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Shielding performance evaluation according to grid particle dispersion method for manufacturing medical radiation thin film shielding sheet

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의료방사선 박막 차폐시트 제작을 위한 그리드 입자 분산 방식에 따른 차폐성능 평가

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Abstract Shielding clothing used as medical radiation shielding requires weight and flexibility so that it does not restrict the activities of the medical staff or patients. Lead is mainly used as the existing shielding material, and flexibility is secured by mixing lead powder and rubber powder to make a rubber sheet. However, there are problems due to the risk and weight of lead. Although some eco-friendly shielding materials such as tungsten, barium sulfate, and bismuth oxide have solved the lightweight problem, it has not reached a level of medical personnel satisfaction. The manufacturing of lightweight shielding sheets focuses on dispersing the shielding material. The uniform dispersion of particles leads to density enhancement, which is an important factor in attenuating the radiation energy intensity by increasing the probability of interaction between particles and radiation. This study evaluates the difference in particle distribution and radiation shielding performance of the grid coating method and the conventional unidirectional coating method in the thin film sheet manufacturing process. The 0.3 mm laminated sheet produced by applying the grid method showed a lead equivalent of 0.033 mmPb, and the sheet of the conventional method showed 0.023 mmPb, indicating that the effect of the grid particle dispersion method was better. Therefore, the grid method is a potentially effective process technology for the future manufacturing of thin film sheets such as shielding gloves and hats.

요 약 의료방사선 차폐로 사용되는 차폐의류는 의료인이나, 환자의 활동성을 제한하지 않는 범위의 무게감과 유연성을 지니고 있어야 한다. 기존에 사용되는 차폐물질은 납을 주로 사용하였으며, 납 분말과 고무 분말을 혼합한 고무시트로 제작하여 유연성은 확보하였지만, 납의 위험성과 중량로 인한 문제점이 있었다. 텅스텐, 황산바륨, 산화비스무트 등의 일부 친환경 차폐물질로 경량화에 대한 문제를 해결하였으나, 아직 의료인이 만족하는 수준은 아니다. 차폐시트의 경량화는 제조과정의 차폐물질의 분산에 중점을 둔다. 입자의 균일한 분산은 밀도 향상으로 이어지며, 입자와 방사선의 상호작용 확률을 높여 방사선 에너지 강도의 감쇠를 만들어 내는 중요한 요소이다. 본 연구에서는 박막시트 제조공정에서 그리드 코팅방식과 기존의 단방향 코팅방식의 입자분포와 방사선 차폐성능의 차이를 평가하였다. 그리드 분산방식을 적용하여 라미네이팅된 0.3 mm 박막시트는 납당량 0.033 mmPb에 해당되며, 기존 단방향 박막시트는 동일한 두께에서 0.023 mmPb를 나타내어 그리드 분산방식이 더 효과적임을 증명하였다. 따라서 향후 차폐장갑, 모자 등 박막시트 제조공정에 효과적인 공정기술로 제안할 수 있다.

Keywords : Lead Equivalent, Coating Method, Tungsten, Shielding Material, X-ray

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1. Introduction

The shielding of the hospital diagnostic radiography area is considered to be the minimum effort to protect patients and medical personnel[1]. Existing shields use lead, but their weight limits the activity of medical personnel[2]. In particular, in the case of surgical shielding gloves, since the thickness is thin, the shielding performance may differ depending on the shielding material or the method of dispersing the material during the manufacturing process. In addition, depending on the combination of mixtures, there may be problems in product flexibility, so manufacturing process technology is very important[3,4].

In medical institutions, thin-film sheet-based shielding products such as shielding gloves and shielding clothing are manufactured in a liquid state by mixing with a polymer material[5]. In the manufacturing process, it is difficult to quantitatively control the degree of dispersion in the liquid state of the shielding material with the polymer, so most of them quantify the degree of dispersion based on the content of the shielding material[6]. The dispersion of the shielding material is directly related to the uniformity of the shielding performance of the final product, so many studies are being conducted for the uniform dispersion of the shielding material particles[7].

