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Dose Calculation for Low Energy X-ray Generator using Monte Carlo Simulation

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1. Introduction

Static electricity appears to cause damage during the manufacturing process of semi-conductors or a liquid crystal panels[1]. Various methods have been introduced to eliminate static electricity of the products in the industrial sector. Currently for this purpose of eliminating static electricity, a photoionizer that generates a low energy X-ray is most commonly being used. A photoionizer emits low energy X-rays of around 10 keV. It is expected significant health damage is not given to radiation workers because a photoionizer emits a low energy X-ray during operation, and furthermore radiation workers don't stay around the photoionizer during its operation. This study calculated radiation dose to radiation workers by photoionizers for typical situation using photoionizer in the field.

2. Materials and Methods

This study has considered an SXN-10 model, a photoionizer manufactured by Vacuum Science /Instrument (VSI) Corporation[2]. The model SXN-10 (figure 1) is composed of a head that projects radiation and a controller that controls radiation generation. The average energy of X-rays emitted from the SXN-10 was 7 keV and the maximum energy was 10.7 keV. Applied voltage of the X-ray tube was 11 kVp and its electric current was 0.28 mA. The irradiation angle of the photoionizer is 115° and is shown in Figure 2. The photoionizer is shielded with aluminum except discharge area. In order to calculate skin dose, which is a focus of the interest of exposure to radiation workers, Monte Carlo calculations have been performed. The calculations were carried out for skin doses from the front, left, and right side of the photoionizer. For dose calculation, two cases in which a radiation worker was directly exposed to either radiation or leakage radiation were considered. The calculation distances were 10cm, 30cm, and 100cm, each. Also, measured results by using a radiation survey meter at the same distance were compared with the calculated results.

2.1 Detector

As photoionizer emits low energy X-ray, an ion chamber type detector that can measure low energy photon from the X-ray generators was used for the measurements. For this measurement, a radiation survey meter, RGD 27091 of Sensortechnik und Elektronik Pockau (STEP) Inc[3] was used. This detector can measure range of 6 keV ~ 7.5 MeV.

2.2 Monte Carlo simulation

Monte Carlo simulation code, MCNPX Version 2.5.0[4], has been employed to calculate skin doses. The dose rates were calculated for 70 µm skin depths averaged 1 cm^2 area, in accordance with the ICRP recommendation[5]. The conversion electrons and backscattered correction were considered as defaults in estimating the dose rate. It was assumed that radiation emit evenly with irradiation angle of 115° from a point source which emits X-rays of 7 keV. Current values per electricity and dose rate (Sv/h) from 70 µm skin depth per photon which is generated from a photoionizer were calculated and F1 and F6 tallies were used to get the results. In order to calculate skin dose, dose conversion coefficients of ICRP 74[6] was used.

Figure 1. Photoionizer SXN-10(Left: Controller, Right: Head)

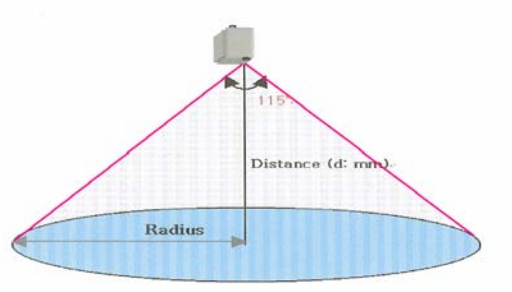

Figure 2. Irradiation angle (115°) of SXN-10 photoionizer

Table 1. Comparison of doses from measurement and calculation

Measurement point (cm)		Survey meter (*m*Sv/h)	MCNPX (*m*Sv/h)
Front	10	Range over	4.11E+03
	30	1.43E+03	3.28E+02
	100	3.50E+01	7.11E+00
Right	10	4.70E+00	1.68E+00
	30	8.30E-01	8.99E-01
	100	6.06E-02	1.60E-01
Left	10	4.70E+00	1.68E+00
	30	8.30E-01	8.99E-01
	100	6.06E-02	1.60E-01

3. Results and discussion

Calculated exposure dose to the skin by location are summarized in Table 1. The difference between measured values and calculated results complies with whether the skin thickness was in consideration. As shown in Table 1, when directly exposed from the front of the discharge area of a photoionizer, one can receive hundreds mSv of doses by distance. The exposure dose by leakage radiation generated from the left and right of a photoionizer was low enough to be ignored. In the calculated results from the left and right sides, MCNPX calculation gives relatively higher doses than measured values. This is probably because of a backscattering effect due to skin thickness. A photoionizer is usually installed inside a shielded room that satisfies shielding criteria, and is fixed on the ceiling to generate radiation from upward to downward direction. Also, a shielded room is designed to make an immediate stop when the door of the shielded room is opened by the safety interlock system. Furthermore, a worker operates photoionizers by using a controller installed outside the shielded room. When an operator is directly exposed to radiation from the front of a photoionizer, he or she may receive a higher dose. However, given the above working environment, it seems that operators will not receive unacceptable high dose.

3. Conclusion

This study made calculations only for a currently used photoionizer model, SXN-10 that generates low energy X-rays of 7 keV. In general, photoionizers generates low energy X-ray around 10keV. When taking into account the above, it may be necessary to calculate results from other photoionizers application. However it is anticipated that the estimation results would be similar to the values obtained in this study. Therefore, if a photoionizer is installed in a shielded room and radiation worker controls the equipment using controller installed outside the shielding room, it seems that there will be no harmful damage to radiation worker by exposures from the photoionizer.

REFERENCES

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