Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 18-19, 2017

Fabrication of optimized flattening filter of miniature X-ray tube based on carbon nanotubes for skin diseases treatment

Hyun nam. Kim, Han beom. Park, Ju Hyuk. Lee, Sung oh. Cho
Department of Nuclear & Quantum Eng. KAIST , Daejeon306701, Republic of Korea
trexpp@kaist.ac.kr

1. Introduction

Since the invention of the X-ray tube [1], it has been medically used in the imaging and treatment, and also it has been used industrially in a variety of imaging, detecting foreign matter and material analysis. X-ray tubes that are mainly used in the current market use a thermal electron source as an electron source. In the case of the X-ray tube using a thermal electron source, since electrons are emitted only after the filament sufficiently heated, the warm-up time is needed for the operation. In addition, since the filament is oxidized if too overheating, cooling time is also necessary. On the other hand, field emission typed X-ray tube does not require a warm-up for operation, also it does not need a large amount of time to cooling it. From these aspects, it can be said that the field emission typed X-ray tube have many advantages than the X-ray tube using a thermal electron source. We made a vacuum sealed field emission typed X-ray tube that can be operated at 50 kV of voltage with 0.3mA of current. This X-ray tube has various application, and has a specification suitable for use in the treatment of skin cancer. However, there are some problems when using the X-ray tube for the treatment of skin cancer, keloid. It is problem that radial dose uniformity of generated x-rays is not uniform. When actually operating the X-ray tube, dose is the highest at the portion of arrive straight from the X-ray source and dose decreases rapidly with increasing distance from that part. In this case, due to the imbalance in the amount of irradiation leads to difficulties and inaccuracies in the treatment. To address this problem, it is necessary to develop a device that make the X-ray dose distribution uniformly. This can be designed in view of the fact that the degree of X-ray attenuation is different depending on the thickness of the material to shield the X-ray. Such a device is referred to as Flattening filter [2-3]. Therefore, the present study aimed improving the flatness of the dose distribution at the patient's skin by introducing a flattening filter.

2. Methods and Results

2.1 Methods

Manufactured X-ray tube was used for experiments. When operating the X-ray tube, the X-ray is radiated in all directions which means not only to the lesions but also to the external lesions. However, since the data that we want is the uniformity of dose distribution of the lesions, it is need to be shielded the X-ray irradiation to the external lesions. Therefore, the collimator was manufactured for this purpose. Design of collimator was obtained by simulating the MCNP Code. In order to obtain the shielding thickness, the operating conditions (50 kV, 0.3 mA) of the X-ray tube was input to the MCNP Code. Finally, collimator having a thickness of results obtained earlier was manufactured. The material of collimator was stainless steel.

The Flattening Filter was manufactured to get better uniformity of dose distribution obtained from X-ray irradiated lesions. When the X-ray transmitted through a substance, the attenuation effect is different when the conditions (material, thickness of substance) of the substance are different. For example, the intensity of the X-ray directed to the center is the strongest. In contrast, the intensity of the X-ray toward the edge of the lesion is weakest. If getting idea to this point, the difference between the intensity of the X-ray directed to the center and the intensity of the X-ray directed to the edge of the lesion can be reduced after the X-ray transmitting the Flattening Filter that is designed by having thick center and thin edge. This is the method of designing the first Flattening Filter, and the material used for Flattening Filter was graphite.

MCNP Code is used for the task of optimizing the design by modifying the geometry of the first Flattening filter. Simulated dose distribution data at the surface adjacent to the Flattening Filter was obtained from MCNP Code simulating with entering the geometry of our X-ray tube, diameter of electron beam and geometry of designed filter to code. The diameter of electron beam of X-ray tube was obtained by using the pinhole method(EN-12543-2) [4]. From analysis of this data, new geometry of Flattening Filter was designed. The geometry of newly designed Flattening Filter by analyzing the characteristics of the dose distribution of data was re-entered to the MCNP Code to obtain the simulated dose distribution data at the surface adjacent to the new Flattening Filter. By repeating this process, it was possible to design an optimized Flattening Filter. After that, mount it on the X-ray tube, and obtain a real dose distribution in the surface adjacent to the filter.

