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The Evaluation of the Thick Polycrystalline HgO and PbO Films Derived by Particle Sedimentation Method for the Mammographic Application

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입자침전법을 이용한 다결정 산화수은과 산화납 필름의 방사선 유방촬영 장치 적용성 평가

노시철, 박지군, 최일홍, 정형진, 강상식, 정봉재

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Abstract

In this study, the morphology and the x-ray quantum efficient of mercury oxide (HgO) and lead oxide (PbO) sensors derived by particle sedimentation method were discussed. In the pursuit of this purpose, we investigated the electrical characteristics and the x-ray quantum efficiency of various thicknesses of HgO and PbO films in mammographic x-ray energy. We have therefore developed a particle-in-binder sedimentation method of fabricating large area polycrystalline films onto transparent glass substrates coated with indium tin oxide. We are currently optimizing the growth method to improve the quantum efficiency with the ultimate goal of obtaining as quantum efficiency close to that of single crystal performance. Our future efforts will concentrate on optimization of large area film growth techniques specifically for deposition on a-Si:H flat panel readout arrays.

Keyword : mercury oxide, lead oxide, x-ray quantum efficient, mammographic application

요 약

본 연구에서는 입자 침전법으로 제작된 HgO와 PbO 기반 영상 센서의 유방촬영 영역에서의 적용 가능성을 조사하였다. 이를 위하여, 다양한 두께에 따른 HgO와 PbO 필름의 물리적 특성과 x선에 대한 양자 효율을 측정하였으며, 몬테카를로 시뮬레이션 결과와 비교 평가하였다. 또한, 입자 침강법을 이용하여 인듐 주석 산화물로 코팅 된 투명 유리 기판 위에 대면적 다결정 박막을 제작하였다. 본 연구에서는 단결정의 효율과 비슷한 양자 효율을 얻기 위하여 필름의 두께와 제작 조건을 변화시켜 최적화 하였다. 본 연구의 결과를 기반으로 차후 대면적 a-Si:H 패널에 적합한 대면적 필름의 제작 기술과 최적화 연구가 가능할 것으로 판단된다.

중심단어 : 산화수은, 산화납, x선 양자 효율, 유방촬영용 장치

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Ⅰ. INTRODUCTION

Recently direct sensors, which are based on an amorphous selenium (a-Se) layer, have high spatial resolution to indirect sensors[1], It is possible because the radiation caused by spreading light is eliminated[2],[3]. But generally low x-ray sensitivity leads to the low conversion efficiency. For it Novel polycrystalline films (HgO, PbO, TlBr, etc.) are being developed as a new detector technology for digital x-ray imaging[4]. Single crystals providing sufficient surface areas are difficult to grow and are therefore cost prohibitive to use in large field of view applications[5]. However, polycrystalline films can be fabricated quickly and cheaply on a variety of surfaces. In this study, we used HgO and PbO for the materials of large area. The developed particle sedimentation method of fabricating large area polycrystalline films onto transparent glass substrates coated with indium tin oxide. And we investigated the electrical characteristics (x-ray sensitivity etc.) and the x-ray quantum efficiency of various thicknesses of HgO and PbO films in mammographic x-ray energy.

Ⅱ. MATERIAL AND METHOD

1. Simulation Conditions

First, we performed a simulation according to the thickness of the layer of HgO and PbO using the Monte carlo neutron and photon code developed in Los Alamos national laboratory (LANL). The area and the thickness of the sensor layer were respectively 3 × 3 cm^2, 10∼100 ㎛, and the absorption efficiency of X-ray photons were estimated according to the thickness. The deliveries of X-ray photons are defined using the Mode P in order to track a passed photon energy spectrum by interaction with the material about diagnostic X-ray photons. The importance for the photon was '1' in Cell & Surface Card; the importance of the empty space in the outside specimen was 0 to prevent the photon. The X-ray source used the X-ray spectrum of 30 kVp in the breast diagnosis area. The Sampling of X-ray source generated on the surface of a rectangular of sensor layer using SUR, and PAR that define X-ray source particle types used PAR2 corresponding to the photon. Finally, Tally specification cards used F1 Tally, and passage probability of the opposite surface was estimated at 50,000 times. Total energy-absorbing efficiency was calculated by integrating in each energy about transmission probability of the photon that having continuous energy[6],[7]. The continuous X-ray energy according to the kVp was simulated by appling the low data as a NCNPX input code. Figure 1 shows the sectional view of the proposed PbO and HgO sensor, and figure 2 shows the MCNPX-F1 model.

