Progress in NUCLEAR SCIENCE and TECHNOLOGY, Vol. 1, p.194-197 (2011)

ARTICLE

Comparison of New Simple Methods in Fabricating ZnS(Ag) Scintillators for Detecting Alpha Particles

Seung Kyu LEE, Shin Yang KANG, Doh Yun JANG, Cheol Ho LEE, Sang Mook KANG, Byoung Hwi KANG, Woo Gyo LEE, and Yong Kyun KIM*

Department of Nuclear Engineering, Hanyang University, Seoul, 133-791, Korea

The silver-activated zinc sulfide, ZnS(Ag), sensor to detect alpha-particles is normally fabricated by means of heat-melting or epoxy mixing spread. However, the fabrication process is very complicated so that it creates high costs and requires special high-tech equipment to manufacture the detector. For this reason, we have developed a new fabrication method which has the advantages of process simplicity and also high efficiency. The alpha particle response of the detector manufactured by the new spreading method was evaluated at varied thicknesses of ZnS(Ag) and the detection efficiency was better than for other methods like liquid brush method with an Am-241 alpha radiation source. Compared to conventional ZnS(Ag) detectors, the new detector shows a good detection efficiency, and its simple and low cost design makes it an economical and commercial alternative to more expensive alpha survey instruments.

KEYWORDS*: *ZnS(Ag), zinc sulfide ,ZnS(Ag) thin film, ZnS(Ag) layer, alpha detector

I. Introduction

Silver-activated zinc sulfide, ZnS(Ag), is one of the oldest inorganic scintillators. It has a very high scintillation efficiency, comparable to that of NaI(Tl). However, it is available only as a polycrystalline powder so that its utilization is limited to thin screens used primarily for alpha particle or other heavy ion detection. Moreover, because of the opacity of the polycrystalline layer to its own luminescence, thicknesses greater than about 25 mg/cm^2 become unusable.[1)]

ZnS(Ag) has been widely used to measure the alpha radioactivity in environmental samples.[2)] In addition, it can be used to detect thermal or fast neutrons if enriched with a lithium compound.[3-4)]

The major processes to fabricate the sensor are two conventional methods and both are rather complicated. One is a method of vacuum evaporation (heat-melting), and the other is epoxy-mixing spread. During the heat-melting method, the layer is grown under H_2+NH_3 gas flow. The total flow rate of H_2+NH_3 gas is about 400-1000 cc/min, and the amount of NH_3 flow is about 100-300 cc/min. The ZnS source and Ag temperatures are kept at 920 ºC. ZnS(Ag) layer grow takes 2-4 hours. The layer thickness grown under these conditions is about 1-4 μm.[5)]

The epoxy mixing spread method involves adhering the ZnS(Ag) scintillator and an epoxy mixture onto a transparent material.[6)] The opaque material is 260 μm aluminized Mylar. A layer of cyanoacrylate is then deposited on top of the opaque material to provide a protective hard-coat resistant to tears, scratches, and corrosives. ZnS(Ag) layer growth takes 24 hours or more. Also, this method requires skillful handling and advanced technology.

Corresponding Author, Tel No: +82-2-2220-2354, Fax No: +82-2-2296-2354, E-Mail : ykkim4@hanyang.ac.kr

Since both methods need much time, skilled operators and high-tech equipment, we have focused on a ‘new simple method of ZnS(Ag) sensor fabrication’ which has the advantages of simplifying the manufacturing process and reducing production costs.

II. Fabrication of the ZnS(Ag) Alpha Detector

1. Conventional ZnS(Ag) Alpha Detector

Table 1 shows the properties of Saint-Gobain commercial ZnS(Ag) powder which was used in this study.