Since the shielding performance for medical radiation is determined by the density and mass of the shielding material used in manufacturing the product, there are selective limitations in reducing the mass of the X-ray shield used in medical institutions[8]. When the density of the shielding material is low, the shielding performance is deteriorated, and if the thickness of the shield is increased to prevent this, the weight of the shield is increased. Therefore, in order to overcome this problem, it is necessary to study a dispersion method that can narrow the gap between the particles by making the particles of the shielding material smaller. Barium sulfate, bismuth, tungsten, and boron are generally used instead of lead[9], and it is difficult to independently process these materials because they have hard solid properties. Therefore, these materials are mixed with polymer materials to form a composite sheet, and commercialization is proceeding as clothing[10].

When manufacturing a sheet using a high molecular compound, the calender method is mostly applied to perform a continuous process, and in this study, laminated coating technology was applied to produce a very thin thin film sheet[11]. Laminating refers to a technology of laminating a liquid polymer compound several times, and in this study, a grid-type cross-coating process technology was applied to improve the shielding performance by increasing the particle composition density of the shielding material.

When working with a mixture of the final casting solution and tungsten particles in a certain size, we want to check whether there is a difference in the shielding performance depending on the laminate coating method. If there is a difference in the shielding performance according to this method, it can be predicted by the effect of the dispersion of the shielding material particles. Therefore, in this experiment, the most effective method of dispersing the shielding material is proposed by evaluating the difference in shielding performance between the grid method and the general unidirectional stacking coding method, the difference in related particle composition, and the difference in lead equivalent.

This development is thought to be able to suggest an effective particle dispersion method in the future development of thin film shields.

2. Materials and Methods

Radiation shielding is achieved as the intensity of radiation decreases when it passes through the shielding material[12]. In order to further reduce the intensity of the incident radiation, the thickness of the shield should be increased. In the case of X-rays incident from the diagnostic area, they interact with the shielding material while passing through the shielding material, and accordingly, the intensity of X-rays is weakened as shown in Eq. (1)[13].

$$I = I_0 e^{-\mu x} \quad (1)$$

Where, I denotes X-ray intensity after passing through the shield, I_0 denotes Incident X-ray intensity, μ denotes Linear attenuation coefficient (cm^{-1}), x denotes Shield thickness (cm)

Since the material in the shield is composed of a mixture of tungsten and bismuth oxide, it is necessary to apply the mass attenuation coefficient ($\frac{\mu}{\rho}$) including the density value of the shield as in Eq. (2) rather than the linear attenuation coefficient (ρ)[14].

$$I = I_0 e^{-(\frac{\mu}{\rho})} x\rho \quad (2)$$

Therefore, the mass attenuation coefficient of the shield is calculated by multiplying the mass attenuation coefficient of each material by the mass ratio as in Eq. (3) and summing it up[15]. In this case, w_i is the mass ratio of the shielding material (i) inside the shield. It can be seen that the intensity of incident radiation decreases as the number of substances increases.

$$\frac{\mu}{\rho} = \sum_i w_i (\frac{\mu}{\rho})_i \quad (3)$$

Although the amount of tungsten particles used as a shielding material inside the shield should be put in as much as possible, in order to reduce the mass generated at this time, a method that can exhibit the same shielding effect with smaller particles should be found. One of these methods can be a uniform dispersion of the particles. Therefore, in this study, the method of reducing the porosity by reducing the inter-particle spacing is applied.

The manufacturing method of the shielding sheet mainly uses the calender method, and there are a method of pressing the sheet using a roller and a coating method of laminating a liquid mixture through a lamination process[16]. In this study, when manufacturing products with a thickness of 5 mm or less, such as shielding gloves, it was expected that lamination, a molded product processing method, would be more effective than the calender method.

