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An Experimental Method to Study the Structural Differences of Surface Barrier Detectors by Studying the Energy Distribution of Noise

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Abstract
In this paper, we studied two surface barrier detectors, which are different in polarity and contacts. Where in the first detector, the negative pole is made of gold and the positive one is made of aluminum. While in the second detector, the situation is reversed. This study showed that the design of the first detector is better than the second one because it emitted less noise. This is because ionization potential of gold is smaller than that of aluminum.
Keywords: surface barrier detectors, distribution of noise.

1. Introduction

Since the detector's leakage current and noise affect overall resolution [1], the factors that reduce the noise are of great importance. These factors include temperature, polarizing voltage, and the detector type [2]. There are also, mechanical and operational reasons such as roughness and welding joints [3]. The total noise decreases significantly when the detector is cooled down [2]. An increase of the polarization voltage leads to a decrease of the diode capacitance and this phenomenon is accompanied by an increasing value of the leakage current [4]. Silicon (Si) is one of the extraordinary semiconductors suited for the fabrication of high-quality radiation detectors. It is possible to manufacture high-quality semiconductor wafers with a band gap of 1.1 e V at room temperature, the intrinsic concentration of charge carriers is low to avoid excessive noise. Charge carrier lifetimes and mobilities are high, which is necessary for low noise detectors with a good timing behavior [5,6].

Some commercially available SSB radiation detectors are using edge protection method by using an amine-free epoxy instead of a guard electrode structure because of its simple design and composition [7]. The noise level increases with increasing capacitance, and this rate of increase is also a specified one. The detector capacitance is reduced at higher voltages, so that the lowest noise and best solution are obtained at higher voltages within the recommended range. At voltages above the recommended by the manufacturer, the reverse leakage current will likely increase, causing excessive noise and a loss of resolution [8-11]. Also, we expect that switching the polarity of the detector, as in Figure 1, can change the level and the distribution of electronic noise generated in the surface barrier semi-conductor detectors. To be the only parameter in the experiment is the detector polarity, we used the same alpha spectroscopy for both detectors, where we changed only the voltage function polarity switch on the preamplifier from negative to positive so that the detector is inverse biased diode in both cases (p-n junction, n-p junction).

A new method to find noise distribution

In this method, alpha spectra of the Am^{241} source at different amplifications are recorded.
Since the amplifier is linear, it means that the amplitude (voltage) of the noise pulses and the pulses generated by the alpha particles are multiplied by the same factor. However, since the noise pulses are small in amplitude, for a certain level of the discriminator, none of them will be recorded. Thus, at the smallest amplification value, if the discriminator level is selected so that the number of noise pulses is small, with the amplification increasing, the number of noise pulses whose height is greater than the discriminator level will increase. When we record alpha spectra at different amplification values, a noise peak will appear in the spectrum, increasing the number of pulses with increasing amplification. If the noise pulses are linearly distributed, the relationship between the number of pulses and the amplification is linear, because the amplification is actually multiplying the pulse voltage by a constant number. But if the distribution is not linear, there will be a certain relationship (we will find it). If we have two detectors of the same type, they differ in structure. For example, differ only in the type of welding material, contacts and its shape, or the type of detector, its shape and polarity..., this will cause noise pulses with differing distributions, depending on the type of welding material, contacts and its shape, or type of the detector, its shape and polarity...etc. In this paper, we studied two surface barrier detectors, which are different in polarity and contacts. Figure (1) shows a diagram of two the surface barrier detectors are different in polarity and contacts. Where in the first detector, the negative pole is made of gold and the positive one is made of aluminum. While in the second detector, the situation is reversed. Hence, our first purpose is to find the noise distribution of a surface barrier detector. The Second one is to determine the effect of the difference in the polarity of the detector and contacts on the noise distribution by studying the difference the distributions of the two surface barrier detectors. In this way, we have established a method by which the difference in the structure of these detectors can be studied. Finally, we will discuss the difference in the distribution function of the noise generated by the detectors.

2. Results and discussion

At similar detection geometry and same spectrometer parameters, we recorded alpha spectra of the Am^{241} source for different amplification values using the two detectors. Figures (2), (3) show the α- spectra using the first and the second detector, respectively. We obtained the Fig's (2) and (3). from the alpha spectra in Figure (2), we obtained the table (1). From the alpha spectra in Figure (3), we obtained the table (2).

