Design Case Studies of Anti-scattering X-ray Grid by MCNP Code Simulation

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Introduction

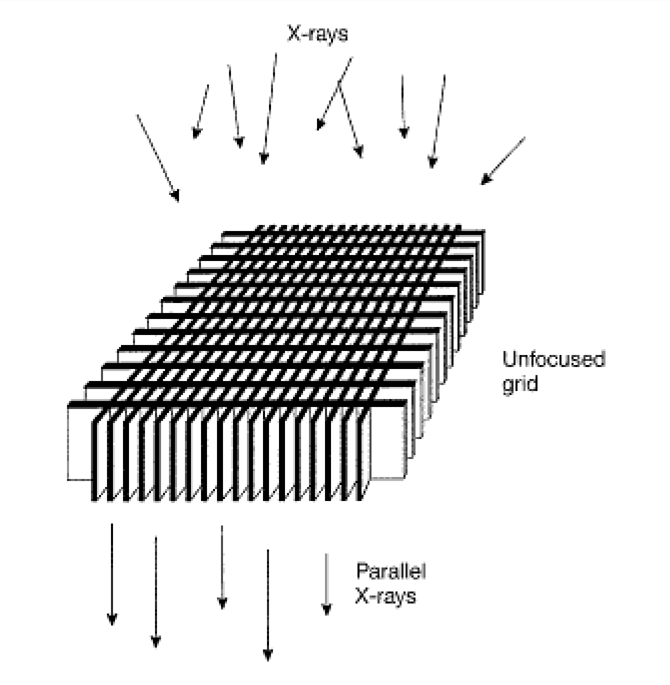


Fig. 1. Schematic of a unfocused grid with parallel walls.

X-ray anti-scattering grid:

- In X-ray imaging system, X-ray interacts with tissue of body and is scattered.
- So proper grid which can reduce the scattered photon should be equipped in the X-ray image system.

Introduction

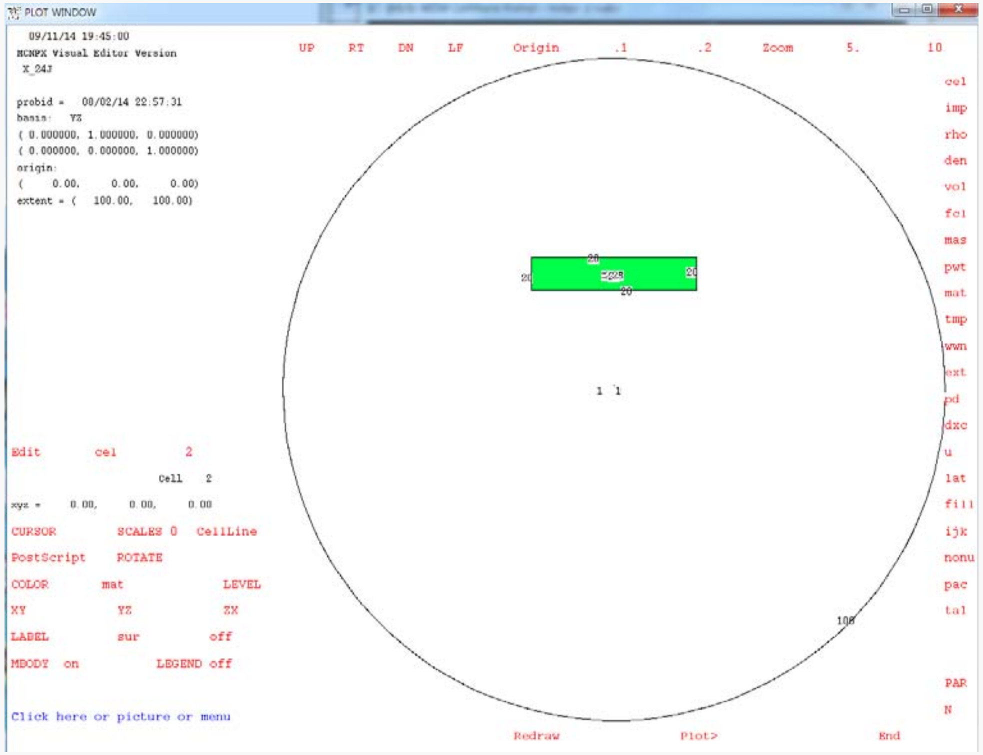


Fig. 2. Basic MCNPX plot window.