Tungsten powder particles (purity 99.0 % or more, 300 μm or less) were used for the mixture used to manufacture the shielding sheet, and PU (P-7195A, Mw 100,000~120,000) was used as the polymer, and the solvent was N, N-dimethylformamide (DMF, 99.5 %) was used. The solution used for casting was prepared by PU solution based on 35-40 wt%, and was mixed using a stirrer and a bubble eliminator. A casting solution was prepared using the final tungsten powder particles, and the casting was completed through a drying process after forming a shape by injecting it into a plate. In this process, thickness control was performed by applying a unidirectional coating method and a grid coating method, and thus, the uniform dispersion of the shielding particles of each product was observed. The existing thin-film sheet manufacturing process uses a unidirectional coating method after injecting the mixture into the mold, but this experiment was conducted to verify the difference from the grid method.

Fig. 1 shows two methods of laminated coating. Multiple layers of the mixture were coated by the two methods presented and worked until a constant thickness was achieved. To understand the particle structure inside the manufactured sheet, SEM analysis was performed using a Field Emission Scanning Electron Microscope, and the degree of particle distribution was observed[17].

In addition, the difference in the shielding performance of the two sheets manufactured according to the two coating methods was observed. Using a diagnostic X-ray generator (MOBIX-1000, Listem, 2010), the average value was calculated by performing 10 experiments based on tube voltages of 60, 80, 100, and 120 kVp and 20 mAs. The radiation detection dosimeter used was an ion chamber (Radcal 2186 (Accu-Dose), Radcal Co, 2017, Correction. 2020), and the experiment was configured as shown in Fig. 2[18].

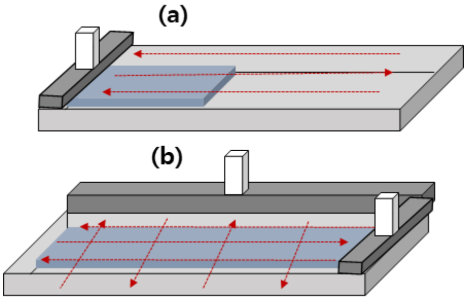

Fig. 1. Casting coating method
(a) is unidirectional coating,
(b) is grid coating in intersecting directions

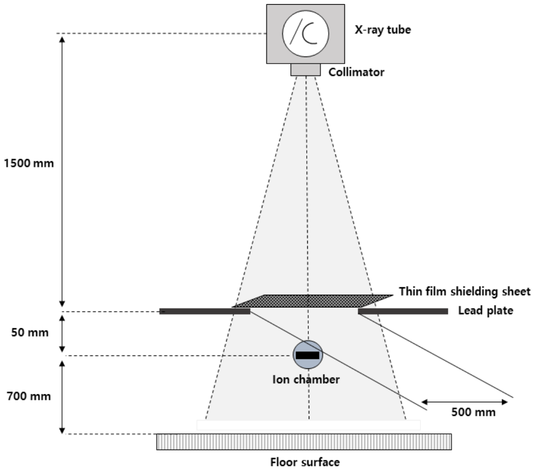

Fig. 2. Experimental configuration for shielding performance evaluation

3. Results

The two sheets used in this experiment had a thickness of 0.03±0.001 mm, a size of 140 mm × 70 mm, and a weight of 4.0±0.04 g, and their appearance is shown in Fig. 3. It is almost impossible to distinguish by appearance, and since they are manufactured under the same conditions such as a laminated structure, the difference between the two process technologies can be evaluated by the difference in the particle composition and dispersion of the shielding material.

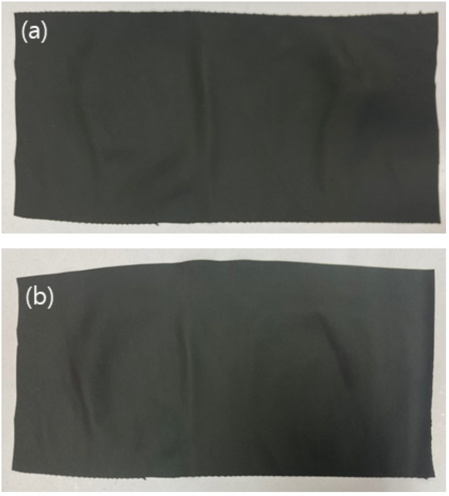

Fig. 3. Appearance of the manufactured thin film sheet
(a) is a sheet manufactured by the grid coating process,
(b) is a sheet manufactured by the conventional process

Fig. 4 shows the SEM analysis result of the thin film shielding sheet produced by the difference in process technology. As shown in the figure, it can be seen that the sheet produced by the cross-grid method has a wider particle distribution area.

