MEASURING X-RAY DOSE DISTRIBUTION USING NANODOT OPTICALLY STIMULATED LUMINESCENCE DOSIMETER

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Abstract: In this work, the nanoDot (Nagase, Landauer) optically stimulated luminescence dosimeters are used for determining the distribution in X-ray generator SOFTEX M-60W (SOFTEX Corp., Ebina-shi, Kanagawa, JAPAN). The arrangement of 361 nanoDots on the 45×45 cm plate which has a standardized size with the X-ray inner chamber section is carried out to measure the dose after exposing by X-ray generator with 50 kV, 2.5 mA. The experiments are performed at three different plates designed with separated distance and available on the X-ray chamber in the same measurement conditions. The result shows that there is a drift of high dose values to the left of all of three X-ray dose graphs in the different distances from X-ray tube. Furthermore, the information of X-ray dose distribution is very useful to locate the position and appropriate dose on the plate. However, performing the experiment in multiple different measurement conditions to estimate the X-ray dose distribution is necessary and more sufficient for future experiments.

Keywords: *X-ray, nanoDot, OSL, microStar, radiation dose*

I. INTRODUCTION

Optically Stimulated Luminescence (OSL) has firstly been applied as the dating method for the geological sediments, ancient fired pottery and brick, etc [1] due to the characterized luminescence of the crystalline structure existing in certain minerals (most commonly quartz and feldspar). Recently, this method has been developed as a new technique for determining accumulated radiation dose in the tissues and cells of an exposed individual such as health care, research, radiation worker as well as investigating environmental dose which is relative to some building materials in the regions of nuclear disaster. Furthermore, Optically Stimulated Luminescence has considered as a high accuracy method for calibration of exposure dose of some characteristic radiation equipment.

In this work, the nanoDot (Nagase, Landauer) OSL dosimeters are used for determining distribution in X-ray generator SOFTEX M-60W (SOFTEX Corp., Ebina-shi, Kanagawa, JAPAN).

II. THEORY AND MATERIAL

II. 1. Theory

Some materials whose structure can "retain" a part of absorbed energy in their metastable states. The absorption of energy from an ionizing radiation source by an insulating or semiconducting material causes the excitation of free electrons and free holes. This phenomenon leads to appear the electronic traps at defects (trapping states) within the material. After removing the excitation, the material may then be stimulated in such a way that absorbed energy causes the liberation of charge carriers of one sign, which are then able to recombine with charge carriers of the opposite sign.

Intensity of emitted luminescence is depended on rate at which the existing states returns to the equilibrium state. Normally, the intensity of the luminescence is obtained as a function of time which gives us the characteristic luminescence versus time curve. Total the OSL intensity output is proportional to the absorbed dose in case of they are not saturation [3].

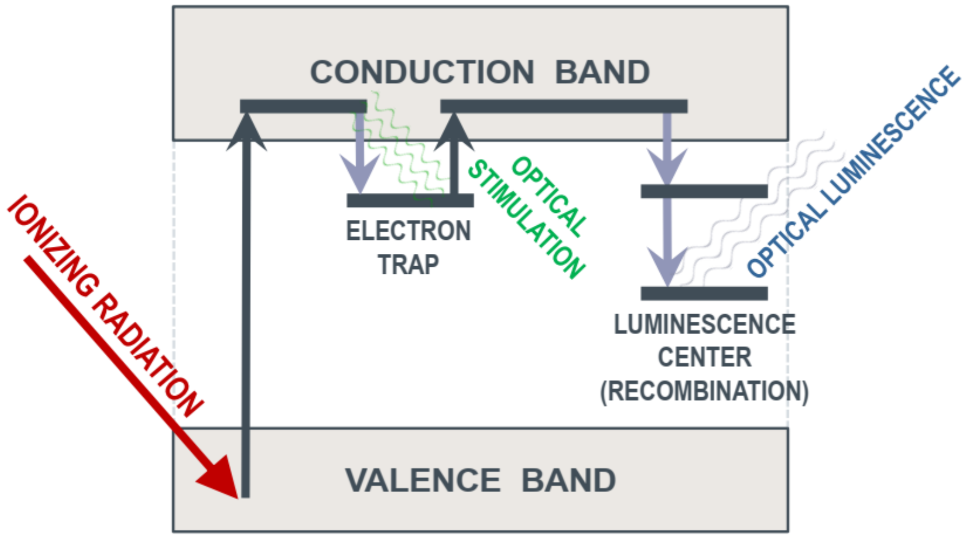

Figure 1. Luminescence mechanism.