Table 1 The properties of ZnS(Ag) powder.[3-7)]

Property	Value
Cleavage plane	Polycrystalline
Density (g/cm^3)	4.09
Wavelength of emission max.(nm)	450
Lower wavelength cutoff(nm)	330
Refractive index at emission max.	2.36
Photoelectron yield[% of NaI(Tl)]	130
Decay constant	110

A conventional alpha scintillation detector typically consists of the folloeing components: transparent material, sensor base, ZnS(Ag) layer, opaque material, and sensor protective material. Usually the silver-activated ZnS is attached to an optically transparent material. The transparent materials are polyester film, PSf (PolySulfone) or acrylic plastic. When alpha particles interact with the ZnS(Ag) layer, photons are created. The optical light guide acts as a guide to focus these photons onto the optical coupled photo multiplier tube (PMT). Conventional alpha detectors use a 0.25 mil layer of aluminized Mylar as radiation entrance window. This thickness provides an excellent opaque shield against ambient light and is thin enough for most alpha particles to penetrate. However, since the fragility of this thin material provides a surface easily punctured, torn, or scratched when used in field environments, the fragile Mylar window can be replaced with Al-Mylar and a protective hardcoat.[8)] The detection efficiencies of various commercially manufactured ZnS(Ag) alpha detectors are ranging from 33 to 44%.[8-9)]

2. New Simple-Method ZnS(Ag) Alpha Detector

In this study the new simple ZnS(Ag) alpha-particle detector was evaluated which has a good detection efficiency and is comparable to conventional ZnS(Ag) alpha detectors. The scintillator sensor consists of a polymer PMMA light guide sensor base, a ZnS(Ag) scintillator layer, opaque material, and a protective surface layer. Two blocks of PMMA light guide sensor bases were prepared for the experiment to determine alpha detection efficiency with respect to ZnS(Ag) layer thickness and sensor layer fabrication method, respectively.[8)]

Focusing on ZnS(Ag) spreading three different spreading methods were tried, that is dry spreading, liquid brushing, and air brushing. For the dry spreading method ZnS(Ag) powder was scattered through an aluminum sieve. Liquid brushing was done by spreading a liquid ZnS(Ag) mixture on the PMMA light guide sensor base. Air brushing was applied by spraying the scintillator onto the PMMA light guide sensor base. The ZnS(Ag) spreading solution was prepared by mixing ZnS(Ag) powder (Saint-Gobain, type Z-151) with hydrocarbon thinner and transparent clear enamel paint. Each sensor's ZnS(Ag) mixture layer thickness was about 38 μm. An Alpha-Step IQ Surface Profiler from KLA Tencor was used for measurement of the ZnS(Ag) sensor layer thickness.

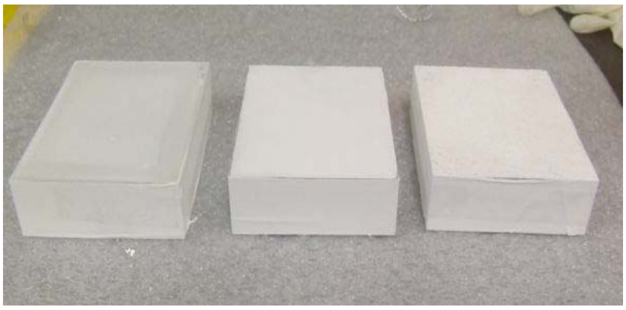

Fig. 1 Air brushing, liquid brushing, dry spreading ZnS(Ag) sensors, left to right

Figure 1 shows the ZnS(Ag) sensor blocks manufactured by each of the three methods.

The key issue of this new simple method is the ZnS(Ag) layer thickness. IWATA REVOLUTION CR 0.3 mm and OLYMPUS HP-100 0.3 mm model air spray guns were used for applying the ZnS(Ag) mixture onto the PMMA sensor base. The sensor manufactured by air brushing was designed for an optically smooth sensor surface. The ZnS(Ag) solution was sprayed onto the PMMA light guide sensor base and layers of the following thickness were realized: 4.798, 13.25, 18.36, 27.14, 41.99, 144.30 μm. The ZnS(Ag)-hydrocarbon thinner mixture quickly settled on the sensor base. The fabricated sensors were dried at room temperature. The sensor layer's drying period was 90 minutes which is much faster than any other conventional fabrication method.