MCNP:

- MCNP is a radiation transport and tracking code.
- MCNP can build up various customized geometry and material and source types.

Simulation Design

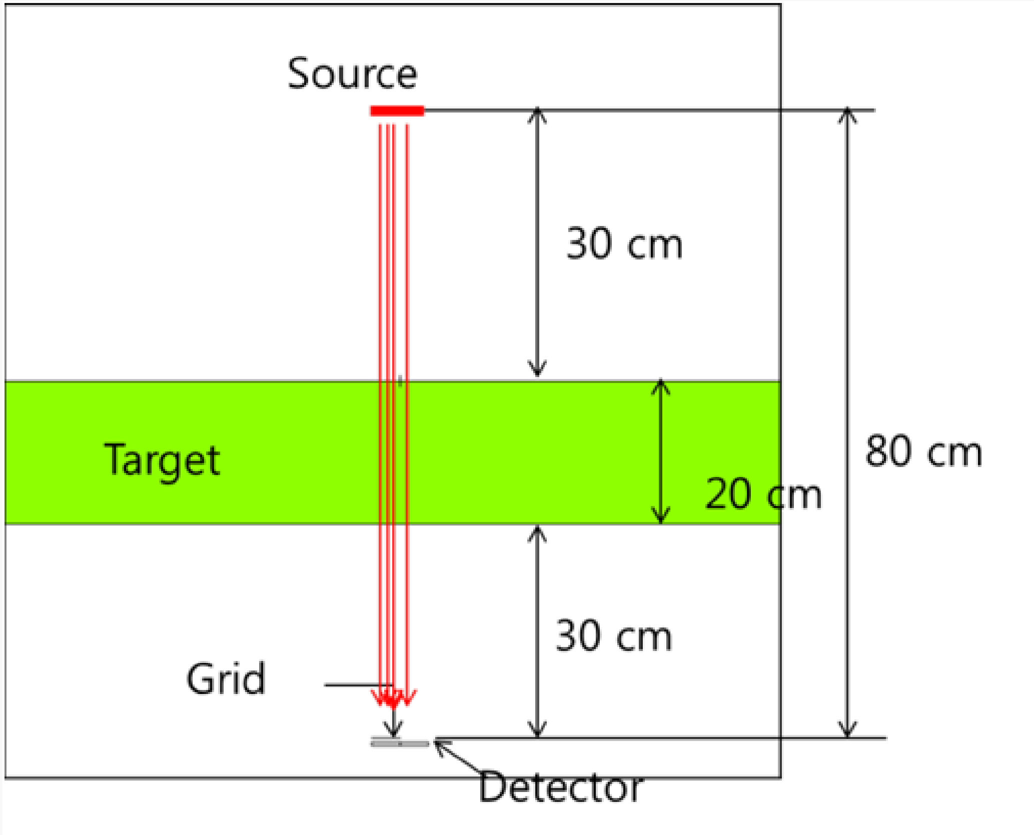


Fig. 3. The simulation geometry.

Fig 3. shows overall view of the simulation geometry that consists of four parts; **source**, **target**, **detector** and **grid**.

- **The source** was placed above 30 cm from the target.
- **The source** was 80 keV single energy photon area source and the photon had direction to the grid and detector normally.