Noise pulses are usually eliminated by placing the discriminator level slightly above the noise level. But since the amplification stage is before discriminator, the noise level will be dependent on the amplification value. Sometimes the threshold is marked at the highest level at which the noise can reach the larger amplification, but this procedure, in fact, leads to a loss of a large number of source pulses. In order to study the noise, the discriminator level should be slightly higher than the lowest level of noise pulses, at the lowest amplification. As the amplification increases, the number of noise pulses whose height exceeds the discriminator level increases and thus is recorded in the spectrum. The noise appears as a peak at the beginning of the spectrum. The greater the amplification, the greater the channel number of the center of the peak. Also, the center of the full-energy peak of the pulses resulting from the upstream is displaced.

Since the dependence of channel number of the full-energy peak to amplification is linear, and since the dependence of the signal-to-noise ratio is not linear, these mean that the probability of generating a noise pulse from the detector, with energy E, is not linearly dependent for energy E, (This probability represents the energy distribution of the noise). Thus, this dependence (probability in terms of energy) represents the distribution of noise resulting from a survey of the noise from higher energy to the minimum energy. This process corresponds to a displacement process for a discriminator level from higher energy to the minimum energy. Thus ,the energy distribution of the noise will have the same form as the signal-to-noise ratio, i.e., the same form as the fitting function, see figure 5.

$$y = a \ln x + b$$

In other words, y corresponds to $P(E)$; the probability of a noise pulse being generated from the detector with an energy E. And x corresponds to E- the energy of the noise pulse; that is:

$$P(E) = 1 - (a \ln E + b)$$

Parameters a and b are two quantities depending on the materials and design of the surface barrier detector. They reflect the intensity of the noise emission. see figure (6). Thus, we can use them to study the effect of differences in materials and design of detector as follows:

From figure (5), we find

For the first detector that

$$a = 6.787 \quad , \quad b = 14.328$$

For the second detector that

$$a = 3.2375 \quad , \quad b = 7.4955$$

This means that the design of the first detector is better than the second detector because it emitted less noise than the second one. This is because ionization potential of gold is smaller than that of aluminum. Since the noise is symmetrical around the zero line, the probability relationship can be written as follows:

$$P(E) = \pm[1 - (a \ln E + b)]$$

It is clear that the actual distribution of the noise in Figure (6) is similar to that of Gauss, but not Gaussian.

3. Conclusions and Recommendations

The design of the first detector is better than the second one because it emitted less noise. This is because ionization potential of gold is smaller than that of aluminum**.**

We recommend to re-study the previous study for a greater number of amplification values and to apply this study to other types of surface barrier detectors.

4. References

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Table 1: dependence of the channel number of the full energy peak, the channel number of the noise peak, the signal-to-noise ratio, for the first detector.

the signal-to-noise ratio	channel number of the noise peak	channel number of the full energy peak	amplification for the first detector
12	3	36	**1**
15.6	3	47	**1.5**
17.25	4	69	**2**
22.25	4	89	**2.5**
21.6	5	108	**3**
25.6	5	128	**3.5**

Table 2: dependence of the channel number of the full energy peak, the channel number of the noise peak, the signal-to-noise ratio, for the second detector.

the signal-to-noise ratio	channel number of the noise peak	channel number of the full energy peak	amplification for the second detector
7.3	3	22	**1**
9	3	27	**1.5**
9.5	4	38	**2**
12.25	4	49	**2.5**
9.5	6	57	**3**
11.6	6	70	**3.5**

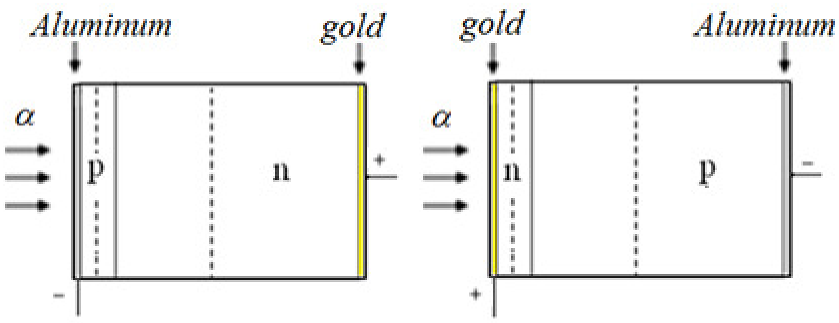

Figure 1: A schematic of two identical surface barrier detectors, which differ by polarization and type of contact.