Real dose distribution data was obtained by analyzing the X-ray irradiated EBT3 film which has the properties of change color depending on the degree of irradiation. Dose distribution data obtained from the operating of X-ray tube with Flattening Filter and without filter are both obtained to compare the uniformity of both case. EBT3 film color changed from the above procedure was analyzed by using a calibration curve obtained from a large amount of irradiated EBT3 film samples [5].

2.2 Effect of Flattening Filter

Geometry and design of the first Flattening Filter, dose distribution obtained by entering it through the simulation were shown in (Fig. 1). In the Dose distribution, it was still in the middle of the dose was found to significantly larger than the dose at the edges. Through the repetition of the comparative analysis. it was able to get the optimum geometry of the design Flattening filter.

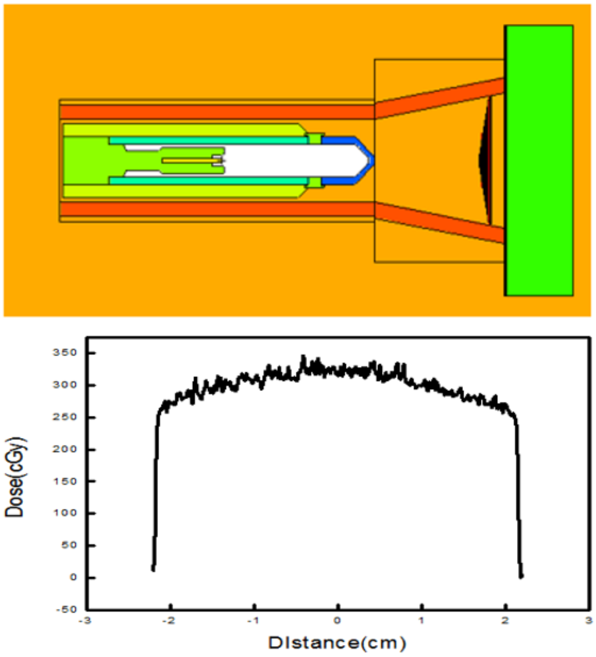

Fig. 2. Geometry and design of the first Flattening Filter, dose distribution obtained by using it

The dose spatial distribution obtained after mounting the Flattening filter was the same as the following (Fig. 3b).

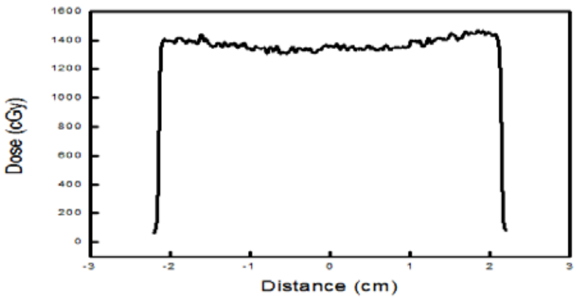

Fig. 2. Dose spatial distribution obtained after mounting the Flattening filter.

Comparing the dose spatial distribution (Fig. 1) obtained without attaching the Flattening filter, the results obtained with Flattening filter has better flatness. If more optimization process will be took, it is possible to get better flatness

3. Conclusions

The entire system equipped with the flattening filter was shown to be suitable for use as an electronic brachytherapy for skin cancer treatment because it has a uniform dose distribution.

REFERENCES

[1] Sung Hwan Heo, Hyun Jin Kim, Jun Mok Ha and Sung Oh Cho "A vacuum-sealed miniature X-ray tube based on carbon nanotube field emitters", Nanoscale Research Letters 7 (2012) 258

[2] Robert Jeraj, Attila Sarvary and Tomas Kron. Optional flattening filter shape of a surface brachytherapy applicator. Phys. Med. Biol. 47, 723–735 (2002)

[3] T. Kron, M. Haque, K. Foulkes, and R. Jeraj. A flattening filter for brachytherapy skin irradiation. Phys. Med. Biol. 47, 713–722 (2002)

[4] European Committee for Standardization: EN 12543–2, E. Brussels, 1999.

[5] Report of the Task Group 186 on model based dose calculation methods in brachytherapy beyond the TG-43 formalism: Current status and recommendations for clinical implementation: Med. Phys. 39 (10), October 2012