The design of hybrid x-ray detector using quantum size effect

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1. Introduction

In current radiography diagnostic imaging area, there is a tendency shifting from film method which is an existing analog method to Digital Radiography(DR) which is a digital method. Radiograph conversion method is divided into two groups in DR as follows: a direct conversion method and an indirect conversion method. A direct conversion method is a process which converts radiation directly into an electrical signal using photoconductor. An indirect conversion method is a process which converts radiation into light, and then visualize an image. Each of the methods has weak points as well as strong points, and what we attempt to do is to fuse two methods into one to maximize strong points by using only one material. CdTe has been considered as the direct conversion material because it generate electron hole pairs at radiation exposure. However, as the technology of quantum dot has been rapidly developed, it is discovered that CdTe can be used as phosphor because the properties CdTe can be changed when it become quantum size. Therefore, in this study, CdTe is manufactured in bulk form, and being utilized as photoconductor. At the same time, it is synthesized nano-sized, and utilized as phosphor. To be specific, this system works as following: First, an x-ray has changed into light on nanoscale phosphor layer, and then the light has been emitted on photoconductor layer. The emission wave length range of phosphor layer was controlled to be coincided with the absorption wavelength range of photoconductor. The change of electronic energy level density depending on the size of a crystal within nano-particle affects optical and electrical characteristic variation, which reflects the quantum size effect. On account of this effect, one material can be utilized as two different kinds of layers, the photoconductor layer and the phosphor layer, by regulating the size of the material. As a result, by changing emission wavelength with the size control of a particle, the most appropriate absorption wavelength to a photoconductor in the bulk state can be emitted from nanoscale phosphor. The goal of this study is to confirm feasibility of confused diagnostic radiography imaging detection system using the quantum sized effect.

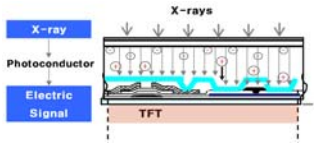


Figure1. Direct conversion schematic diagram

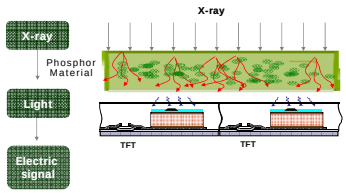


Figure2. Indirect conversion schematic diagram

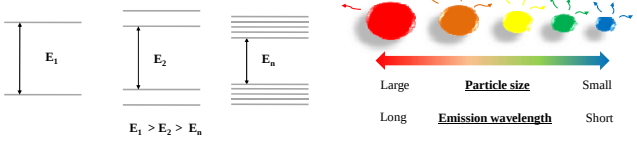


Figure 3. Quantum Size Effect : The change of electronic energy level density depending on the size of a crystal within nano-particle affects optical and electrical characteristic variation, which reflects the quantum size effect.

2. Experimental Procedure

❖Photoconductor layer fabrication

As the method of depositing the CdTe film, this study adopted the close-spaced sublimation method.

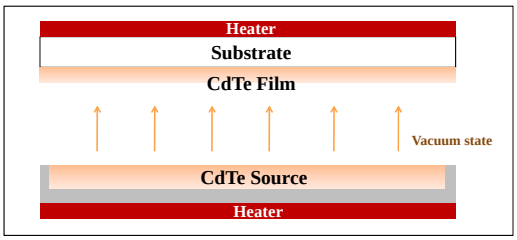
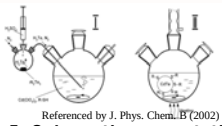


Figure 4. Photoconductor layer deposition Method : The Close-spaced sublimation method (It is normally used by photovoltaic area) substrate temperature : 500 ℃ , Source temperature : 650 ℃

❖Luminescence layer fabrication



Referenced by J. Phys. Chem. B (2002) Nikolai Gaponik

Figure 5. Schematic presentation of the synthesis of aqeous solution CdTe nano-scale phosphor.

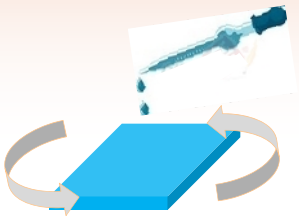


Figure 6. Nano-phosphor deposition Method : Multilayer spin coating

First stage: The formation of CdTe precursors by controlling H2Te gas.
Second stage: The formation and growth of CdTe nanocrystals promoted by reflux.
Third stage : Spin coating of the fabricated nano-scale phosphor

❖Hybrid detector fabrication process

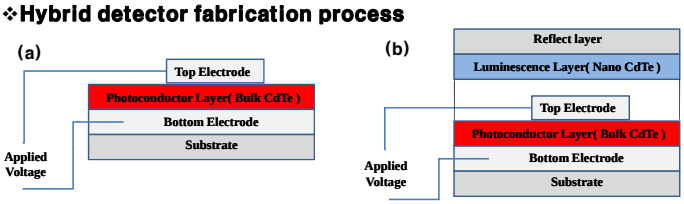


Figure 7. Structure of X-ray conversion system with CdTe : (a) conventional structure (b) Hybrid Structure

Fabrication

CdTe photoconductor was manufactured using the close-spaced sublimation method , and it had a 50um of thickness and a 3 x 3 cm^2 of width. CdTe nano-scale phosphor was synthesized using aqueous solution method, and it was of the 2nm size. The radiation wavelength of the synthesized nano-scale phosphor was accorded with the absorption wavelength of CdTe photoconductor. Reflective layer was put on phosphor layer to increase the efficiency. There was a spacer between photoconductor layer and phosphor layer, and ITO was used as an electrode.

Measurement

Luminescence efficiency of nanoscale phosphor was measured using PL spectroscopy and generated signals from the photoconductor were measured using electrometer and oscilloscope.

3. Result & Discussion

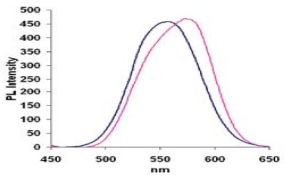


Figure 8.Nano phosphor PL Spectrum

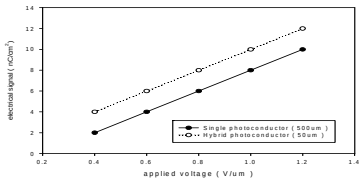


Figure 9. Electrical Signal comparison of single photoconductor

4. Conclusion

- In this study, we found the feasibility of confused diagnostic radiography imaging detection system using quantum sized effect.
- It is possible to change the emission wavelength range by regulating the size below 10nm of phosphor, which called quantum size effect. In this study, we synthesized nano-scale phosphor for 550nm of emission wavelength accorded with absorption wavelength of bulk CdTe. Also, as the result of PL, we obtained the phosphor with 550nm of emission wavelength. It is increase the absorption efficiency of photoconductor layer.
- The hybrid system can have low applied voltage because thickness of hybrid system photoconductor layer is thinner than thickness of general CdTe photoconductor layer. Thin photoconductor is possible because phosphor layer converted x-rays which have high transmittance into visible light which have low transmittance. It eliminates the disadvantage of direct method as high applied voltage.
- In the case of signal, the results showed around 2nA/cm^2 higher sensitivity than that of reference data. The result is not epoch-making, but it is high enough to judge feasibility of confused x-ray detector.
- Further studies about absorption efficiency, thickness control, distance control of space, and blurring effect are necessary to optimize the structure of a hybrid system.

5. Acknowledgment

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