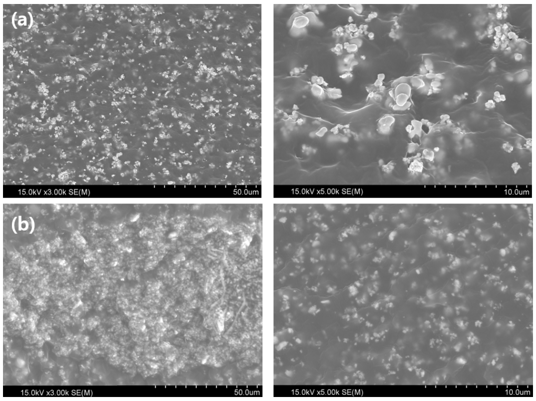

Fig. 4. Particle dispersion degree results analyzed by SEM
(a) Thin film sheet applied with general process method,
(b) Thin film sheet applied with cross grid method

Table 1. Shielding performance evaluation of lead (purity over 99.0 %) according to thickness

mmPb	Transmission Dose	60 kVp	80 kVp	100 kVp	120 kVp
0.03	Dose (μR)	69.30	254.21	558.12	731.24
	Shielding rate (%)	83.59	71.32	62.85	61.40
0.04	Dose (μR)	21.31	118.32	301.47	421.02
	Shielding rate (%)	94.95	86.65	79.93	77.77
0.05	Dose (μR)	8.41	58.16	182.91	254.53
	Shielding rate (%)	98.00	93.44	87.82	86.56

Table 2. Comparison of the performance of two thin film shielding sheets according to the difference in process technology (TFSS: Thin Film Sheeting Sheet)

Method	Transmission Dose	60 kVp	80 kVp	100 kVp	120 kVp
		TFSS	TFSS	TFSS	TFSS
Non-Grid	Dose (μR)	175.5	433.21	846.87	1108.06
	Shielding rate (%)	61.02	50.53	43.49	41.10
	Lead equivalent (mmPb)	0.026	0.023	0.022	0.021
Grid	Dose (μR)	108.51	310.97	656.21	892.02
	Shielding rate (%)	73.87	64.49	56.21	52.59
	Lead equivalent (mmPb)	0.038	0.035	0.032	0.030

Tables 1 and 2 show the results of evaluating the difference in the shielding performance of the two thin film sheets using X-rays. When converted to lead equivalent, the thin film sheet of the cross-grid coating process showed a lead equivalent of about 0.033 mmPb, and the lead equivalent of the thin film sheet produced by the unidirectional coating process was 0.023 mmPb. There was a difference of 0.01 mmPb in lead equivalent between the two sheets. In terms of shielding performance, the cross-grid thin film sheet showed a shielding performance of 56.21 % at 100 kVp, and the sheet of the existing process showed 43.49 %, showing a difference of about 12.72 %. Therefore, as confirmed, it was found that there was a difference in the shielding performance according to the distribution state of the particles.

4. Disucssion

In the conventional casting method, there is a difficulty in controlling the thickness of the sheet in the process of evaporating the solvent. Therefore, there is a limit to mass production because it is difficult to maintain the same shielding performance with the same sheet thickness. Controlling the thickness of the shielding sheet directly affects the density and dispersion of the shielding material, which causes a difference in shielding performance[19]. In particular, the thinner the thin film, the greater this effect.

