Determination of the Optimum Counting Condition of a ZnS(Ag) Scintillation Detector for Contamination Monitoring

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1. Introduction

Wastes generated during decommissioning must be surveyed for clearance. There are so many types of decommissioning wastes, such as, pipes, vessels, concretes, etc. Especially, it is very difficult to monitor the contamination of a pipe because of small diameter. In the previous study[1] we estimated a basic concept for the detector system for monitoring the in-pipe contamination consisted with a silver-activated zinc sulfide (ZnS(Ag)) scintillator and photomultiplier tube(PMT).

In setting up a counting system, it is often desirable to establish an operating point which will provide maximum stability over long periods of time [2]. It is recommended not to use too high voltage in a PMT, because the lifetime of the phototube may be a little longer at the lower voltage. At the same time, the operating voltage should be taken above the threshold voltage of the plateau. With a suitable choice of bias it is possible to obtain a satisfactorily long plateau and to determine the true alpha counting rate to within a few percent.

The operating voltage is one of the criteria to select the optimum counting conditions in a ZnS(Ag) scintillation detector. The operating voltage should be selected in a region referred to as the plateau in which minimum sensitivity to drifts in the supply voltage and/or in discrimination level are achieved. This criterion involves the selection of the operating voltage at one third of the plateau length or 75 V above the low voltage end of the plateau, which ever is less [3-5]. Therefore, we suggest the optimum voltage and low level discrimination (LLD).

2. Methods and Results

2.1 ZnS(Ag) scintillation detector system

The detector electronics consist of two components which are adjustable by the user: the high voltage applied to the photomultiplier tube (PMT) and the low level discriminator (LLD), which is used to eliminate the electronic noise. The high voltage and LLD optimization are useful for reaching the optimum counting conditions.

The measurements were carried out in a ZnS(Ag) scintillation alpha detector. It is supplied as a flat phosphor sheet manufactured by ELJEN Technology (model EJ-440). This product consists of a very uniform deposit of blue-emitting silver activated zinc sulfide phosphor applied to one side of clear polyester plastic sheet. The photomultiplier tube used is 3/4 inch diameter 10-stage head-on type, manufactured by HAMAMATSU (model R5611-01). The maximum ca anode to cathode voltage for the PMT recommended by manufacturer was 1250 V. The low level discriminator varies from 0 to 100 %. The discriminator is closed and pulses are not counted in the case LLD is 100 %.

A Am-241 solution with total activity of about 300 Bq/sample on the 5 cm diameter stainless steel planchet was slowly evaporated to fix the Am-241 in the dryer. After the evaporation, a polyester surface of a 4.5 cm diameter ZnS(Ag) scintillation detector was placed on the planchet. This sample was faced toward the entrance window of the PMT at a 1.2 cm distance as Figure 1.

A background sample was prepared placing a ZnS(Ag) scintillation detector on a clean planchet without a Am-241 source.

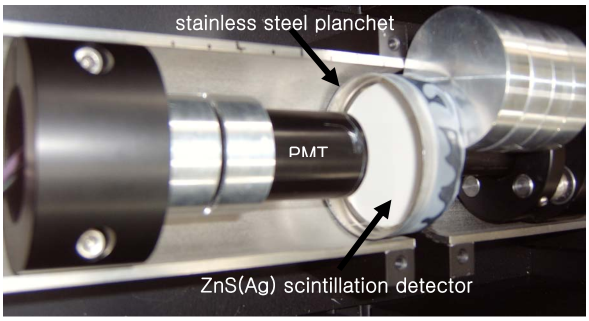

Figure 1. The photograph of ZnS(Ag) scintillation detector system for the measurement of alpha samples.

2.2. Characteristic curve and plateau

The characteristic curve was determined by measuring the alpha source in a ZnS(Ag) scintillation alpha detector and increasing the voltage from 460 to 1480 V in 60 V step and in all case the LLD was increased from 1 to 4 % in 1 % unit step. Counting time was 10 min for each voltage/LLD combination. The region of minimum slope of the curve is referred to as the plateau. The slope is given as the percentage increase in the counting rate per 100 V increase in the applied voltage:

$$\%/100V = \frac{100(R_2 - R_1)/R_1}{V_2 - V_1} \times 100 \qquad (1)$$

where R_1 and V_1 are the count rate and voltage at the begin of the plateau and R_2 and V_2 at the end. A good tube should have a slope no greater than 5-10 % per 100 V [3, 4].

Figure 2 describe a characteristic curve for a ZnS(Ag) scintillation detector. The potential at which counts began to be detected is known as the starting potential. Then, when the voltage was increased, a very rapid increase in the counting rate was observed. This voltage is known as the threshold. Beyond the threshold, further increases in the voltage over quite a range produce little effect on the counting rate. If the voltage is increased beyond the plateau region, the dark current region is reached [6] and then, most of the counts do not correspond to alpha interactions with the detector. Therefore, we can not use this count rate to determine the counting efficiency. The major sources of dark current may be categorized as follows: (i) thermionic emission of electrons, (ii) ionization of residual gases, (iii) glass scintillation, (iv) leakage current and (v) field emission [7].

The relative plateau calculated through Eq. (1) for a LLD of 1 % was 6.06 % per 100 V. It ranged from V_1=700 V to V_2=1120 V, so the plateau length was 420 V and the operating voltage at one third of the plateau length was 840 V. It is also observed that operating voltage at one third of the plateau length became increased when low level discriminator was increased. These operating points are not recommended because the lifetime of the phototube may be a little longer at the lower voltage.

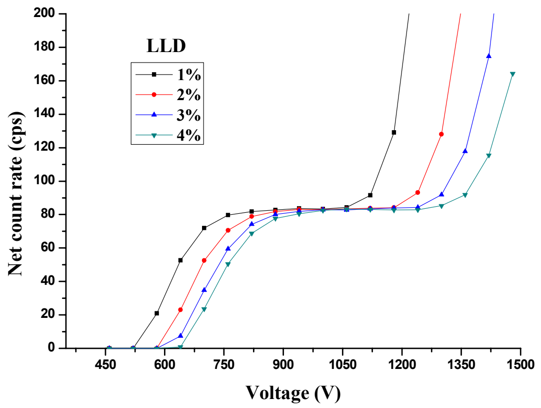

Figure 2. Characteristic curves in a ZnS(Ag) scintillation detector at different low level discriminator (LLD) settings.

3. Conclusion

The ZnS(Ag) scintillation detector was prepared to establish a operating point such as a voltage applied to the PMT and LLD. For selecting the optimum counting conditions, the counts per second obtained on the system were plotted as a function of the voltage. The curves obtained have a flat portion of plateau with a slope no greater than 5-10 % per 100 V. For a LLD of 1 %, the slope of plateau was 6.06 % per 100 V and the operating voltage at one third of the plateau length was 840 V. This counting condition meets the Korean Industrial Standards as well [8].

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