Figure 2 shows a ZnS(Ag) sensor block as manufactured by the air brushing method.[10-17)]

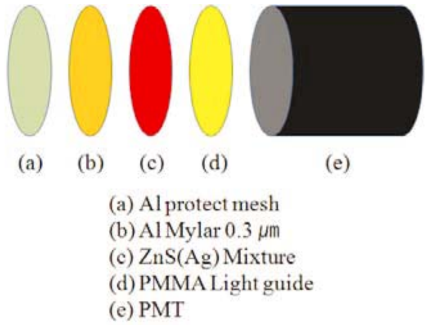

Fig. 2 ZnS(Ag) sensor block fabricated by the new simple method

III. Experiments and Results

1. Alpha particles measurements

The spectra were measured with a 2 inch BICRON 8575 photomultiflier tube (PMT). The ZnS(Ag) sensor was coupled onto the photocathode with optical grease, and the sensor was wrapped with several layers of white reflector tape. The pulse height spectrum was measured with ^{241}Am 5.5 MeV α-particle sources. **Figure 3** shows a diagram of the measurement electronics. The amplifier used in the experiment was an ORTEC 572A. Also, high voltage supply and MCA were ORTEC model 556 and ORTEC 920E ETHERNIM, respectively. Experiment set-up factors were 100 gain, -1700 volt and 0.5 μsec shaping time.[18-19)].

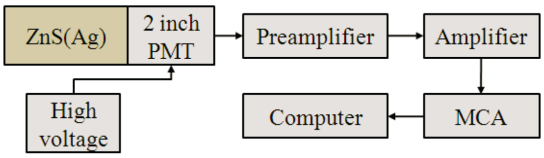

Fig. 3 Schematic diagram of the experimental setup

2. Results

The pulse height spectra of the ZnS(Ag) sensors fabricated by two methods are shown as **Fig. 4**. The air brushing spread method showed the best alpha-particle detection response.

The relative detection efficiency of alpha particles was calculated by the total number of counts of counts under the curve of the alpha particle spectrum. The detection efficiency is assumed as 100% for the liquid brushing method sensor. The relative detection efficiency for the air brushing method sensor of 41.99 μm thickness can then be obtained by the following equation;

Relative detection efficiency [%] =
Total counts of air brushing method sensor/
Total counts of liquid brushing method sensor

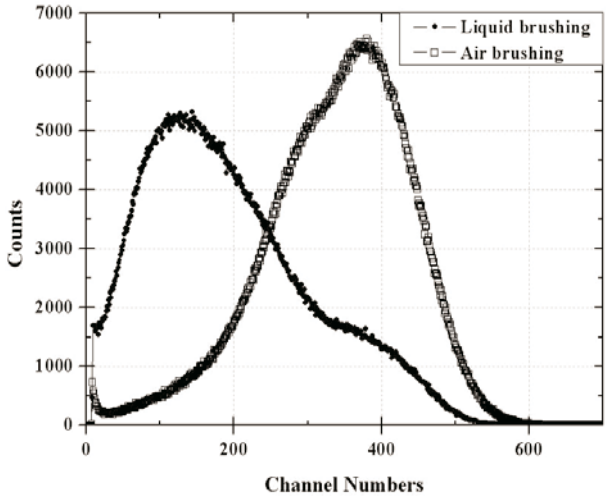

Fig. 4 Alpha particle pulse height spectra measured by the ZnS(Ag) sensors fabricated by two different spreading methods. (^{241}Am 5.5 MeV alpha source)

The total number of counts of alpha particles for the liquid brushing method sensor was 1.35 x 10^6 counts, and for the air brushing method sensor was 1.4795 x 10^6 counts. The measured value for the relative detection efficiency of the air brushing method was about 110%.

