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Comparison of Shielding Capacity of Self-produced nano-size and micro-size molybdenum shielding sheet with diagnostic X-ray imaging system

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Abstract

Background/Objectives*: Lead is widely used as a material for shielding radiation. but lead is harmful and expensive to dispose of. shielding materials that can be used in place of lead are bismuth (Bi), tungsten (W) and molybdenum (Mo). as these materials become smaller in size, the surface area of the entire material increases dramatically, resulting in nano sized materials having different physical properties therefore, the purpose of this study is to use molybdenum, which is harmless to the human body as a material to replace lead, to produce shielding sheets according to particle size and to compare shielding capacity.*

Methods/Statistical analysis*: Nano-sized molybdenum and micro-sized molybdenum particle was analyzed using TEM equipment. molybdenum was used to fabricate micro and nano sized shielding sheets and to analyze the shielding performance according to energy band. shielding ability of the nano-sized molybdenum shielding sheet and the micro-sized molybdenum shielding sheet was compared according to the kV range. the low energy range was set from 41kV to 70kV, and 5 times were measured in the range of 41-50, 51-60, 61-70 with increasing kV by 1. the Middle Energy Range was set from 71kV to 100kV, and the measurement was repeated five times in the range of 71-80, 81 -90, 91-100 with increasing kV by 1*

Findings*: In the low-energy area (41-70kV), micro-shields had 81% higher transmittance than nano shielding. In the middle energy area (71-100kV), micro shielding had an 18% higher transmission rate than nano shielding. In high-energy areas (101-140kV), the transmittance rate of micro and nano shielding was the same.*

Improvements/Applications*: As a result of comparing the shielding ability of the molybdenum of the micro particle size and the nano particle size, the shielding ability of the nano particle size molybdenum sheet showed better shielding ability in the low energy region.*

Keywords*: Lead, Shielding Material, Nano particle, Molybdenum, Transmissivity*

1. INTRODUCTION

Radiation is widely used in the medical field to diagnose and treat patients' diseases. however, when radiation is irradiated to human tissues, care should be taken to cause biological radiation injury such as cancer, cataracts and leukemia [1]. in order to prevent such radiation injury, a shielding material is used to reduce the exposure dose of not only patients but also radiation workers [2]. most of the materials used to shield use lead shielding materials. due to the low cost, it is economical and easy to manufacture with low melting point. However, lead is harmful to humans such as nervous system damage, and also has a problem that the cost of disposing of lead is quite high. therefore, studies are being conducted actively to replace lead used to shield radiation. [3,4]. Shielding materials that can be used in place of lead are bismuth (Bi), tungsten (W) and molybdenum (Mo). as these materials become smaller in size, the surface area of the entire material increases dramatically, resulting in nano sized materials having different physical properties [5]. therefore, recent studies on tungsten have been reported to improve the X-ray shielding ability according to the particle size [6-8]. the purpose of this study is to compare the shielding capacity of molybdenum of micro-particle size and nanoparticle-sized molybdenum as an alternative to lead to particle size within the X-ray energy range of the diagnostic area.

2. MATERIALS AND METHODS

2.1. *Molybdenum Particle Size Analysis*

The particle size of molybdenum was analyzed using TEM (Transmission Electron Microscope, Model: JEM-2100F, Rigaku JEOL, Japan). TEM is an analytical device that can identify images, crystal structures of local regions, and arrangement of atoms through research with very high resolution in the material field [Figure 1].