Simulation Design

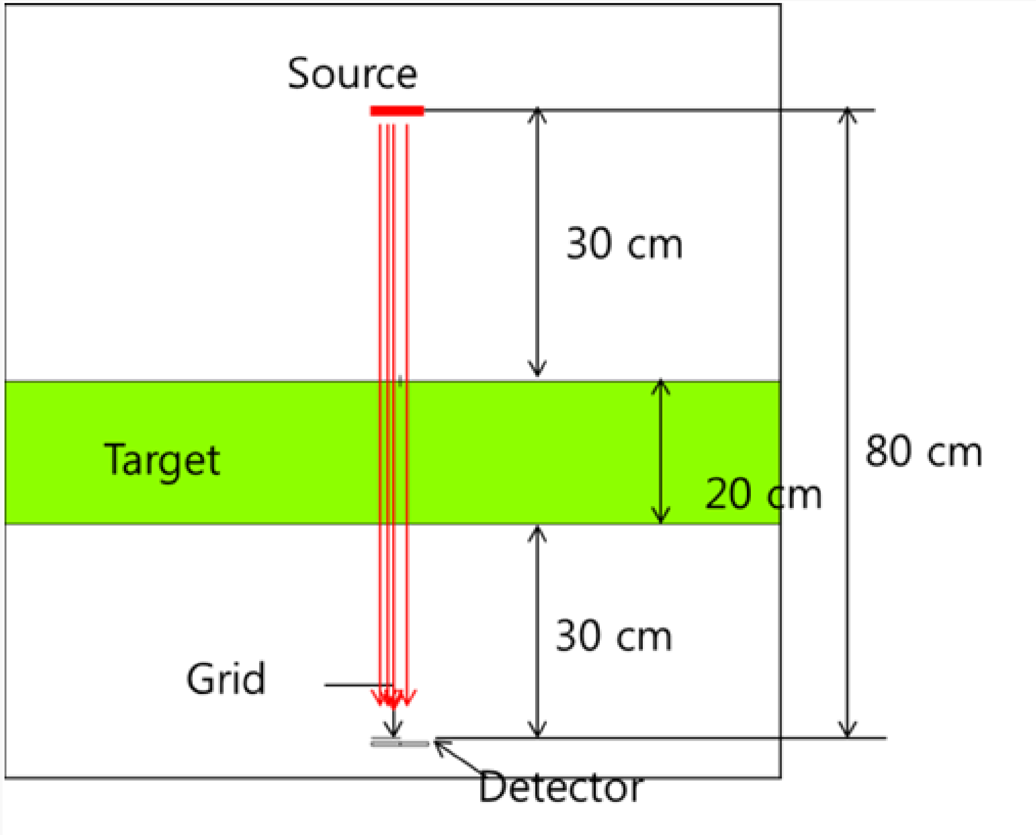


Fig. 3. The simulation geometry.

(continued)

- **The target** had height of 20 cm and grid and was placed above 30 cm from the grid.

- **The target** was composed of H_2O and had density of 1.00 g/cm^3.