The thin-film sheet is manufactured through the molding manufacturing process, and when it is manufactured in the form of a plate, it was confirmed that the cross-grid process method performed in this study is more effective in dispersing particles. The use of thin film sheets in medical institutions is mainly for the purpose of shielding scattering rays, which are indirect rays rather than direct rays. Scattered radiation exposure mainly occurs in interventional procedures in medical institutions. This is done due to the irregularity of the examination time, and also because many people who require radiographic images such as patients, operators, and assistants are gathered in close proximity to the radiation generator[20,21].

Recently, the number of tests and procedures is increasing due to the diversification of treatment methods, etc., and appropriate defense against this is required[22]. The thin film sheet produced in this study has the advantage of ensuring the activity of medical personnel because it is thin and light in weight. Therefore, it is considered to be suitable as a fabric for functional shielding clothing that can be worn at all times from a distance of 1 m or more by those concerned, not the medical personnel performing the procedure. However, there is still no mass production process other than the binder process, so it is necessary to develop a process technology that guarantees the reproducibility of the shielding performance.

In general, the solvent casting method used in the production of thin film sheets is a method of evaporating the solvent after thinly applying a solution in which a resin is dissolved in a solvent on a casting roll or belt[23]. In this method, since it is possible to filter foreign substances in the solution, a film having a uniform thickness can be manufactured. However, a separate facility is required because a solvent recovery means is required in the process technology. The lamination coating method is a method of continuously laminating a liquid coating material, and in this study, the cross-grid coating method was applied to achieve the effect of improving the shielding performance. However, this study has limitations in that it requires an expanded facility for mass production and that it lacks a review on the problem of production cost when the liquid mixing process and coating process are performed in large quantities.

Recently, due to the risk and weight of lead, there is a demand for a shield that satisfies the environment-friendly and lightweight conditions. Lead-based shielding clothing used in medical institutions weighs 3.15 to 3.45 kg based on 0.25 mmPb, which limits the activity of medical staff and causes a physical burden on the wearer[24]. Tungsten, bismuth oxide, and barium sulfate are known as the most representative radiation shielding materials, and a new process technology that satisfies the maximum dispersion condition with a small amount to satisfy the light weight condition is being studied[25]. When shields are manufactured based on the same thickness, the mixed shielding material has a lower shielding rate than pure lead, but it is expected to solve the problem if the dispersion technique is developed in the future. In addition, making the sheet thin through the mixed shielding material is the most important prerequisite for producing various types of shields such as shielding gloves, shielding suits, and hats suitable for the purpose. In this study, tungsten was used to reduce the weight, but it is considered that future studies on the use of mixtures to improve lamination and density are needed.

5. Conclusion

In this study, a grid-type cross-coating method was proposed to improve the shielding performance among the laminated coating technologies used to manufacture a quantitative thin film sheet for shielding medical radiation X-rays. The sheet produced by applying the grid cross coating method showed a difference of about 12.72 % at 100 kVp in shielding performance compared to the sheet of the existing process method, indicating that the performance was better, and the lead equivalent was 0.01 mmPb higher.

References

[1] S. M. R, Biso, M. I. Vidovich, "Radiation protection in the cardiac catheterization laboratory", *Journal of Thoracic Disease*, Vol.12, No.4, pp.1648-1655, Dec. 2020.
DOI: http://dx.doi.org/10.21037/jtd.2019.12.86

[2] J. M. Shoag, B. K. Michael, S. S. Kahlon, P. J. Parsons, P. E. Bijur, B. H. Taragin, M. Markowitz, Lead poisoning risk as-sessment of radiology workers using lead shields, *Arch Environ Occup Health*, Vol.75, No.1 pp.60-64, Jan. 2020.
DOI: https://doi.org/10.1080/19338244.2018.1553843

[3] R. Li, Y. Gu, Y. Wang, Z. Yang, M. Li, Z. Zhang, Effect of particle size on gamma radiation shielding property of gadolinium oxide dispersed epoxy resin matrix composite, *Materials Research Express*, Vol.4, No.2, pp.1-19, Mar. 2017.
DOI: http://dx.doi.org/10.1088/2053-1591/aa6651