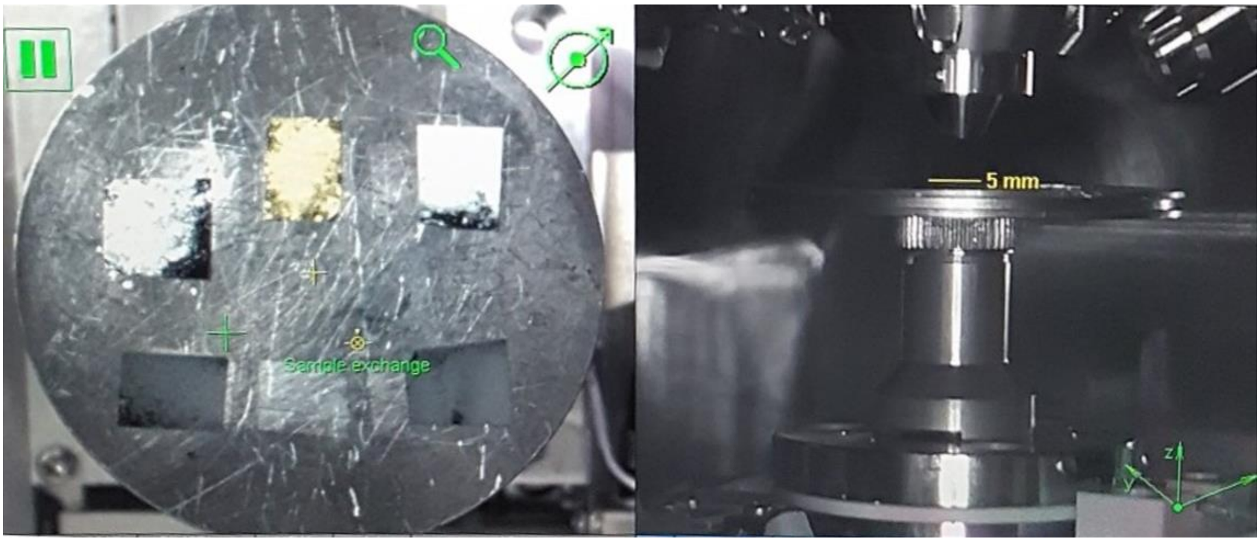


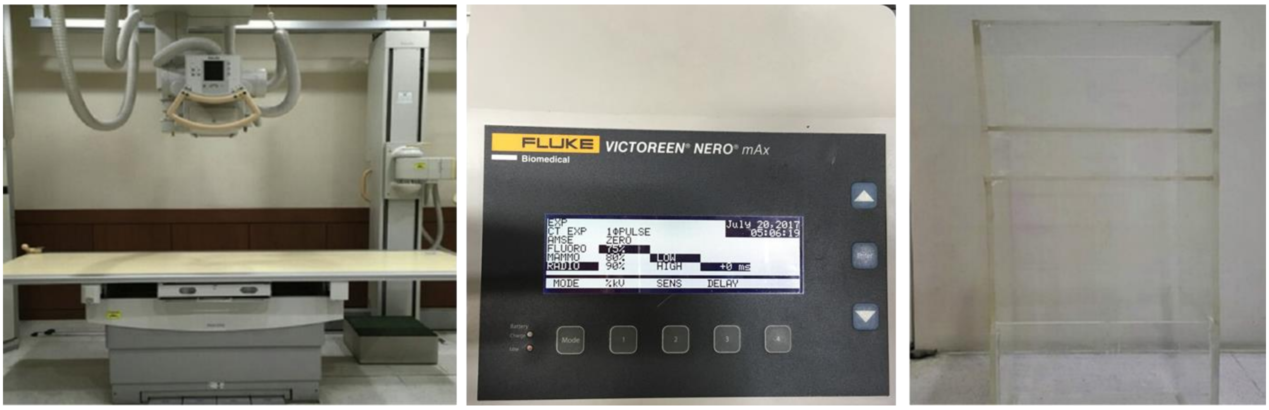
Figure 1. Image of Molybdenum particle analysis using Transmission Electron Microscope equipment

2.2. *Self-produced molybdenum shielding sheet*

Molybdenum shield was prepared in 200 X 200 X 1mm size through the process of drying, molding, pressing, and aging by stirring Nano Molybdenum powder with particle size less than 100 nm and Micro Molybdenum powder of 180μm size with silicon polymer.

2.3. *Shielding Capability Measurement*

The X-ray generator used for the measurement was Philips Digital Diagnost VR (IR-1100-150, Philips, Eindhoven, Netherlands). The dosimetry device used in this study was an 8000 Victoreen NERO mAx. Phantom composed of acryl (94.5 X 40 X 40 cm) was used [Figure 2].