When an OSL material is excited by light, this process can release absorbed energy in the form of ultraviolet, visible or infrared light. It's called stimulated optically luminescence [2, 3, 4, 5]. After stimulating, the phenomenon is attribute to as OSL, the material for dosimetry is called optically stimulated luminescence dosimeter (OSLD).

II. 2. Material

Optically stimulated luminescence dosimeters (OSLDs) offer a potential method for rapid and accurate dosimetry using Al_2O_3 crystal. The nanoDot (Nagase, Landauer), one of Al_2O_3 based OSLDs, has high sensitivity, reusability, small size, and is commercially available that making it a realistic choice for single point measurements.

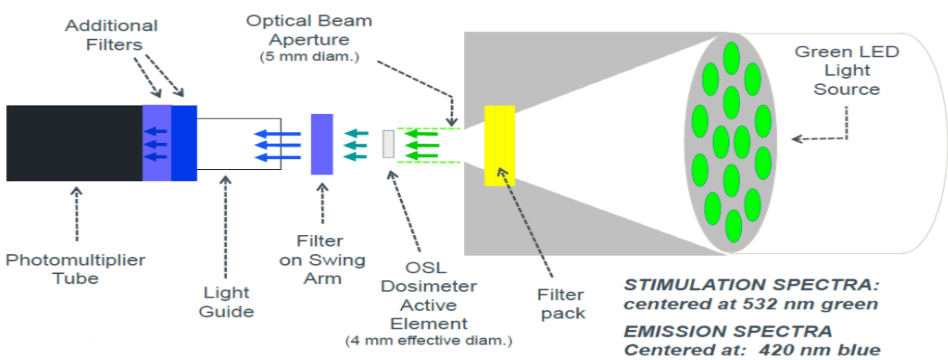

Figure 2. OSL Process of microStar (source microStar manual (Nagase Landauer))

NanoDot® (Nagase Landauer, Ltd., Japan) is a flat, approximately 10 mm × 10 mm size, a plastic cassette that contains a disk of aluminum oxide doped carbon crystals (Al_2O_3:C) [Figure 3a]. Nanodots are based on optically-stimulated luminescence (OSL) dosimetry as opposed to the more commonly-used thermo-luminescence dosimetry (TLD) method. Each Nanodot is prescreened by the manufacturer for variation in crystal sensitivity and adjusted to be within 2% between Nanodots and is supplied with a unique serial number and bar code.

Table 1. Some characteristic of nanoDot (source: Nagase Landauer).

Dose operating range	For general applications, useful dose range 10 µGy to >100Gy;
Lower Limit of Detection (LLD)	0.1 mGy
Useful Energy Range	From 5 keV to 20 MeV
Energy Dependence	Accurate within ±10% over diagnostic energy range 70-140 kvP; within ±5% for photons and electrons from 5 MeV-20MeV
Accuracy (total uncertainly - single measurement)	±10% with standard nanoDot; ±5.5% with screened nanoDot
Precision	±5%, k=2 for both standard and screened nanoDot