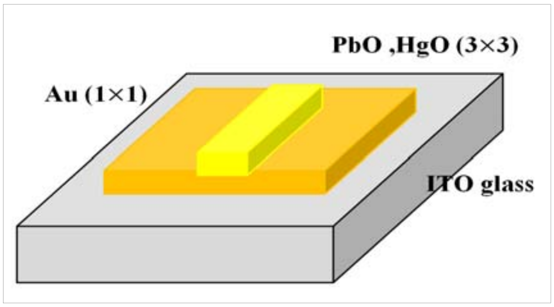

Fig. 1. The sectional view of PbO and HgO.

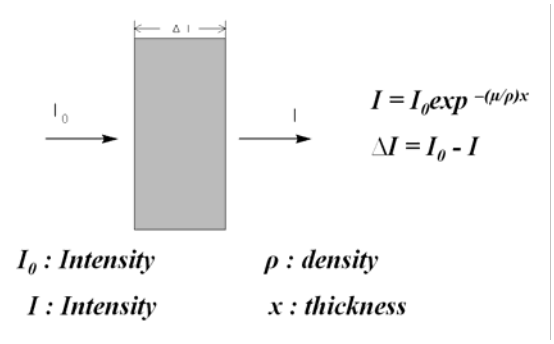

Fig. 2. MCNPX-F1 for mammographic application.

2. Sample Fabrication

After, the specimen was prepared using the particle sedimentation method. In the production order, first, a raw material powder of the photoconductor material was

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passable in type of sol-gel using the binder material and a solvent. After fixed the mask of 3 × 3 cm^2 area on the glass substrate, the film layer was formed by paste precipitating at an atmospheric pressure. Finally, the formed specimens were sintered for 3 hours at 100 ℃. In addition, to investigate the quantum efficiency by thickness, the three kinds of HgO and PbO specimen was produced. In order to observe a shape of the fabricated specimen, SEM (Jeol JSM-6380LV, Japan) was used.

Ⅲ. RESULT AND DISCUSSION

1. Film Sensor Fabrication

Figure 3 and 4 show cross-section of HgO and PbO, made by the particle sedimentation method, sensor layer and a surface SEM shape. HgO was checked spherical particles uniformly formed of tens ㎚, and thickness is about 40 ㎛, 70 ㎛, 85 ㎛. While, PbO is formed by a number of ㎛ sized nonuniform particles, it can know that surface is formed nonuniform, and formed thickness is about 70 ㎛, 90 ㎛, 125 ㎛. In addition, can be observed that the thickness and the density was not uniformity, can know at both two film cross section image, could be seen empty space in between photoconductive particles, contrary to vapor deposition method. From these results, the particle size of the photoconductor is a sphere and as the smaller the particle size, uniformity and particle packing factor may be more improve. Also we thought that manufacturing process improvements needed such as dispersant and high-pressure precipitation method.

2. Evaluation of Film Sensor

And then, we measured the quantum efficiency of fabricated HgO and PbO specimen using mammography device. The exposure condition was set as 25 kVp of tube voltage, and beam area was set as 10 × 10 mm. After the X-ray irradiation, by using the Ion chamber (2060C model, Radical Cooperation Inc.) the transmitted X-ray dose was measured and the quantum efficiency was calculated.

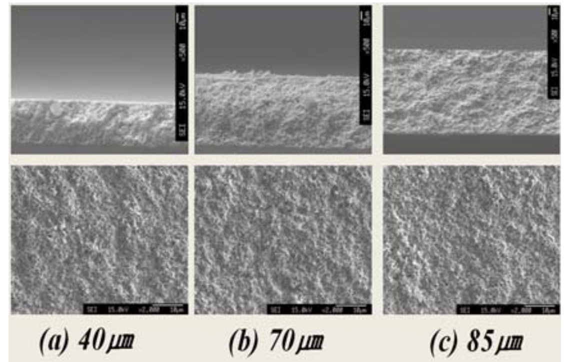

Fig. 3. SEM image of fabricated HgO film according to the thickness.

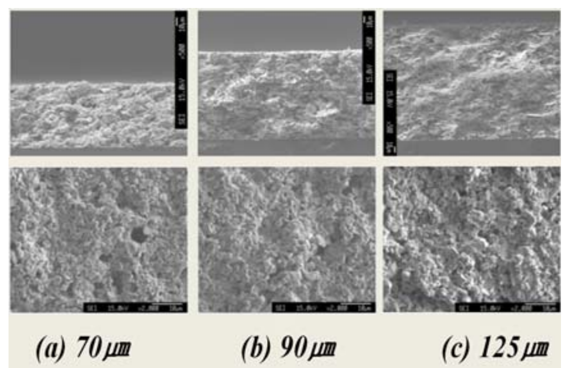

Fig. 4. SEM image of fabricated PbO film according to the thickness.