Simulation Design

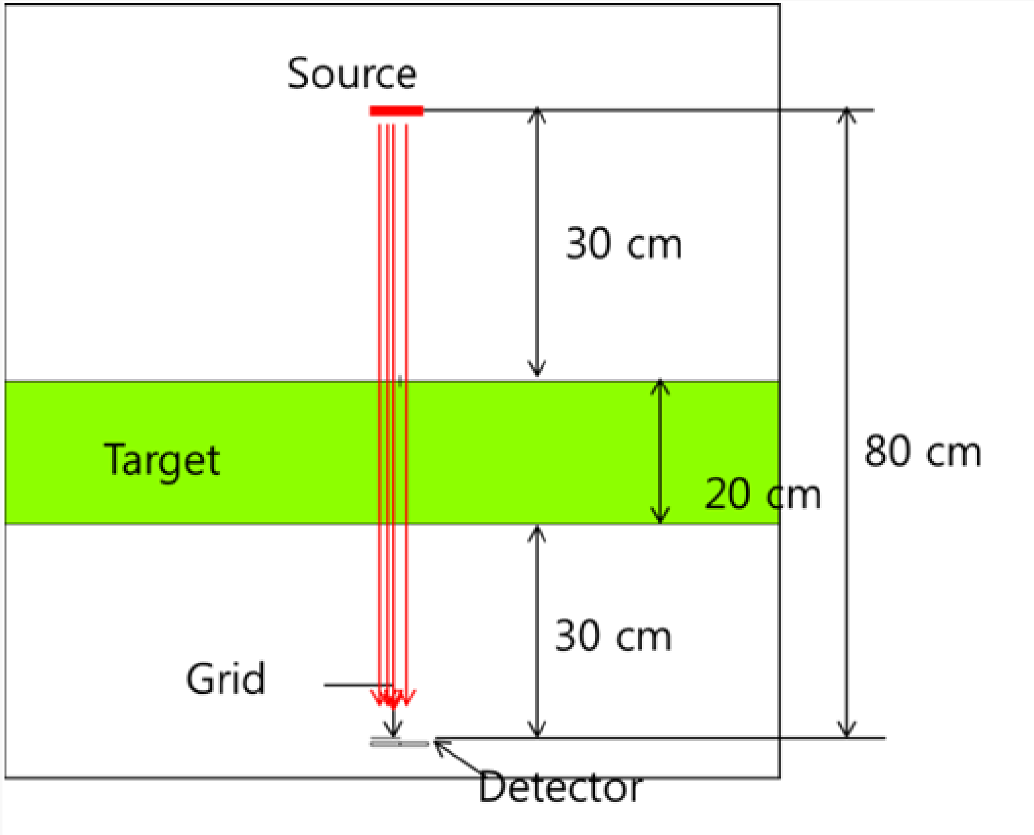
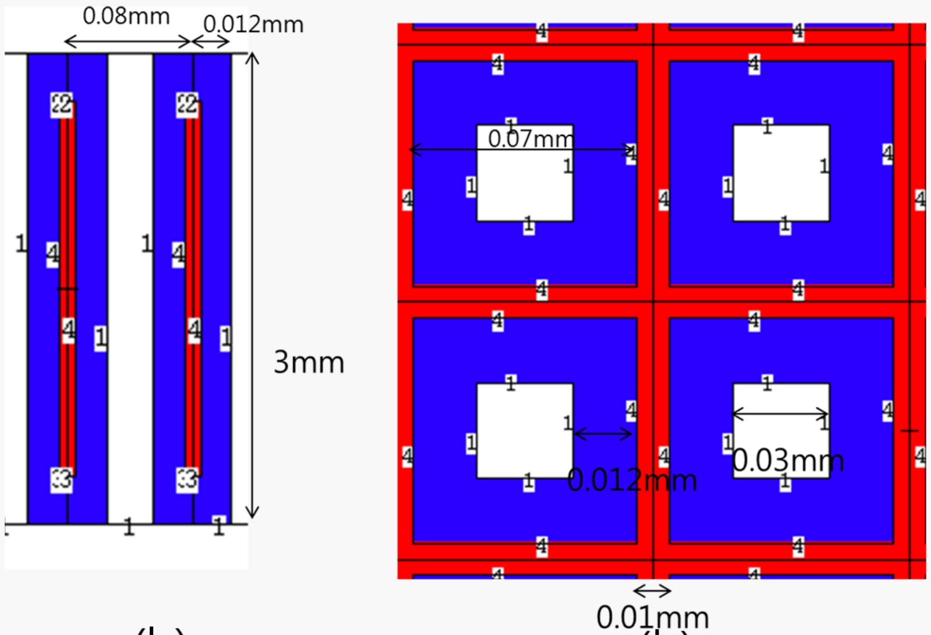


Fig. 3. The simulation geometry.

(continued)

- **The detector** was a 8 cm × 4 cm × 1 mm rectangular void cell.
- **The grid** was placed only placed on the left (x<0) side of detector because of comparison between data with grid and without grid.

Grid Design



(b) (b)

Fig. 4. The geometry **of square-type grid.**

- The whole grid shape was 4 cm × 4 cm square and thickness (z-direction) is 3 mm.
- The red part represents glass, the frame structure, and the blue part gold, the shielding material which had 19.3 g/cm^3 of density.
- For square-type, length of a lattice cell was 0.08 mm.
- The thickness of frame structure was 0.005 mm and thickness of shielding material was 0.012 mm.