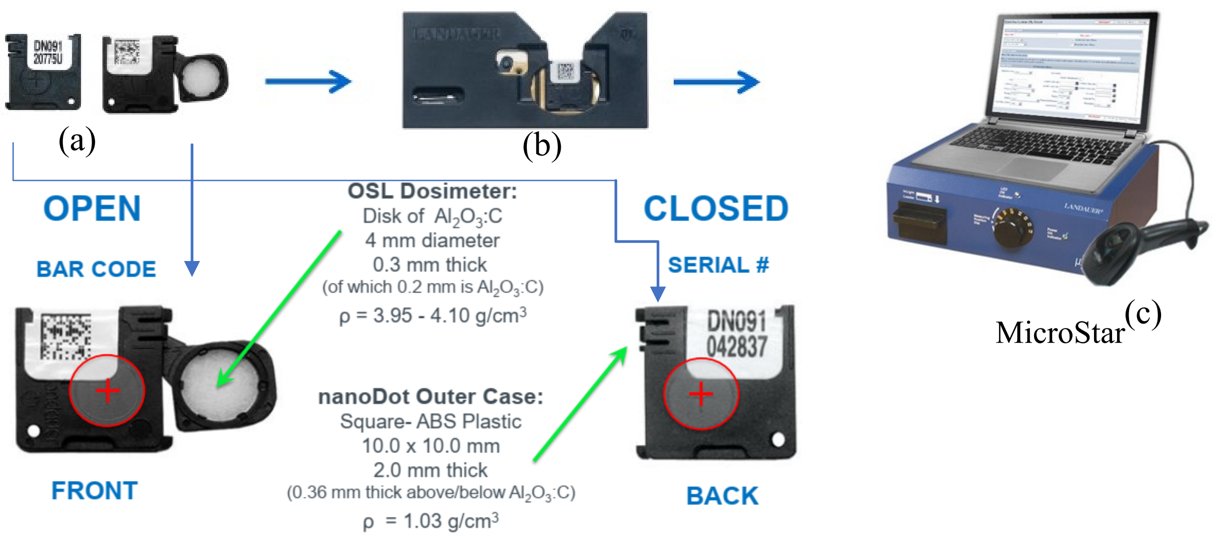

Figure 3. OSL microStar system: (a) nanodot dosimeter, (b) adapter, (c) microStar reader, laptop with microStar and IMLS management software.

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The dose level of nanoDot is read out by a reader called microStar which contains a dosimeter kit, a laptop with the microStar and IMLS management software.

In this work, we use nanoDots in order to estimate the distribution of dose inner X-ray generator SOFTEX M-60W (SOFTEX Corp., Ebina-shi, Kanagawa, JAPAN). It is the best choice because of its characteristic as mentioned above.

