PERFORMANCE OF A ROOM TEMPERATURE GAS PROPORTIONAL SCINTILLATION COUNTER IN X-RAY ANALYSIS OF METALLIC ALLOYS EXCITED WITH ALPHA PARTICLES


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ABSTRACT

A gas proportional scintillation counter with a large detection area (≈ 1000 mm²) is described. The curved grid technique was used for solid angle compensation and the photosensor is a photomultiplier tube with a 50 mm diameter quartz window. For an energy range between 2.5 and 25 keV it can work at counting rates up to 20,000 events/s, presenting for 5.9 keV X-rays an energy resolution of 7.8% for a 1 mm collimated beam that degrades to 9% when the full detector window is used. Results for its performance in the analysis of some common metallic alloys excited with alpha particles are presented.

INTRODUCTION

Gas proportional scintillation counters (GPSC) are large window area, room temperature radiation detectors that provide very competitive performance when compared to the most commonly used gas detectors, namely an energy resolution about twice better than that of standard proportional counters (PC), i.e. about 8% for 6 keV X-rays. Also, as GPSCs work below the ionization threshold of the filling gas, there are no space charge effects and a high counting rate is achievable (≈ 25,000 events/s). A large detection area is also possible using focusing techniques or curved grids and masked photosensors for solid angle effects compensation [1,2]. For very soft X-rays (below about 1 keV) their performance is even comparable to the one obtained with solid state detectors, like Si(Li) and HpGe detectors [3–5]. X-ray astronomy, X-ray fluorescence analysis and Mossbauer spectroscopy are some of the applications for this kind of detector.

Since GPSCs achieve the amplification of the primary electron signal, through the production of secondary scintillation by the gas atoms, a photosensor is needed to detect the scintillation light. The most commonly used photosensor, and the one that still originates the best GPSC performance, is the photomultiplier tube, in spite of the continued effort carried out in the last decade to replace the photomultiplier with a less bulky photosensor, namely using photodiodes [6] and CsI and KBr covered microstrip plates [7,8]. Concerning the choice of gas filling, Xe is the most commonly used one, since it presents high-detection efficiency and a very good scintillation yield. Nevertheless some other rare gases and their mixtures have been tested with success, namely Ar, Ar-Xe [9,10], and Ne-Xe mixtures for very soft X-ray detection [4].

In the present work we describe a gas proportional scintillation counter filled with pure xenon at atmospheric pressure with a large area (≈ 1000 mm²) window, and its performance in the analysis of some common metallic alloys is presented.
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EXPERIMENTAL

A schematic of the GPSC used in this work is presented in Figure 1. It uses a 38 mm diameter radiation window of 50 µm thick Kapton film aluminized in the inner side to make electrical contact with the stainless steel detector body. The Kapton thickness limits the detection of X-rays down to about 2.5 keV. The first grid (G1) has an ellipsoidal shape [11], and the second one (G2), made of chromium, was vacuum deposited onto the photomultiplier tube quartz window (model 9266QB from Electron Tubes) with a diameter of 50 mm. The first grid is isolated from the detector body through the use of Macor. The absorption/drift region between the radiation window and G1 is 4 cm long, and the minimum length of the scintillation region, between G1 and G2, is 1 cm. The detector was filled with Xe at slightly above atmospheric pressure, continuously purified through convection using SAES getters.

Operating principles of the GPSC has already been described in detail [3,12]. In our case the reduced electric field, $E/p$, in the absorption region was 0.2 V cm$^{-1}$ Torr$^{-1}$ and about 5 V cm$^{-1}$ Torr$^{-1}$ in the scintillation region. The curvature of G1 is such that the increase in the reduced electric field for larger radial distances and the larger production of scintillation photons will compensate for the lower solid angle seen by the photosensor for events detected at larger radial distances [1,11].

RESULTS AND DISCUSSION

We started by testing the linearity of the GPSC, using targets of known elements from Ca ($K\alpha = 3.7$ keV) to Ag ($K\alpha = 22$ keV) excited with a $^{244}$Cm radioactive alpha particle source. Although it is known that near the Xe absorption edges there are slight discontinuities because of the availability of new subshells for photoionization [13], we concluded that these effects did not affect significantly the linearity of the detector in the energy range studied. The energy resolution $R$ varied between 11% for 3.7 keV and 5% for 22 keV.

We studied the performance of the GPSC with a counting rate using a 1 mm collimated 5.9 keV X-ray beam (Mn$K\alpha$ line from a $^{55}$Fe source with the $K\beta$ line filtered with a Cr foil). Spectra were obtained for 150 counts/s and 20,000 counts/s with energy resolutions of 7.8% and 8.2%, respectively. For the higher counting rate, the peak shifts 150 eV to higher energies because of pile up effects.
We also compared the performance of the detector for a 1 mm collimated beam and for an uncollimated beam entering the full 1000 mm² window of the detector, for 5.9 keV X-rays. The counting rate was about 150 counts/s in both cases. The spectra obtained are presented in Figure 2. We can observe a degradation of $R$ from 7.8% to 9% as we increase the area of the beam entering the detector from about 1 to 1000 mm², with a slight shift to the lower energies, because of the events absorbed at larger radial distances for which the lower solid angle is not completely compensated by the grid curvature.

![Spectra obtained with the GPSC for 1 mm collimated beam (black) and for the full 1000 mm² window area (gray) for 5.9 keV X-rays.](image)

In Figures 3–5 we present the spectra obtained using this large area GPSC in the analysis of some common metallic alloys, using a $^{244}$Cm alpha particle source to excite the samples. This radioactive source, besides the alpha particles, also emits several X-ray lines. The $L$ lines from Pu (14 to 18 keV), coherently scattered from the samples into the detector, can be observed in all obtained spectra. We can observe that although this GPSC cannot separate, in the energy range studied, the $K$ lines from consecutive elements (Figure 6) can separate $Z$ and $Z+2$ elements present in the most common metallic alloys, as can be seen in Figure 5 for Cr, Fe, and Ni.
Figure 3. Energy spectrum obtained by exciting a 1000 Escudos silver coin (1994, Portugal) with a $^{244}$Cm alpha particle source.

Figure 4. Energy spectrum obtained by exciting a roman coin with a $^{244}$Cm alpha particle source.
Figure 5. Energy spectrum obtained by exciting with a $^{244}$Cm alpha particle source a stainless steel spoon with a silver bath.

Figure 6. Energy spectrum obtained by exciting with a $^{244}$Cm alpha particle source a 60¢ coin from East Timor (1958), with 19% Ni, 61% Cu, and 20% Zn in its composition.

CONCLUSION

Since the analysis of low Z metallic alloys with portable X-ray spectrometry units requires the use of room temperature or close to room temperature detectors and radioactive sources as weak as possible (which means large window area detectors), the gas proportional scintillation counter referred to above can be a good choice in this kind of analysis. As shown, it can separate Z and Z+2 elements present in the most common metallic alloys. This GPSC can work at counting rates up to 20,000 events/s and its energy resolution for a 1 mm collimated beam of 5.9 keV X-rays is 7.8%, degrading to 9% when the full area of the detector window (about 1000 mm$^2$) is used. The lower limit of detection, about 2.5 keV, can be further lowered to 200 eV with the use of a large
area polyimide window, and this is the aim of future work to be developed, as well as the use of Xe-Ar and other rare gas mixtures for soft X-ray detection.

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