From the experimental results, the quantum efficiency (QE) of 40 ㎛-HgO film was 94.5% in simulation and 65% in experiment, respectively. Also, the QE of fabricated 70 ㎛ and 85 ㎛ HgO samples were about 72%. By the way, the quantum efficiency of simulated 40 ㎛-PbO film was lower 92% than HgO. And almost x-ray photons (98.7%) were absorbed in 80 ㎛ thickness of PbO. Also, the QE of fabricated 90 ㎛ and 125 ㎛ HgO samples were about 76%. In addition, compared to the a-Se specimen, the HgO of less than 70 um thickness has excellent quantum efficiency. But the lower efficiency was shown with thicker specimen. The PbO specimens represent the lower efficiency than a-Se specimens, respectively. Figure 5 and 6 show the changing trends of quantum efficiency of PbO and HgO specimen according to the thickness.

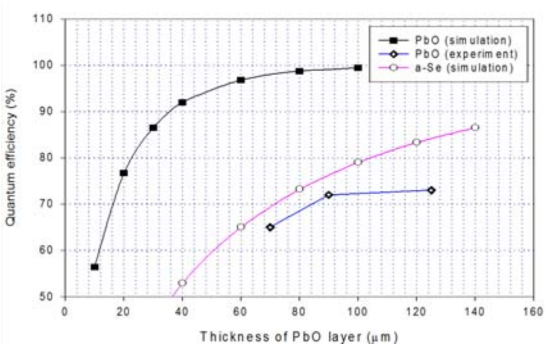

Fig. 5. The quantum efficient of PbO according to the thickness.

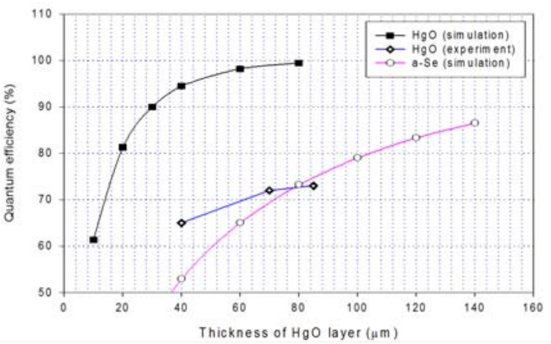

Fig. 6. The quantum efficient of HgO according to the thickness.

Finally, the X-ray Sensitivity of specimen according to the supply voltage was measured. The exposure conditions were set as 80 kVp of tube voltage and 7.5 mAs of tube current. The DC power supplier (3033B model, Protek Inc.) was used to change the applied voltage till 40 V with 10 V step. Figure 7 and 8 show the experimental setup for sensitivity measurement.

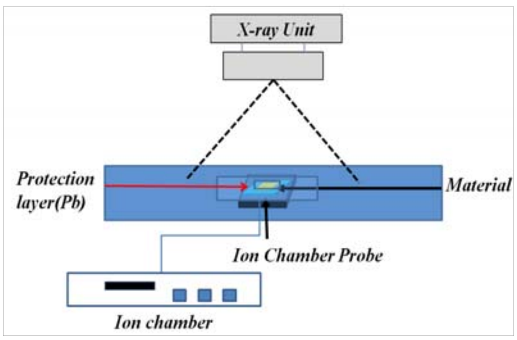

Fig. 7. Experimental setup for mammographic device.

Fig. 8. Experimental setup for sensitivity measurement.

Figure 9 and 10 represent the sensitivity changing of PbO and HgO specimen according to the supplied voltage. By using the digital oscilloscope (6517A model, keithley Inc.) the sensitivity was estimated. In both HgO and PbO specimen, the Q-value which means the sensitivity was increased linearly as increasing the supply voltage. The Q-Value of HgO and PbO specimen was found about 34 times difference with 40 V of the applied voltage (0.0000178 C/mR · cm2 of HgO and 0.00000053 C/mR · cm2 of PbO). Otherwise, as increasing the applied voltage, the Q-value differences between two materials were reduced.

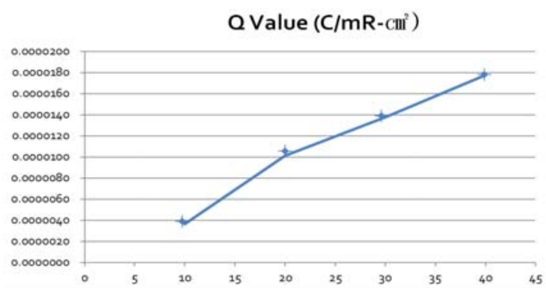

Fig. 9. Sensitivity changing of HgO specimen according to the supplied voltage.