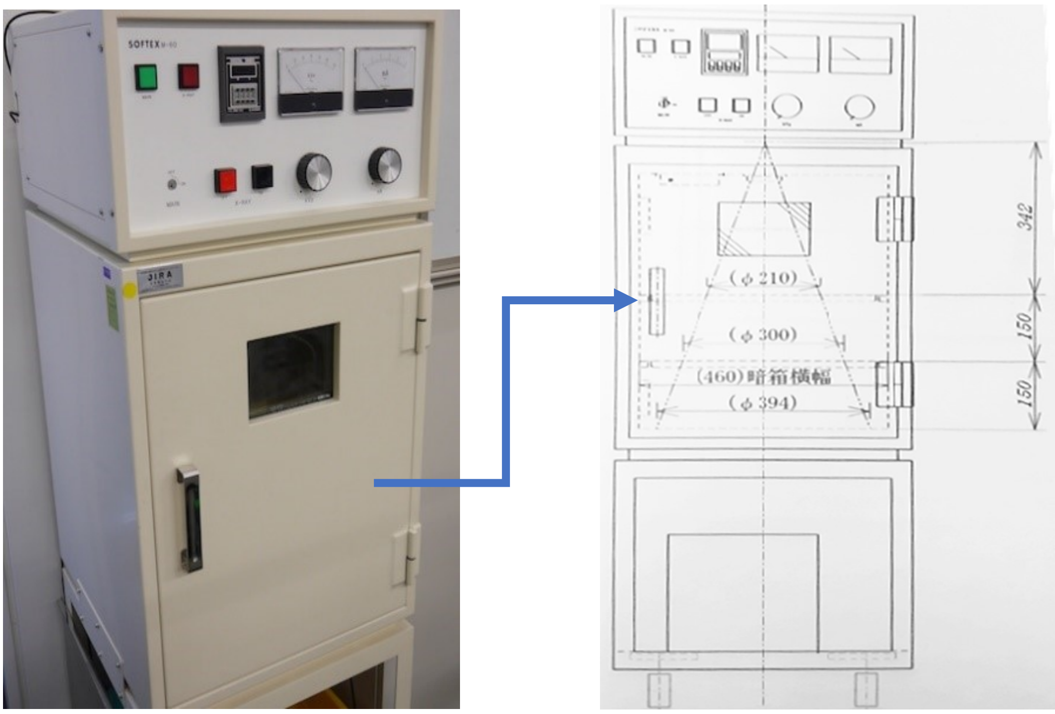

Figure 4. X-ray generator SOFTEX M-60W and schematic inner its X-ray chamber with three different height steps (source: manual of Softex M-60W).

III. EXPERIMENT

The metal plate for irradiating samples is available in the X-ray chamber. The experiment is to know dose level appropriate to a position on the plate by using nanoDot dosimeter to proceed three measurements with the same arrangements on distinguishing steps inner the X-ray chamber.

Preparation and measurement

Step 1: Preparing the OSL Reader system (Nagase Landauer, Ltd., Japan)

- MicroStar reader
- NanoDots dosimeter: After being bleached under high intension light (figure 5a.), only nanoDots are used with measurement result less than 100 counts [6]. The quantity of nanoDots is 361.

Step 2: The 45 cm x 45 cm plate (available in SOFTEX M-60W) is covered by the 2.5 cm grid paper. Therefore, 361 nanoDots are arranged on 361 intersections in the paper as figure 5b.

Step 3: X-ray Irradiation

- X-rays from generator SOFTEX M-60W (60 kVp, 5 mA).
- Put the nanoDot plate on the bottom (first step) in the X-ray room.
- Irradiate the nanoDot with X-ray (50 kV, 2.5 mA) for a minute.

Step 4: NanoDot Read Out

- Reading out the nanoDot dosimeters using microStar reader with the control software on the PC after the exposure at less 30 minutes.

- Store and analysis the dose data to be displayed the dose distribution.

Step 5: Repeat steps from 1 to 4 but the plate position is changed according to plate holders (second and third step) and start next exposure with “new” nanoDots.