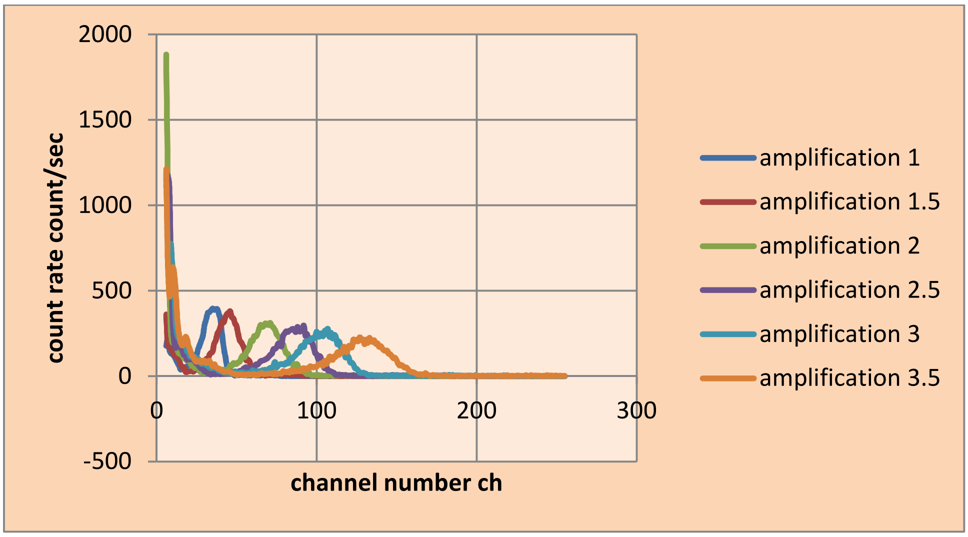

Figure 2: Alpha spectra for the first detector.

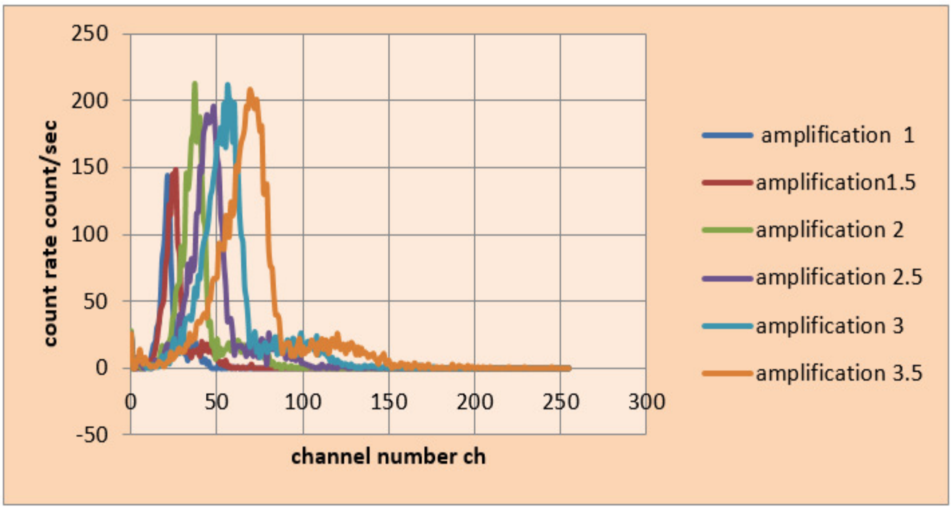

Figure 3: Alpha spectra for the second detector.

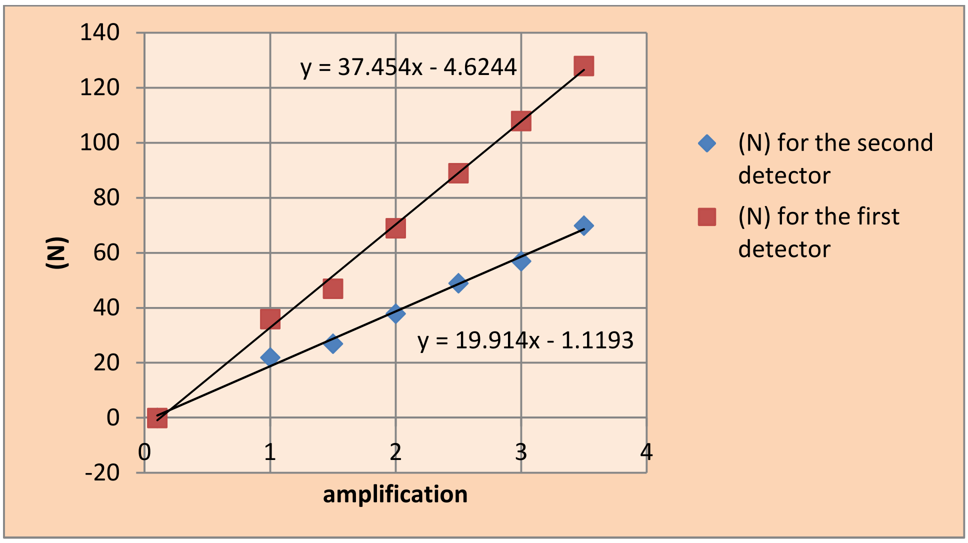

Figure 4: The dependence of the channel number of the full-energy peak (N) to amplification values for both detectors.