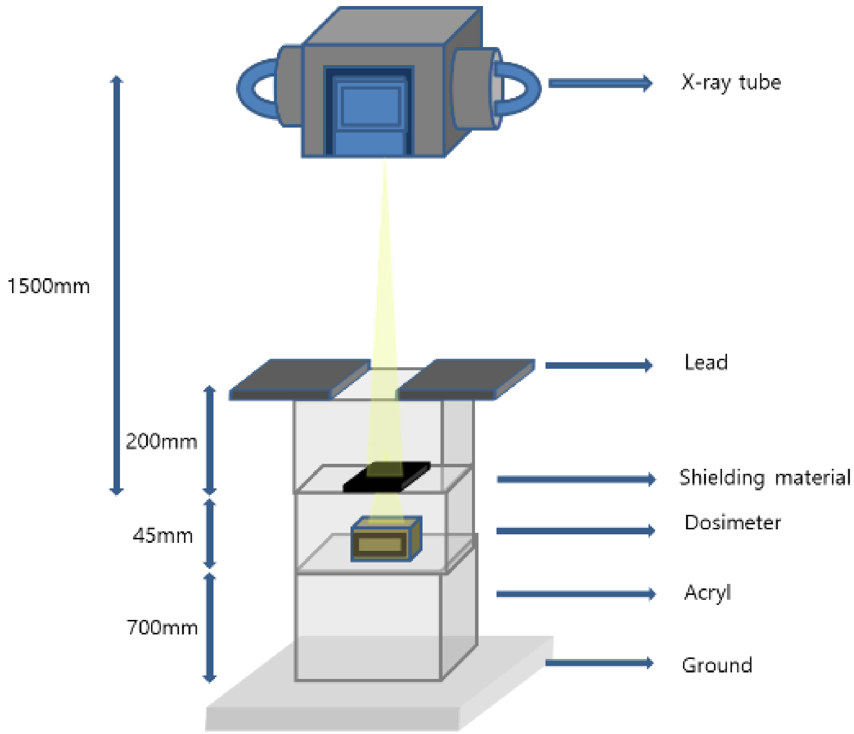


(a) (b) (c)

Figure 2. Photo of the equipment used in the experiment: (a) X-ray generator (b) dosimetry (c) acryl phantom.

The test method for measuring the transmittance was applied in accordance with the same method as the X-ray protective product lead equivalent test method (KS A 4025: 1990, 2005). The distance between X-ray tube and X-ray dose meter is 150cm, the distance between lead and shield of acryl Phantom is 20cm, the distance between shield and X-ray dose meter is 4.5cm, and the distance between X-ray dose meter and bottom is 70cm. Fix it. After the mAs was fixed to 10, the shielding ability of the nano-sized molybdenum shielding sheet and the micro-sized molybdenum shielding sheet was compared according to the kV range. The low energy range was set from 41kV to 70kV, and 5 times were measured in the range of 41 ~ 50, 51 ~ 60, 61 ~ 70 with increasing kV by 1. The Middle Energy Range was set from 71kV to 100kV, and the measurement was repeated five times in the range of 71 ~ 80, 81 ~ 90, 91 ~ 100 with increasing kV by 1. The high energy range was set from 101kV to 140kV, and the measurement was repeated five times in the range of 101 ~ 110, 111 ~ 120, 121 ~ 130 with increasing kV by 1 [Figure 3].