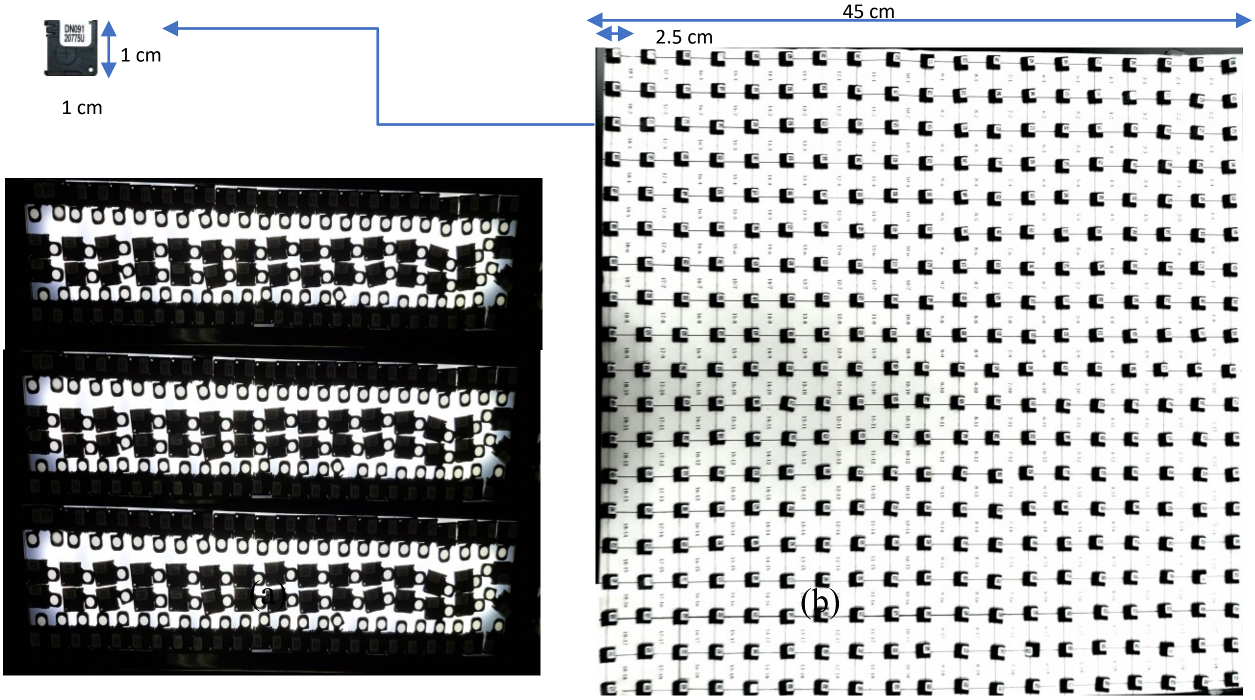

Figure 5. (a) bleaching nanoDots; (b) the plate with 361 nanoDots after the arrangement.

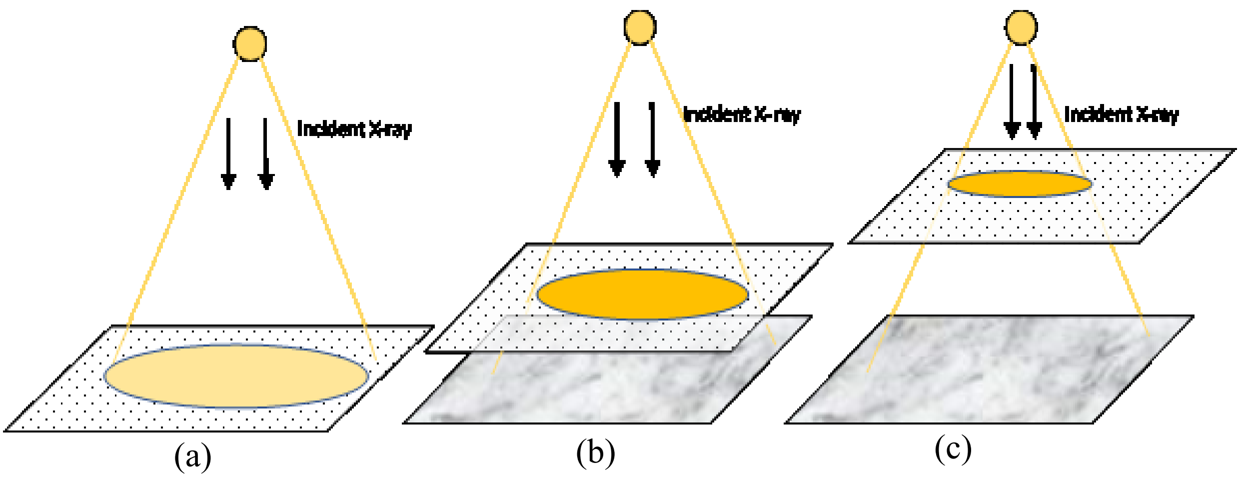

Figure 6. Three positions which the plate can be put in the X-ray chamber; (a) first step (the bottom), (b) second step (15 cm from the bottom), (c) third step (15 cm from the second step).

IV. RESULTS AND DISCUSSION

After the measurements, the dose distributions are graphed as Figures 7, 8, 9 and integrated all three layers in Figure 10.