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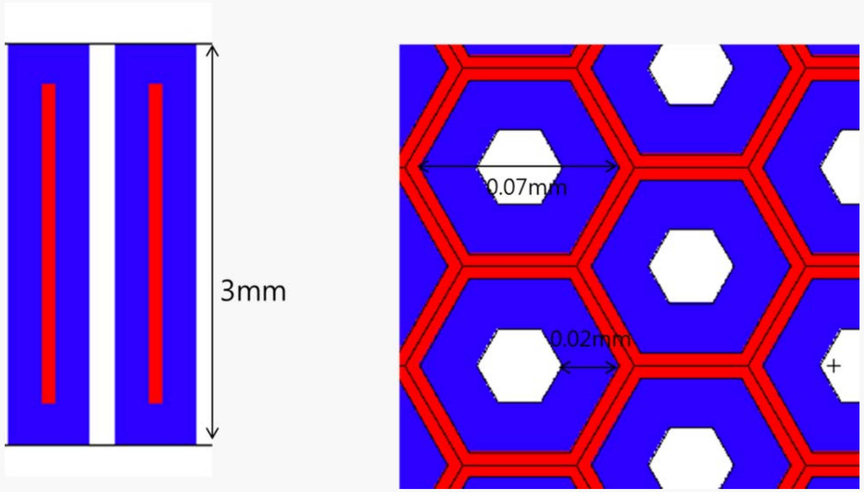
Grid Design

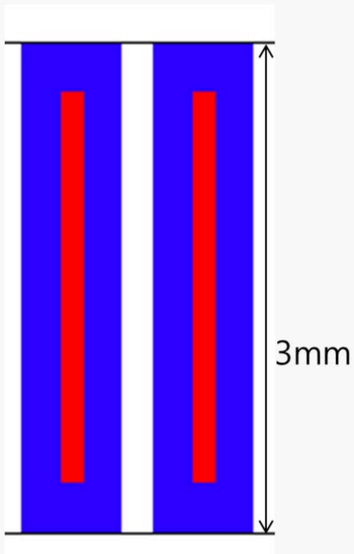


(a) (b)

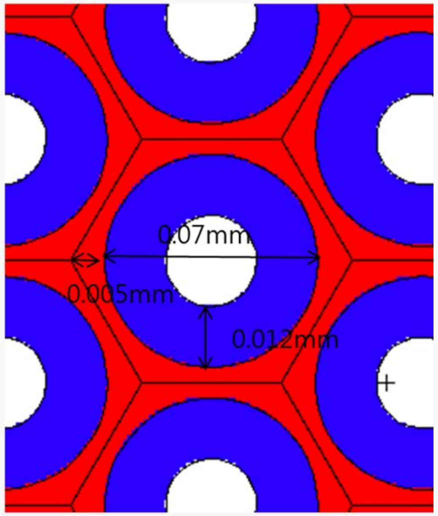
Fig. 5. The geometry **of honeycomb-type grid.**

- For honeycomb-type, it was hexagonal repeated lattice.
- Length of a side of hexagon was 0.040 mm.
- Thicknesses of frames structure and shielding material were 0.005 mm and 0.012 mm for each cell, respectively.
- The thickness of shielding material varied in optimization study.

Grid Design



(a)



(b)

Fig. 6. The geometry **of circle-type grid.**

- For circle-type, it was hexagonal repeated lattice.
- Diameter of a circle was 0.07 mm. Frame structure was filled among each cell.
- Thickness of shielding material was 0.012 mm.

Results & discussion

- First, shielding material thickness optimization was conducted.

- By using energy distribution tally, recorded photon was classified by two parts. The one is 0~79.999 keV which means scattered photon, and the other one is 79.999~80keV which means primary photon.

- S/P (scattered to primary ratio) is a criterion of performance of grid. If S/P is lower, which means scattered photons are relatively fewer, the performance is higher.

- The condition of grid was as following;
  - For a side length 0.035 mm, thickness of shielding material for 1~25 μm was conducted.
  - For a side length 0.040 mm, thickness of shielding material for 1~15 μm was conducted.
  - For a side length 0.045 mm, thickness of shielding material for 1~20 μm was conducted.