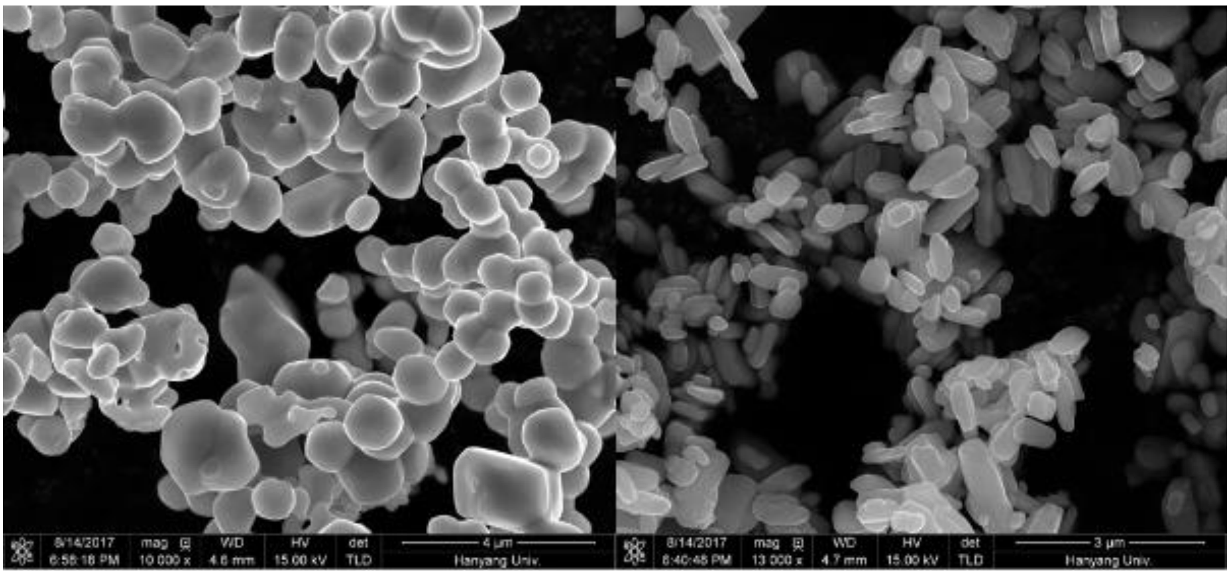
Figure 3. The acrylic phantom was developed to maintain a fixed distance between the X-ray tube and the shielding material specified in the guidance of KS.



3. Results And Discussion

3.1. *Molybdenum Particle Size Analysis*

An image analysis of the structure and properties of particles using TEM equipment showed that nanoscale tungsten was more dispersive than particles of more than micro size, resulting in a significantly lower air gap rate [Figure 4].



(a) (b)

Figure 4. Image of a Molybdenum particle magnified using TEM equipment: (a) Micro particle size moly bdenum (b) Nano particle size molybdenum

3.2. *Shielding Capability Measurement*

In the low-energy area (41~70kV), micro-shields had 81% higher transmittance than nano shielding. In the mi ddle energy area (71-100kV), micro shielding had an 18% higher transmission rate than nano shielding. In high-energy areas (101-140)kV, the transmittance rate of micro and nano shielding was the same [Table 1, Table 2, T able 3], [Figure 5].

Table 1: Transmissivity rate of Low-energy X-ray Range

kV Range	Micro size transmissivity average	nano size transmissivity averagre	Micro size transmissivity /nano size transmissivity	low energy transmissivity average
41 ~ 50	2.43	1.12	2.16	1.81
51 ~ 60	2.56	1.43	1.79	
61 ~ 70	2.67	1.79	1.49	

Table 2: Transmissivity rate of Middle-energy X-ray Range

kV Range	Micro size transmissivity average	nano size transmissivity average	Micro size transmissivity /nano size transmissivity	Middle energy transmissivity average
71 ~ 80	2.72	2.1	1.29	1.18
81 ~ 90	2.92	2.48	1.17	
91 ~ 100	3.07	2.84	1.08	

Table 3: Transmissivity rate of high-energy X-ray Range

kV Range	Micro size transmissivity average	nano size transmissivity average	Micro size transmissivity /nano size transmissivity	high energy transmissivity average
101 ~ 110	3.38	3.34	1.01	1.0
111 ~ 120	3.79	3.79	1.0	
121 ~ 130	4.22	4.22	1.0	
131 ~ 140	4.73	4.72	1.01	