[4] S. Laurenzi, G. D. Zanet, M. G. Santonicola, Numericfal investigation of radiation shielding properties of polyethylenebased nanocomposite materials in different space environments, *Acta Astronautica*, Vol.170, pp.530-538, May 2020.
DOI: https://doi.org/10.1016/j.actaastro.2020.02.027

[5] H. Eskalen, Y. Kavun, S. Kerli, S. Eken, An investigation of radiation shielding properties of boron doped ZnO thin films, *Optical Materials*, Vol.105, pp.1-6, Jul. 2020.
DOI: https://doi.org/10.1016/j.optmat.2020.109871

[6] M. F. Lai, C. H. Huang, C. W. Lou, Y. C. Chuang, C. Y. Wei, J. H. Lin, Multi-walled Carbon Nano-tubes/Polypropylene-based Coating Layer on the Composite Metal Filaments: Characteristic Evaluations and Radia-tion-shielded Fabric, *Fibers and Polymers*, Vol.23, pp.768–774, Mar. 2022.
DOI: https://doi.org/10.1007/s12221-022-3793-0

[7] M. U. Khan, S. Ahmad, A. A. Naqvi, H. J. Al-Gahtani, Shielding performance of heavy-weight ultra-high-performance concrete against nuclear radiation, *Prog. Nucl. Energy*, Vol.130, pp.1-10, Dec. 2020.
DOI: https://doi.org/10.1016/j.pnucene.2020.103550

[8] H. Chai, X. Tang, M. Ni, F. Chen, Y. Zhang, D. Che, Y. Qiu, Preparation and properties of novel, flexible, lead-free X-ray-shielding materials containing tungsten and bismuth(III) oxide, *Journal of Applied Polymer Science*, Vol.133, No.10, pp.1-7, Mar. 2016.
DOI: https://doi.org/10.1002/app.43012

[9] H. Çetin, A. Yurt, S. H. Yüksel, THE ABSORPTION PROPERTIES OF LEAD-FREE GARMENTS FOR USE IN RADIATION PROTECTION, *Radiat Prot Dosimetry,* Vol.173, No.4, pp.345-350, Apr. 2017.
DOI: https://doi.org/10.1093/rpd/ncw004

[10] A. M. Huda, V. Arun, D. Pradip, W. Lijing. Bismuth oxide-coated fabrics for X-ray shielding, *Textile Research Journal*, Vol.86, No.6, pp.1-10, Jul. 2015.
DOI: https://doi.org/10.1177/0040517515592809

[11] H. A. Maghrabi, A. Vijayan, F. Mohaddes, P. Deb, L. Wang, Evaluation of X-ray radiation shielding performance of barium sulphate-coated fabrics, *Fibers and Polymers*, Vol.17, No.12, pp.2047-2054, Nov. 2016.
DOI: https://doi.org/10.1007/s12221-016-5850-z

[12] F. Akman, M. R. Kaçal, N. Almousa, M. I. Sayyed, H. Polat, Gamma-ray attenuation parameters for polymer composites reinforced with $BaTiO_3$ and $CaWO_4$ compounds, *Progress in Nuclear Energy*, Vol.121, No.37, pp.1-9, Mar. 2020.
DOI: https://doi.org/10.1016/j.pnucene.2020.103257

[13] E. Şakar, Ö. F. Özpolat, B. Alım, M. I. Sayyed, M. Kurudirek,. Phy-X / PSD: Development of a user friendly online software for calculation of parameters relevant to radiation shielding and dosimetry, *Radiation Physics and Chemistry*, Vol.166, pp.1-33, Jan. 2020.
DOI: https://doi.org/10.1016/j.radphyschem.2019.108496

[14] S. F. Olukotun, S. T. Gbenu, F. I. Ibitoye, O. F. Oladejo, H. O. Shittu, M. K. Fasasi, F. A. Balogun, Investigation of gamma radiation shielding capability of two clay materials, *Nuclear Engineering and Technology*, Vol.50, No.6, pp.957–962, Aug. 2018.
DOI: https://doi.org/10.1016/j.net.2018.05.003

