Measurements of dose enhancement induced by gold-coated nanofilm using flatbed scanner

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1. Introduction

Radiotherapy is one of the most common selections for cancer treatment. One obstacle to radiotherapy is resistance of tumor cells to radiation. Advancement of nanotechnology has suggested metal nanoparticle as radiosensitizer for this issue. Radiosensitizing using nanoparticles is useful in therapeutic purpose for its local dose enhancement to tumor cells.

Although the mechanism of radiosensitization is unclear, local dose enhancement induced by low energy secondary electrons is thought as the reason of radiosensitization. When X-ray bombards metal nanoparticles, several secondary electrons occur with various type of interactions. Among them, from the view of microscopic dose enhancement, Auger electrons are most possible factor due to their extremely short range in water. Among many metal nanoparticles, gold nanoparticles (GNPs) is promising for their good biocompatibility, and high Z-number that occurs superior amounts of Auger electrons [1].

Studies measuring the amount of local dose enhancement from GNPs with physical method have been rare due to low energy of secondary electrons. In this study, the direct measurement of local dose enhancement from GNPs was tried. Thin gold films with nanometer thickness was used as substitute for GNPs of equivalent size.

2. Methods and Results

Preparing procedure of gold nanofilm and measurement methods are described. Results of dose estimation is also discussed in this part.

2.1 Gold nanofilm

Bare polyethylene terephthalate (PET) film was cut into 1×1 cm^2 size as coating substrate for gold film. PET films were rinsed with distilled water after washing in ethanol with ultrasonic cleaning.

PET films was fixed with Kapton tapes on glass plates to maintain their flatness and position during coating procedure. These glass plates were set in the thermal evaporator to form gold nanofilms. Gold particles were deposited to form thin films on PET substrates using thermal evaporator (Centus OL100). Gold nanofilm with thicknesses of 20, 30, 40, 50, 100, 150, 200, 300 nm were made.

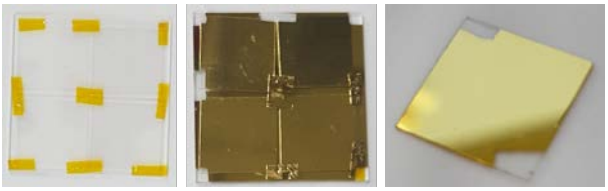

Figure 1 Deposition procedure of gold nanofilm. PET films were fixed on glass plates (a), and gold particles were deposit with thermal evaporator (b). Each gold nanofilm with substrates were removed from glass plates (c).

2.2 Unlaminated EBT-XD radiochromic film

Radiochromic films (GafChromic EBT-XD, Ashland) were used to measure the exposed dose into gold nanofilms. To measure low energy electrons from gold nanofilms, one side of protective layers of EBT-XD film was removed carefully. These unlaminated EBT-XD film was prepared with 3×3 cm^2 size.

Gold nanofilm and bare PET film were put tightly on each unlaminated EBT-XD film. Orientation of gold nanofilm was adjusted that the gold side of gold nanofilm and the active layer of EBT-XD film was put together. Bare PET films were attached on the side of gold nanofilms to compare the dose difference with and without gold.

An X-ray beam of 50 kVp (Xrad 320, Irradiation Systems) was used to deliver 0.3-3.0 Gy to gold nanofilm and bare PET film on unlaminated EBT-XD film at the same time.

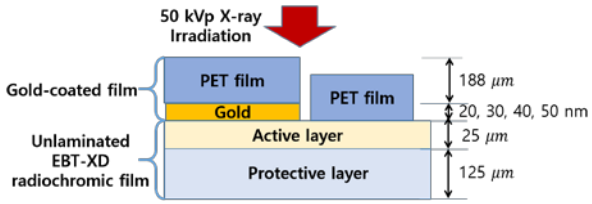

Figure 2 Exposure setup of gold nanofilm and unlaminated radiochromic film.