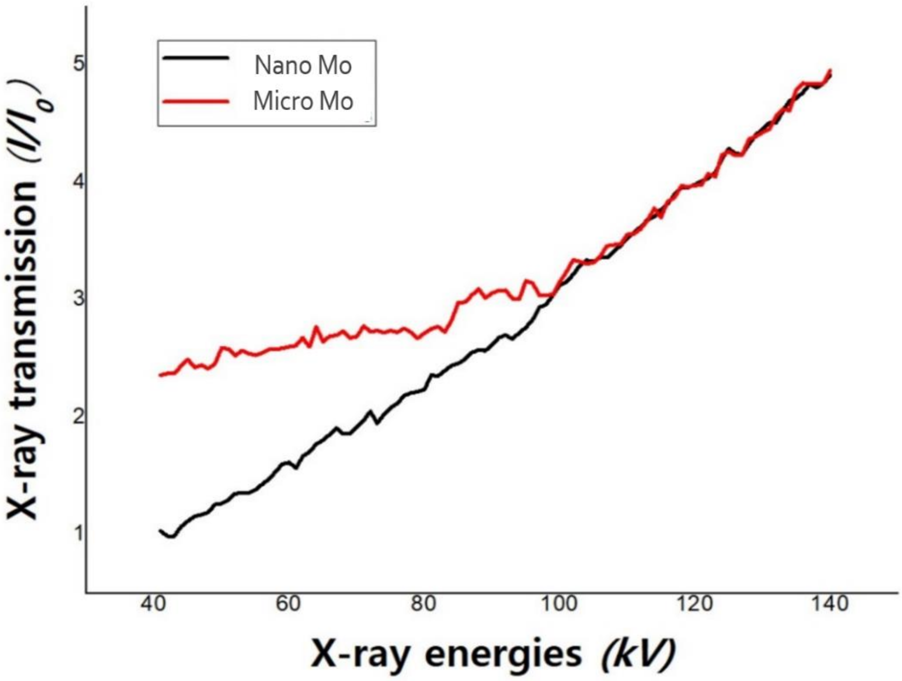


Figure 5. Graph of comparison result of X-ray transmissivity between micro sized and nano sized molybd enumshielding materials for tube voltage range of 41–140 kVp

3.3. *Statistical analysis*

As a result of statistically analyzing the transmittance according to the energy, the shielding rate of the shielding sheet composed of micro-sized particles and nano-sized particles in all tube voltage ranges was statistically significant since the paired t-test showed p <0.05. 8 [Table 4].

Table 4: Result of statistically analyzing the transmittance according to the energy

Energy Range		Mean±SD	t score	p-value
Low energy	Micro	1.67±0.37	-13.152	p < 0.05
	Nano	2.32±0.12		
Middle energy	Micro	2.75±0,24	-6.34	
	Nano	2.97±0.26		
High energy	Micro	4.02±0.53	-4.14	
	Nano	4.03±0.52		

* Statistically significant < 0.05, by pared t –test.

SD: standard deviation

3.4. *Discussion*

Lead is widely used for radiation shielding, as it has the advantage of being economical and easy to process due to its superior radiation shielding rate with high atomic number and low price. However, it has disadvantages such as harm to the human body and the environment and heavy weight when manufactured with an apron for radiation protection. Therefore, studies are actively being conducted to find substances that are not harmful to the human body and the environment to replace these lead, and molybdenum has been selected in this study. A sheet was made of molybdenum the size of a microparticle and molybdenum the size of a nanoparticle to test the shielding rate. Tests have shown that shield sheets made up of nanoparticles have better shielding rates in low energy areas (41 to 70kv) compared to sheets made up of micro-size. In the low-energy area (41~70kv), micro-shields had 81% higher transmittance than nano shielding. In the middle energy area (71-100kv), micro shielding had an 18% higher transmission rate than nano shielding. In high-energy areas (101-140)kV, the transmittance rate of micro and nano shielding was the same. The reason for these results is that nanoscale particles can be evenly distributed without cohesion compared to micro-sized particles, improving the ability of X-ray attenuation, and the smaller the particle's size, the smaller the air gap itself, the more shielding efficiency. This was similar to a trioxide tungsten experiment with nano-size and micro-size [8-11]. The properties of molybdenum fine powder consisting of nanoscale particles were analyzed using TEM equipment. An analysis of particle structure images using TEM equipment showed that nanoscale molybdenum was more highly dispersive than particles larger than micro-sized, resulting in significantly lower free space between particles. The determination and shielding efficiency of molybdenum of nanoparticle size were analyzed to confirm that nanoparticles of molybdenum, a substance, were superior in the low energy area of the diagnostic area to replace lead.

4. Conclusion

As a result of comparing the shielding ability of the molybdenum of the micro particle size and the nano particle size, the shielding ability of the nano particle size molybdenum sheet showed better shielding ability in the low energy region. Therefore, it is thought that applying nanoscale molybdenum to shield low-energy radiation, the main exposure factor for patients and radiation workers, would reduce the exposure dose of patients and radiation workers.

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