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Results & discussion

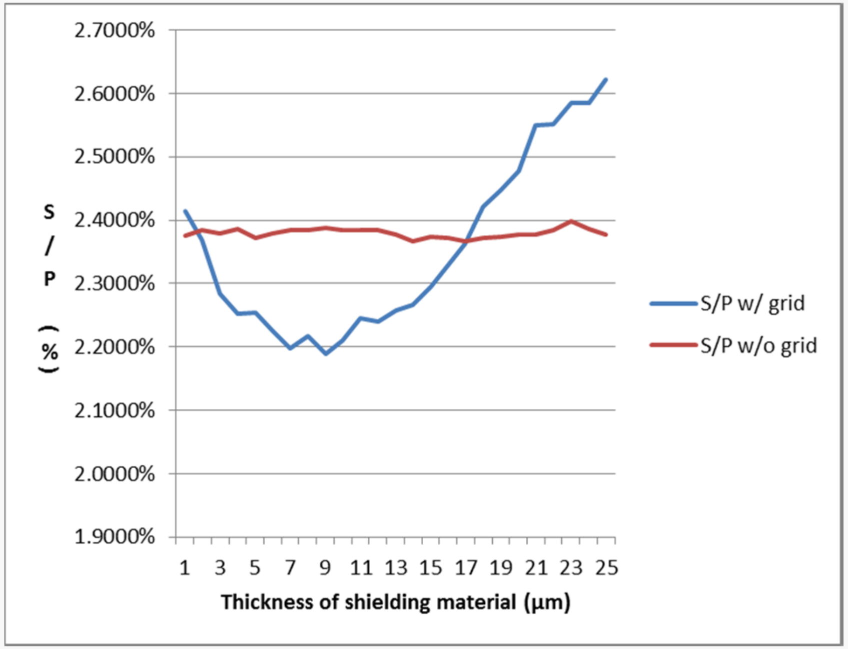

Fig. 7. The S/P (%) according to the thickness of shielding material (μm) for honeycomb-type (length of a side of hexagon : 0.035 mm)

- When length of a side was 0.035 mm, S/P was minimum when the thickness was 7~9 μm.
- If the thickness of shielding material was increased too much (>17 μm) S/P with gird is higher than S/P without grid, which means the grid makes the image quality worse.

Results & discussion

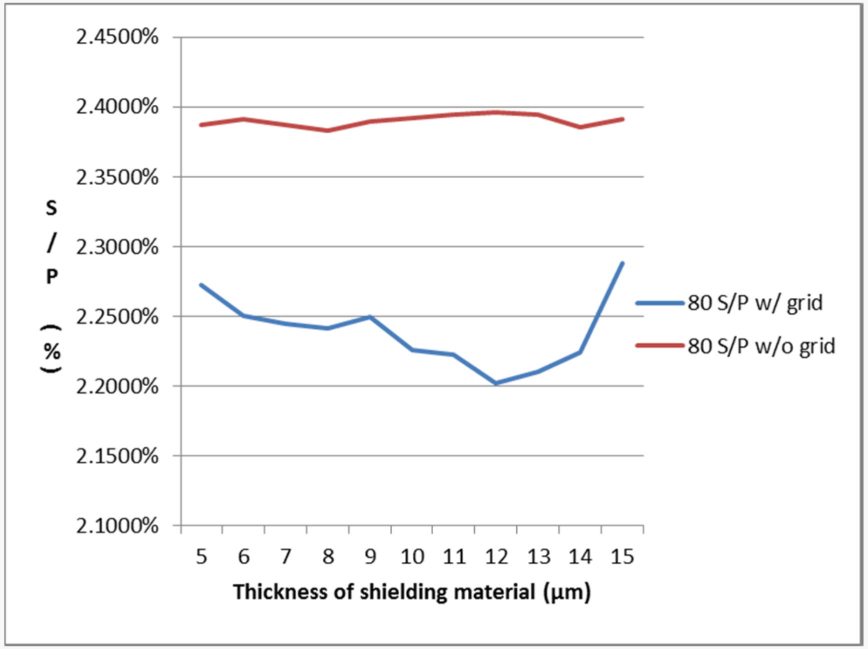

Fig. 8. The S/P (%) according to the thickness of shielding material (μm) for honeycomb-type (length of a side of hexagon : 0.040 mm).

- When length of a side was 0.040 mm, S/P was minimum when the thickness was 12 μm.