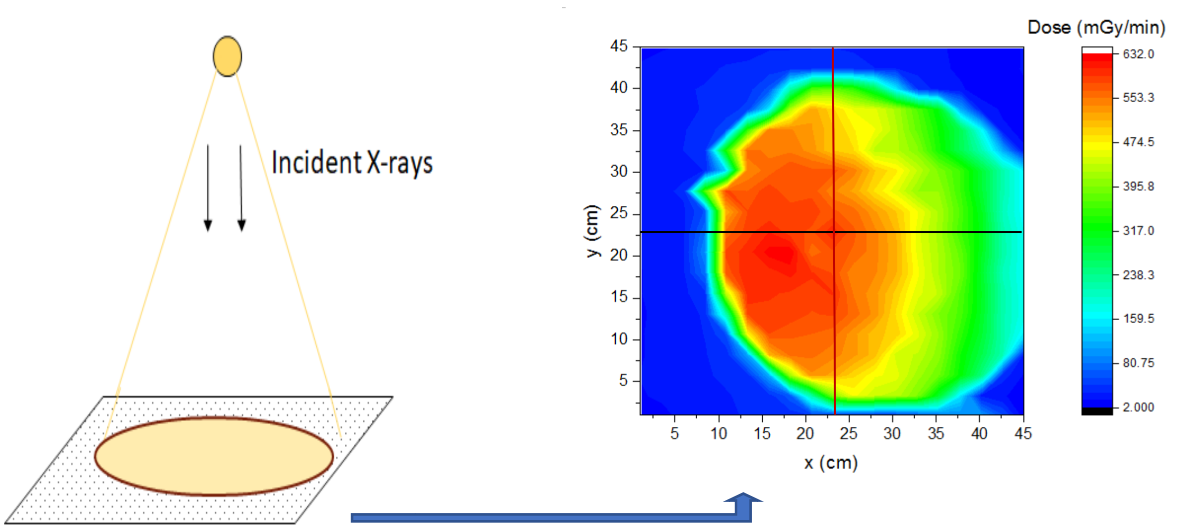

Figure 7. The X-ray dose distribution at the bottom (first step) in the X-ray room.