[15] W. Cheewasukhanont, P. Limkitjaroenporna, S. Kothan, C. Kedkaew, J. Kaewkhaoab, The effect of particle size on radiation shielding properties for bismuth borosilicate glass, *Radiation Physics and Chemistry*, Vol.172, pp.1-9, Jul. 2020.
DOI: https://doi.org/10.1016/j.radphyschem.2020.108791

[16] A. S. Muhammad, K. A. Nahrul, H. A. Khaidzir, A review on multilayer radiation shielding, *IOP Conference Series: Materials Science and Engineering*, Vol.555, No.1, pp.1-8, 2018.
DOI: https://doi.org/10.1088/1757-899X/555/1/012008

[17] S. C. Kim, Preparation and Performance Evaluation of X-ray-Shielding Barium Sulfate Film for Medical Diagnosis Using PET Recycling and Multi-Carrier Principles, *Coatings*, Vol.12, No.7, pp.1-11, Jul. 2022.
DOI: https://doi.org/10.3390/coatings12070973

[18] S. C. Kim, Tungsten-Based Hybrid Composite Shield for Medical Radioisotope Defense, *materials*, Vol.15, No.4, pp.1-11, Feb. 2022.
DOI: https://doi.org/10.3390/ma15041338

[19] H. O. Tekin, V. P. Singh, T. Manici, Effects of micro-sized and nano-sized WO_3 on mass attenauation coefficients of concrete by using MCNPX code, *Applied Radiation and Isotopes*, Vol.121, pp.122-125, Mar. 2017.
DOI: https://doi.org/10.1016/j.apradiso.2016.12.040

[20] M. L. Kirkwood, J. B. Guild, G. M. Arbique, J. A. Anderson, R. J. Valentine, C. Timaran, Surgeon radiation dose during complex endovascular

procedures, *Journal of Vascular Surgery*, Vol.2, No.2, pp.457-463, Aug. 2015.
DOI: https://doi.org/10.1016/j.jvs.2015.02.050

[21] A. C. Nachiappan, G. L. Horn, S. C. Spann, R. C. Mayo, D. M. Wynne, B. R. Archer, J. A. Hancock, Operator Radiation Dose Reduction During Fluoroscopic Interventional Procedures, *Journal of the American College of Radiology*, Vol.12, No.5, pp.527-530, May 2015.
DOI: https://doi.org/10.1016/j.jacr.2015.01.001

[22] Y. K. Lim, Recent Trend of Occupational Exposure to Ionizing Radiation in Korea, 2015-2019, *Journal of Radiation Protection and Research*, Vol.46, No.4, pp.213-217, Dec. 2021.
DOI: https://doi.org/10.14407/jrpr.2021.00311

[23] S. Feng, F. Zhang, S. Ahmed, Y. Liu, Physico-Mechanical and Antibacterial Properties of PLA/TiO2 Composite Materials Synthesized via Electrospinning and Solution Casting Processes, *Coatings*, Vol.9, No.8, pp.1-17, Aug. 2019.
DOI: https://doi.org/10.3390/coatings9080525

[24] E. Fakhoury, J-A. Provencher, R. Subramaniam, D. J. Finlay, F. RPVI, Not all lightweight lead aprons and thyroid shields are alike, *Journal of Vascular Surgery*, Vol.70, No.1, pp.246-250, Jul. 2019.
DOI: https://doi.org/10.1016/j.jvs.2018.07.055

[25] N. Aral, M. A. Duch, M. Ardanuy, Material characterization and Monte Carlo simulation of lead and non-lead X-Ray shielding materials, Radiation *Physics and Chemistry*, Vol.174, pp.1-9, Sep. 2020.
DOI: https://doi.org/10.1016/j.radphyschem.2020.108892

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〈Research Interests〉
Radiation Shielding, Medical Devices, Medical Information