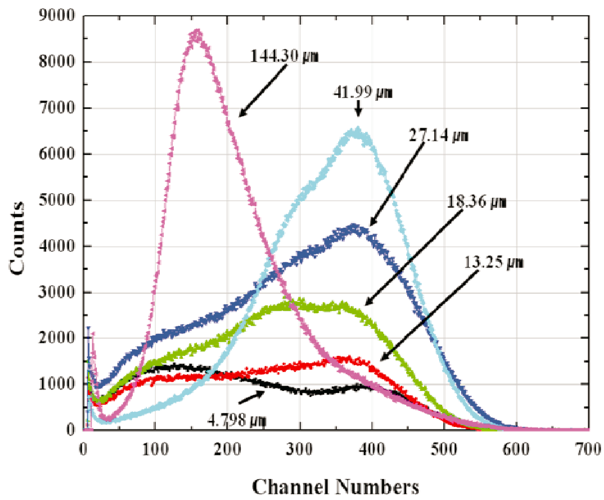

Fig. 5 ^{241}Am pulse height spectrum with respect to ZnS(Ag) layer thickness.

Figure 5 shows the ZnS(Ag) sensor pulse height spectrum with respect to ZnS(Ag) sensor layer thicknesses. The ZnS(Ag) sensor of 41.99 µm thickness shows the best alpha-particle detection efficiency as seen in **Fig. 6**.

The new simple-method ZnS(Ag) detector was designed as an alternative to conventional alpha particle detectors. **Figure 7** shows the prototype of the ZnS(Ag) detector probe fabricated by the "air brushing method". The sensor layer thickness was 41.99 µm.

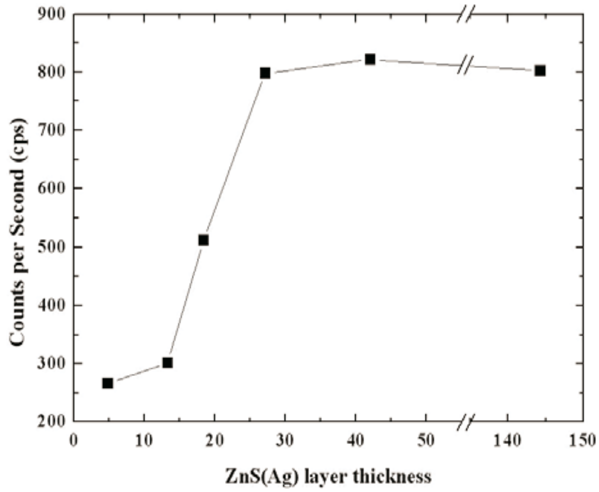

Fig. 6 Detection efficiency of ZnS(Ag) sensors fabricated with 6 different layer thicknesses

Fig. 7 New-method ZnS(Ag) alpha-particle detector probe.

IV. Conclusion

We have developed a new ZnS(Ag) alpha detector which was manufactured by employing the 'air brushing' spread method. This detector has a good detection response compared with liquid brushing method sensors. The faster and simpler fabrication process provided by this air brushing spread method makes the detector ideal for industrial manufacture and this new alpha detector design is relatively cheap, requiring only ZnS(Ag) powder, hydrocarbon thinner and optically transparent clear enamel paint. We believe this new ZnS(Ag) alpha detector fabrication method provides a major breakthrough in alpha scintillation survey instruments and its simple and low-cost design makes it an economical and commercial alternative to expensive alpha survey instruments. We aim at improving the performance of the new alpha detector through further study to incorporate waterproof, protective materials and linearity measurement.

Acknowledgment

This work was supported by the research of Hanyang University (HY-2009-O).