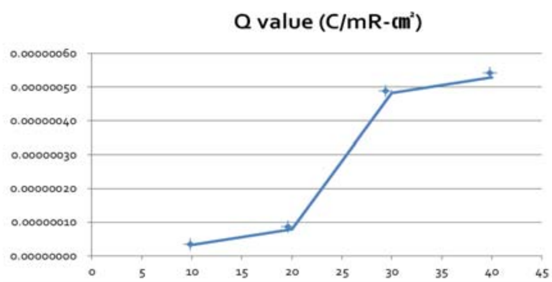

Fig. 10. Sensitivity changing of PbO specimen according to the supplied voltage.

Ⅳ. CONCLUSION

The purpose of this study is optimizing the particle sedimentation method to improve the quantum efficiency with the ultimate goal of obtaining as quantum efficiency close to that of single crystal performance. For it we investigated the electrical characteristics (leakage current, x-ray sensitivity) and the x-ray quantum efficiency of various thicknesses of HgO and PbO films in mammographic x-ray energy. These polycrystalline films have a high resistivity producing a very low dark current typically about 1 nA/cm^2. In addition, it has 30% lower quantum efficiency than theoretical quantum efficiency for the continuous X-ray range of mammography. These are determined by the empty space created by the Binder of family of polymer which is used in the particle sedimentation method. Subsequently, more research for the cause analysis and manufacturing process improvements are needed. Our future efforts will concentrate on optimization of large area film growth techniques specifically for deposition on a-Si:H flat panel readout arrays.

Reference

[1] S.S. Kang, B.J. Jung, S.C. Noh, et. al., “Feasibility study of direct-conversion x-ray detection using cadmium zinc telluride films”, Jinst, doi:10.1088/1748-0221/7/01/C01010, 2011.

[2] M.S. Yun, S. H. Nam, “Electrical Analysis of a Planar-type Digital X-ray Detector with Inert Gas”, Journal of the Korean Physical Society, Vol. 56, No. 4, pp. 1083-1087, 2010.

[3] S. Tokuda et al., “Experimental evaluation of a novel CdZnTe flat-panel x-ray detector for digital radiography and fluoroscopy” , SPIE Proc. Ser. 4320, P0140, 2001.

[4] Jhons H. E, Cunningham J. R, “The Physics of Radiology, 4th edit, toronto, Charles C Thomas, 1997.

[5] M. Lachaine, B.G Fallone, “Monte Carlo simulation of x-ray induced recombination in amorphous selenium”, J. Phys. D, 33, 2000.

[6] M. Hjelm, B. Norlin, H. E. Nilsson, “ Monte Carlo simulation of the imaging properties of scintillator-coated X-ray pixel detectors”, Nuclear Instruments and Methods in Physics Research, Vol. 509, pp. 76-85, 2003.

[7] M. Schieber, H. Hermon, R. A. Street, et. al., "Theoretical and Experimental Sensitivity to X-rays of Single and Polycrystalline HgI2 Compared with Different Single-Crystal Detectors", Nucl. Instr. and Meth., A 458, pp. 46, 2001.

[8] M. J. Berger, J. H. Hubbel and S. M. Seltzer, XCOM(Photon Cross Sectins Database), National Institute of Standards and Technology

[9] T. W. Choi, C. S. Lee, and S. C. Yoo, "Electrical and mechanical properties of ceramics", Trans. on EEM, Vol. 15, No. 1, p. 10, 2001.

[10] E. Dubaric, H. -E. Nilsson, and C. Frödh, " Monte Carlo simulation of the response of a pixellated 3D photo-detector in silicon" ,Nuclear Instruments and Methods in Physics Research A 487, pp. 136-141, 2002.

[11] K. T. Kim, S. S. Kang, S. C. Noh, et. al, “Absorbed Spectrum Comparison of Lead and Tungsten in Continuous X-ray Energy using Monte Carlo Simulation”, Journal of the Korean Society of Radiology, vol. 6, no. 6, pp. 483-487, 2012.

[12] S. T. Kim, S. K. Kang, C. Y. Kim, “Monte Carlo Simulation for absorbed dose in PMMA phantom during the low-energy X-ray irradiation”, Journal of the Korean Society of Radiology, vol. 5, no. 6, pp. 383-389, 2011.