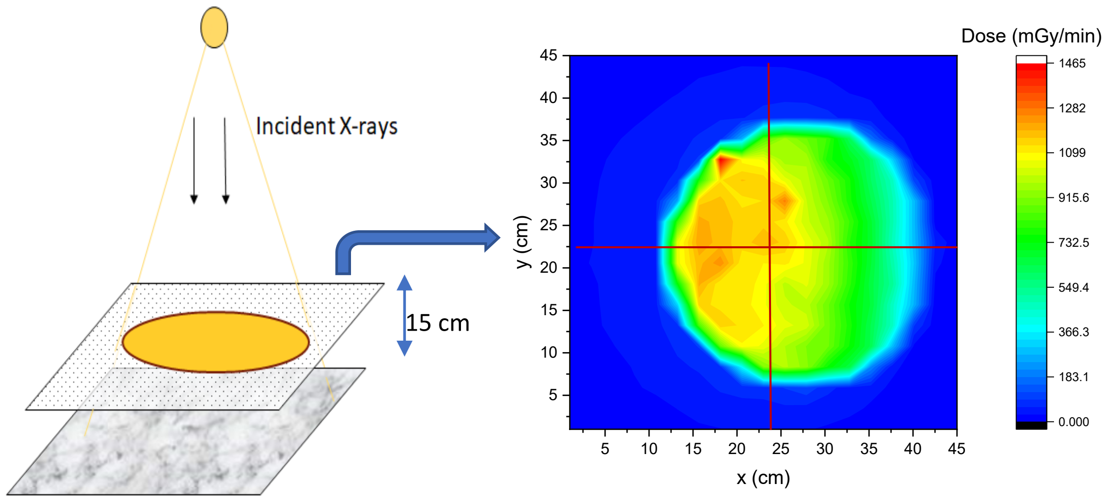

Figure 8. The X-ray dose

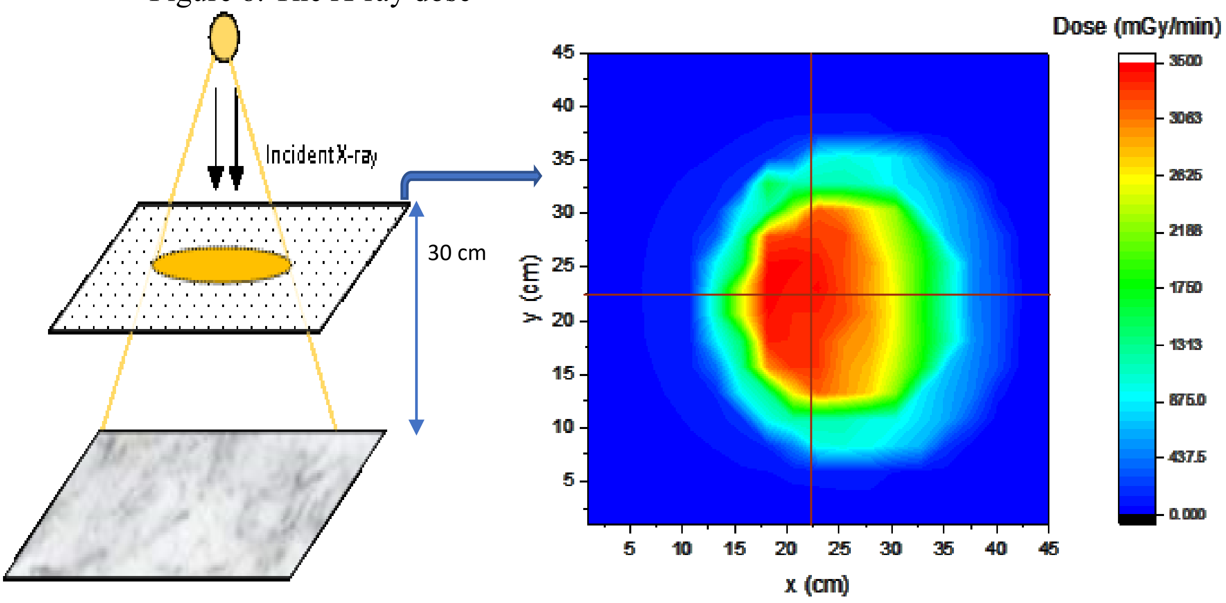

Figure 9. The X-ray dose distribution at the three steps in the X-ray room in the same graph.