References

1) G. F. Knoll, *Radiation Detection and measurement*, John Willey and Sons, New York, (1999)
2) M. Ardid, J.L. Ferrero, A. Herrero, 'Study of the background on a ZnS(Ag) alpha counter with a plastic veto detector', *Nucl. Instrum. and Meth. in Phys. Res. A*, 557, 510-515 (2006).
3) www.bicron. com
4) N. Kubota, M. Katagiri, K. Kamijo, H. Nantoa, 'Evaluation of ZnS-family phosphors for neutron detectors using photon counting method', *Nucl. Instrum. and Meth. in Phys. Res. A*, 529, 321-324, (2004)
5) S. Kishimoto, T. Yamamoto, and S. Iida, 'Fabrication of p-type ZnS with blue-Ag emission by triple-codoping method', *Materials Research Society 2002 Spring Meeting, San Francisco, Defect and Impurity Engineered Semiconductors and Devices III*, (2002)
6) Bum-Kyoung Seo, Yeon-Hee Jumg, Gye-Hong Kim, Kune-Woo Lee, Chong-Hun Jun and Myeong-Jin Han, 'Study on preparation of a thin film type of ZnS(Ag) scintillator sheet for alpha-ray detection', *Analytical Science and Technology*, 19, 5, 389-393, (2006)
7) www.eljentechnology.com
8) S.A. McElhaney, J.A. Ramsey, M.L. Bauer and M.M. Chiles, 'A ruggedized ZnS(Ag) /epoxy alpha scintillation detector', *Nucl. Instrum. and Meth. in Phys. Res. A*, 299, 111-114, (1990)
9) www.canberra.com, SA-100 Alpha Probe specification
10) www.ludlums.com, LUDLUM MODEL 43-90 alpha probe specification
11) Yeon-Hee Jung, So-Jin Park, Bum-Kyoung Seo, Kune Woo Lee, and Myeong-Jin Han, 'Effect of Coating Technique on the Characteristics of ZnS(Ag) Scintillation Composite for Alpha-ray Detection', *J. Korean Ind. Eng. Chem*, 17, 6, 604-608, (2006)
12) Bum-Kyoung Seo, Zu-Hee Woo, Gye-Hong Kim, Kune-Woo Lee, Dong-Gyu Lee and Chong-Hun Jung, 'Development of ZnS(Ag)/plastic dual scintillator sheet for simultaneous alpha- and beta-ray counting', *Analytical Science and Technology,* 21, 2, 117-122, (2008)
13) E. Bacaksiz, O. Görür, M. Tomakin, E. Yanmaz, M. Altunbaş, 'Ag diffusion in ZnS thin films prepared by spray pyrolysis', *Materials Letters*, 61, 5239–5242, (2007)
14) Masanori Tanaka, Shinya Sengoku, Manabu Kato, Yasuaki Masumoto, 'Luminescence properties of ZnS phosphor nanocrystals prepared by the laser-induced gas-evaporation method', Journal of Applied Physics, 87, 12, 8535-8540, (2000)
15) N. Kubota, M. Katagiri, K. Kamijo, H. Nantoa, 'Evaluation of ZnS-family phosphors for neutron detectors using photon counting method', *Nucl. Instrum. and Meth. in Phys. Res. A*, 529, 321-324, (2004)
16) Shigekazu Usuda, Satoshi Sakurai, Kenichiro Yasuda, 'Phoswich detectors for simultaneous counting of α-, β(γ)-rays and neutrons', *Nucl. Instrum. and Meth. in Phys. Res. A*, 388, 193-198, (1997)
17) Dong Chin Lee, Sergey A. Bukesov, Sora Lee, Jong Hyuk Kang, Duk Young Jeon, Do Hyung Park, and Jin Young Kim, 'The Effects of Surface Treatment for ZnS:Ag,Cl Using a Combination of Stirring and Ultrasonication in KOH Solutions', *Journal of The Electrochemical Society*, 151(11), 227-231. (2004)
18) S. Sakamoto, H. Takakura, 'Efficiency of a large size scintillation cell', *Journal of Radio analytical and Nuclear Chemistry*, 236, Nos 1-2, 257-260, (1998)
19) T. Iimoto, S. Tokonami, and R. Kurosawa, 'Estimation Method for Alpha Particle Counting Efficiency for Scintillation Flasks', *Radiation Protection Dosimetry*, 72, 1, 55-60, (1997)