2.3 Dose estimation using flatbed scanner

Exposed unlaminated EBT-XD films were scanned with flatbed scanner (Expression 11000XL, Epson) after removing gold nanofilms and bare PET films. Red

channel was adopted for its better sensitivity and stability over the other two color channels.

2.4 Results

Thicknesses of gold nanofilms with thicknesses from 100 to 300 nm were estimated. Alpha-step (Alpha-Step IQ surface profiler, KLA-Tencor) was used and showed average 89% of intended thickness. (Table I)

Table I: Estimated thickness of gold nanofilm

Intended thickness (nm)	Estimated thickness (nm)	Deposit ratio
100	88.8	0.89
150	137.0	0.91
200	175.7	0.88
300	266.9	0.89

2.5 Dose estimation

A dose response curve was prepared for the dosimetry purpose for flatbed scanner and Raman spectroscope at 50 kVp X-ray beam. Dose enhancement factor contributed by gold-coated nanofilm were 2.09, 2.49, .40, 3.34, 5.13 for 20, 30, 40, 50, 100 nm thickness of gold, respectively estimated using flatbed scanner. Raman spectroscopy showed 1.95, 2.23, 2.39, 2.47, 3.12 of dose enhancement factor for each thickness.

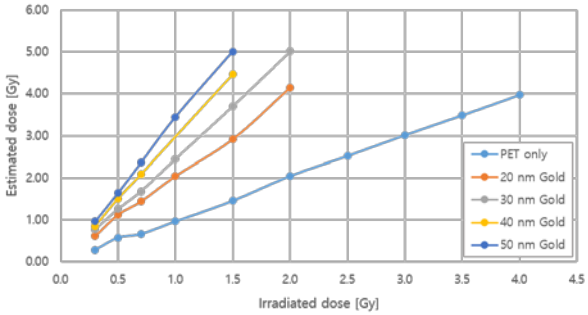

Figure 3 Dose estimation of 20-50 nm thickness gold nanofilms

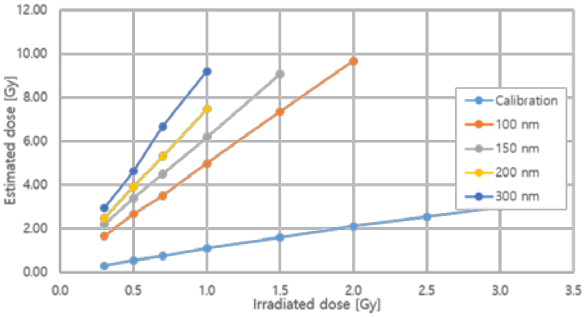

Figure 4 Dose estimation of 100-300 nm thickness gold nanofilms

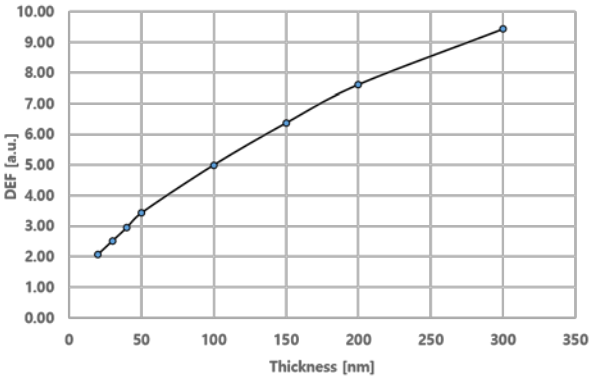

Figure 5 Dose enhancement factor curve with thicknesses of gold nanofilms

3. Conclusions

Dose enhancement increased with thicker gold-coated nanofilm up to 300 nm. Geant4 showed that dose enhancement factor increased until 5000 nm gold-coating thickness. These results implies that local dose enhancement contributed by gold nanoparticles also increases with increased particle size.

REFERENCES

[1] Wonmo Sung, Seongmoon Jung, Sung-Joon Ye, Evaluation of the microscopic dose enhancement for nanoparticle-enhance Auger therapy Physics in Medicine and Biology. 2016; 61(21):7522– 35.