Results & discussion

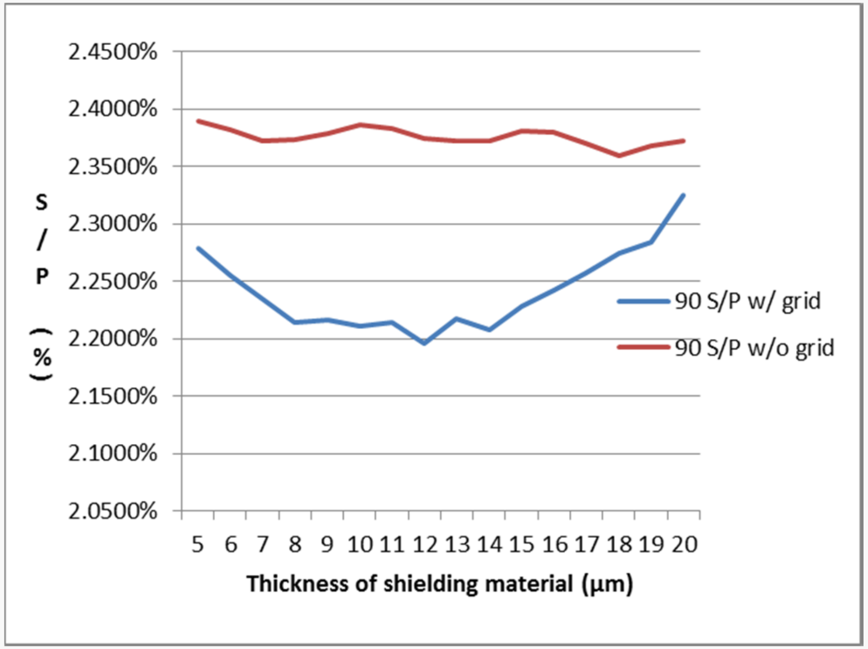

Fig. 9. The S/P (%) according to the thickness of shielding material (μm) for honeycomb-type (length of a side of hexagon : 0.045 mm)

- When length of a side was 0.045 mm, S/P was minimum when the thickness was 11~13 μm.

Results & discussion

- S/P had minimum value at 10~12 μm.
- The minimum S/P point was increased when the length of cell is increased.
- Additionally, comparison for three grid types (square, honeycomb and circle type) was conducted.
- In this simulation, thickness of shielding material was same for 12 μm.

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Results & discussion

Table 1. The simulation result for each type. The number of scattered photon, the number of primary photon and their ratio.

Type	Number of Scattered photon	Number of Primary photon	S/P
Square	1.68E-05	7.27E-04	2.3070 %
Honeycomb	1.66E-05	7.27E-04	2.2902 %
Circle	1.75E-05	7.53E-04	2.3203 %
None	2.41E-05	1.02E-03	2.3558 %

Results & discussion

- All the result had 0.9 % of relative error in simulation.
- The results of three types had no big difference.
  - ✓ Relative difference was less than 1 %
- The circle type had relative high S/P. It was thought that circle type had much glass part which can contribute to photon scatter.
- The ratio of cross-sectional area of glass part when the length of a side is 80 μm is as following:

$$\text{Square} : \text{Honeycomb} : \text{Circle} = 1:1:3.16$$

- But this is not efficient to explain.

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Results & discussion

- cross-sectional area of void part could be a cause because both scattered photons and primary photons are increased. But it is not exactly matched.

- The ratio of cross-sectional area of void part per cell is as following:

$$\text{Square : Honeycomb : Circle} = 1:1:\frac{2\pi}{3\sqrt{3}} \sim 1.21$$

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Conclusion

- The design case study of anti-scattering X-ray grid was performed for the three designs of square, honeycomb and circle type by MCNP simulation.
- The optimization of thickness of shielding material was conducted on three cases of the length of a side of hexagon of honeycomb type anti-scattering X-ray grid.
- It was understood that the performance of grid had **very little dependency** (<1 %) on the **grid geometry type** in this fundamental approach.
- It was thought the analysis results could be extended to the further study on the thickness optimization for each type and variable selection.

References

[1] A. Dowling, T. Kenny, J. Malone "Acritical overview of acceptance testing using various measured indices", Radiation Protection Dosimetry, **94** (2001) 53-58
[2] Rebecca Fahrig, James G. Mainprize, Normand Robert, "Performance of glass fiber antiscatter devices at mammographic energies" **21** (1994) 1277-1282
[3] C.-M. Tang, E. Stier, K. Fischer, H. Guckel "Antiscattering X-ray grid", icrosystem Technologies, **4** (1998) 187-192
[4] Los Alamos National Laboratory, "MCNP – a general monte Carlo N-Particle Transport Code version 5" (2008)