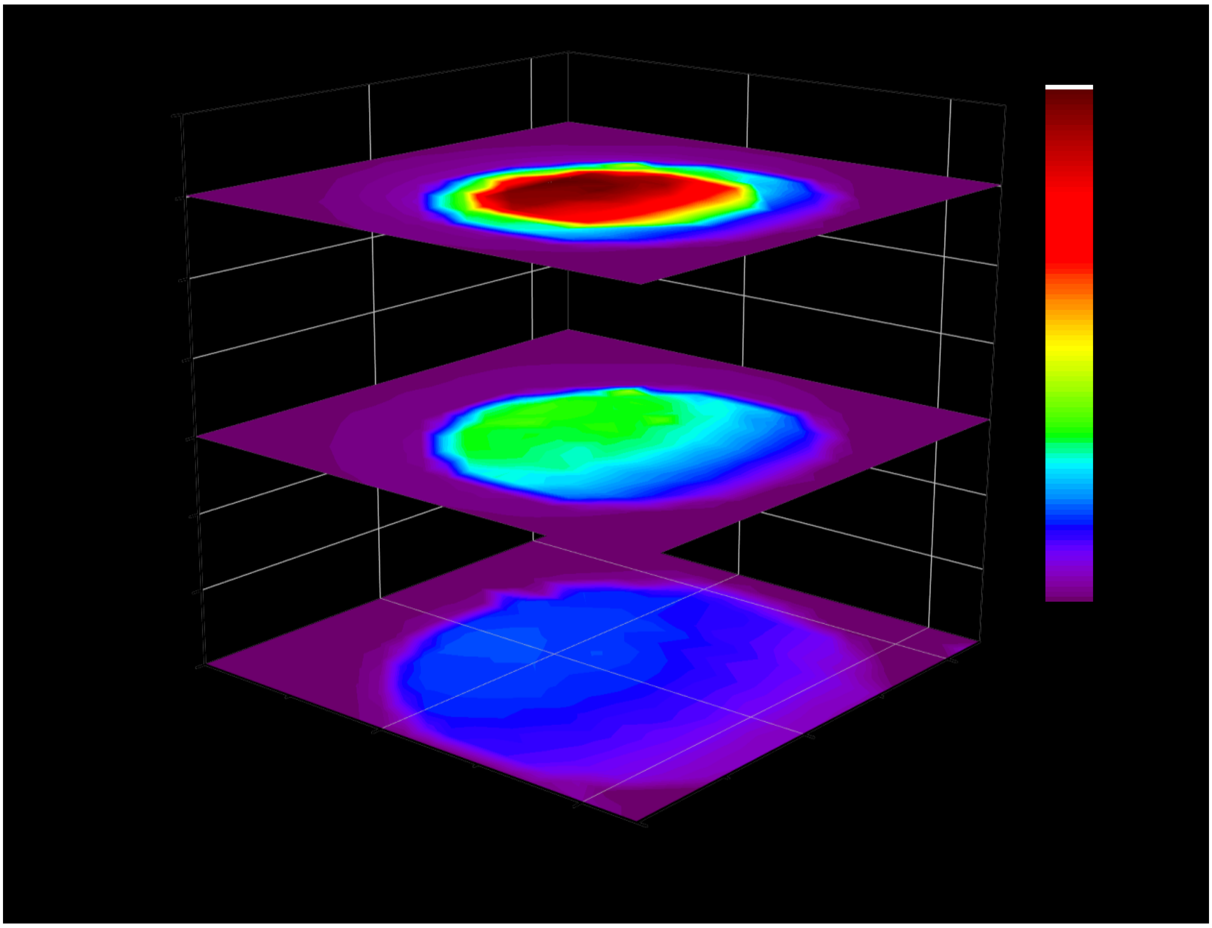

Figure 10. The X-ray dose distribution at the third step in the X-ray room.

V. CONCLUSIONS

The result shows that the shape of irradiation field in the X-ray chamber is not a perfect cone. There is a drift of high dose values to the left of the plate and it happens in all of three X-ray dose graphs in the different distances from the X-ray tube. Furthermore, the information of X-ray dose distribution is very useful to locate positions and appropriate doses on the plate for future experiments.

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PHÂN BỐ LIỀU BỨC XẠ TRONG BUỒNG ĐO MÁY PHÁT TIA X SỬ DỤNG LIỀU KẾ QUANG PHÁT QUANG NANODOT

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Tóm tắt:Trong thí nghiệm này, chúng tôi sử dụng liều kế quang phát quang nanoDot (Nagase, Landauer) đánh giá sự phân bố liều bức xạ trong máy phát tia X SOFTEX M-60W (SOFTEX Corp., Ebina-shi, Kanagawa, JAPAN). Sắp xếp và đánh giá mức liều của 361 liều kế nanoDot trên tấm kim loại kích thước 45×45 cm cùng kích thước với tiết diện mặt đáy bên trong buồng phát tia X sau khi chiếu xạ chúng bởi máy phát tia X ở điều kiện 50kV, 2.5 mA. Thí nghiệm được thực hiện với cùng điều kiện đo chỉ vị trí tấm kim loại thay đổi ở ba nấc có sẵn trong buồng phát tia X tương ứng ba khoảng cách khác nhau tính từ ống phát tia X. Kết quả cho thấy có sự lệch trái của các mức liều cao của cả ba phân bố. Các thông tin về sự phân bố mức liều bức xạ tia X trong thiết bị này rất hữu ích trong việc xác định vị trí và mức liều nhận được tương ứng trên tấm kim loại khi đặt trong buồng phát tia X. Tuy nhiên, thực hiện thí nghiệm này với nhiều điều kiện đo đạc nhằm đánh giá sự phân bố liều bức xạ trong máy phát tia X một cách đầy đủ hơn và cần thiết đối với các thí nghiệm khác trong tương lai.

Từ khóa: tia X, nanoDot, OSL, microStar, liều bức xạ.