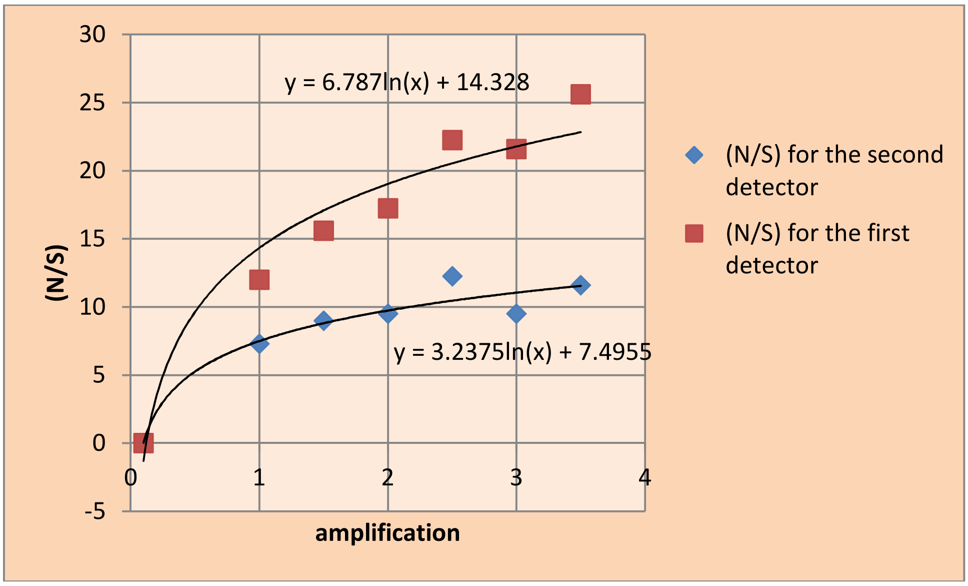

Figure 5: The dependence of the signal-to-noise ratio (N/S) to amplification values for both detectors.

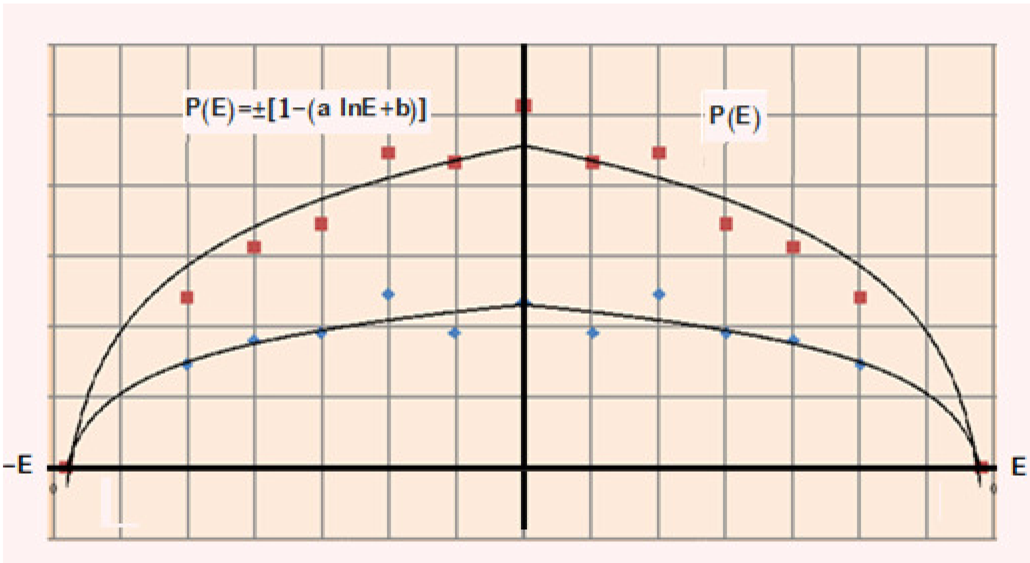

Figure 6: Experimental distribution of noise