as defined in claim 5 also comprising a curing agent to be combined with the leucodye and the chloroform.

7. A method of detecting spatial dose distribution in an anthropomorphic radiation dosimeter, said method comprising the steps of:
   - applying ionizing radiation to the dosimeter which comprises a silicone elastomer in combination with an indicator which under the influence of the ionizing radiation provides a colour change in the dosimeter;
   - detecting the colour change in the irradiated dosimeter with an optical scanner operative at selective wavelengths to derive the spatial dose distribution of the ionizing radiation.

8. A method as defined in claim 7 also comprising the step of deforming the dosimeter whilst applying the ionizing radiation.
9. A method as defined in either of claims 7 or 8 wherein the step of detecting the colour change in the dosimeter involves selective wavelength scanning of the irradiated dosimeter using the optical scanner.

10. A method as defined in claim 9 wherein the selective wavelength scanning of the irradiated dosimeter is performed using a dual wavelength CT scanner.

11. Use of an anthropomorphic radiation dosimeter to detect spatial dose distribution in the dosimeter which comprises a silicone elastomer in combination with an indicator which under influence of ionizing radiation provides a colour change in the dosimeter from which the spatial dose distribution of the ionizing radiation is derived.

12. Use of an anthropomorphic radiation dosimeter to detect spatial dose distribution in the dosimeter which comprises a silicone elastomer in combination with an indicator which under influence of ionizing radiation provides a colour change in the dosimeter from which the spatial dose distribution of the ionizing radiation is derived with an optical scanner operative at selective wavelengths.
Figure 1a

Figure 1b
Absorption predominantly by leucodye

Figure 2(a)

Absorption predominantly by matrix

Figure 2(b)

Figure 2(c)

Figure 2(d)
Figure 4(a)

Figure 4(b)
Dose sensitivity (cm$^{-1}\cdot$Gy$^{-1}$)

Figure 5
Figure 6
Figure 7(a)

Figure 7(b)

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GUI and control software in Matlab-code

Figure 10(a)
Figure 10(b)
INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2015/000274

A. CLASSIFICATION OF SUBJECT MATTER

G01T 1/00 (2006.01)  G01J 1/00 (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC.

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI, EPODOC: G01T1/-, G01J1/- and Keywords (Radiation, Colour, Dosimeter, Spatial and like terms).

Applicant Search

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Documents are listed in the continuation of Box C

X Further documents are listed in the continuation of Box C  
X See patent family annex

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Name and mailing address of the ISA/AU

AUSTRALIAN PATENT OFFICE
PO BOX 200, WODEN ACT 2606, AUSTRALIA
Email address: pct@ipaaustralia.gov.au

Authorised officer

Timothy Williams
AUSTRALIAN PATENT OFFICE
(ISO 9001 Quality Certified Service)
Telephone No. 0262832067

Form PCT/ISA/210 (fifth sheet) (July 2009)
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End of Annex

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.