ISSN:1306-3111
e-Journal of New World Sciences Academy
2010, Volume: 5, Number: 2, Article Number: 1A0084

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ENGINEERING SCIENCES
Received: September 2009
Accepted: March 2010
Series : 1A
ISSN : 1308-7231

CHARACTERIZATION AND CALIBRATION OF ION-IMPLANTED-SILICON DETECTOR FOR ALPHA PARTICLES MEASUREMENT

ABSTRACT

Ion implanted - silicon detectors are widely used in the alpha radiation, especially for quantitative analysis in environmental applications. For quantitative measurements of the alpha radiation, their characterization and electronic calibration is required. We have tested the silicon detector and CSA (Charge sensitive amplifier) at the room temperature with test setup, using a Am-241 source with a characteristic energy of 5.485 MeV. The purpose of these experiments was to calibrate and characterize the response of the radon system to charged particle of the same types and energies as those encountered in soil. To meet these requirements, discriminating with pulse width of 400 ns is adjusted. The experimental count results demonstrated that this system can be used in online radon measurements.
Keywords: Silicon Detector, Charge Sensitive Amplifier, Radon, Alpha Particle, Am-241

ALFA PARÇACIK ÖLÇÜMLERİ İÇİN İYON İMPLANTLI SİLİKON BİR DEDEKTÖRÜN KARAKTERİZASYONU VE KALİBRASYONU

ÖZET

İyon implantlı silikon detektörler özellikle çevresel uygulamalardaki nicel analizler için alfa radyasyonu tespitinde kullanılmaktadırlar. Alfa radyasyonunun nicel ölçümleri için, bu tip detektörlerin karakterizasyonu ve kalibrasyonu mutlaka gerekmektedir. Bu çalışmada, oda sıcaklığında 5.485 MeV'luk karakteristik enerjiye sahip olan Am-241 kaynağı kullanarak silikon detektör ve CSA (yüke duyarlı amplifikatör) test edilmiştir. Bu deneylerin amacı ise toprak içinde karşılaşılan radyasyon enerjileri ve aynı tipteki parçacıklara karşı detektörün tepkisini ortaya koymak ve detektörün kalibrasyonu olmuştur. Bunu sağlamak için ise 400 ns'lik puls genişliği diskriminasyonu ayarlanmıştır. Deneysel sayım sonuçları bu sistemin gerçek zamanlı radon ölçümlerinde kullanılabileceğini göstermiştir.
Anahtar Kelimeler: Silikon Detektör, Yüke Duyarlı Yükselteç, Radon, Alfa Parçacığı, Am-241

1. INTRODUCTION (GİRİŞ)

Solid state detectors are widely used in many fields of physical and environmental research [1, 2 and 5]. Of those detectors, low voltage ion-implanted Si detectors are a new standard for continuous air monitoring applications in order to reduce cost and to be used in the environment studies. They do not require separate HV supply and can operate between +15 to 24 V. One of the significance advantages of these type detectors in environmental studies is resistant to climatic conditions such as humidity, temperature and pressure. Because of these features, they are preferred for continuous radon measurements [7].

Radon gas data obtained by this type of detector is evaluated in different studies such as earthquake prediction and health risks for population giving the most significant relationships [3]. The most common method for monitoring radon concentration in underground soil is to measure the gas by using an ion implanted silicon detector. This kind of monitoring requires considerable time, cost and labor [4].

In this study, our purpose is to adjust the calibration between an ion-implanted silicon detector and electronic device in continuous radon measurement system and to improve performance of detection efficiency for the alpha radiation. Thus, we optimized the configuration of the detector system and tested a continuous radon monitoring system in order to use underground soil. We also present some time variation data using the developed underground radon monitoring systems.

2. RESEARCH SIGNIFICANCE (ÇALIŞMANIN ÖNEMİ)

The significance of this work is to reveal the performance characteristics of a low voltage ion-implanted Si detector which is used at online radon measurement system in the fault zones.

3. EXPERIMENTAL METHOD (DENEYSEL YÖNTEM)

Our system consists of three blocks, namely the ion-implanted silicon detector, charge sensitive preamplifier unit and counter. This experimental assembly uses an AMPTEK A121 Charge Sensitive Amplifier-Discriminator (CSA) as close to the ion-implanted silicon detector manufactured by ORTEC as possible, the silicon detector was directly mounted on CSA via BNC connector. The typical dimension of this detector is 32x12,3x15,9 mm and it has 450 mm^2 active area. The one side of the metal box is connected to the detector; the other side is connected to the counter with a coaxial cable that is as short as possible. The amplifier was housed in a metal box in order to minimize noise and improving shielding to gain immunity to electromagnetic fields. This also permits the use of the circuit very close to the detector, reducing noise due to the length of the cables.

A schematic block diagram showing the experimental arrangement and the principle of operation of the system is shown in Figure 1.

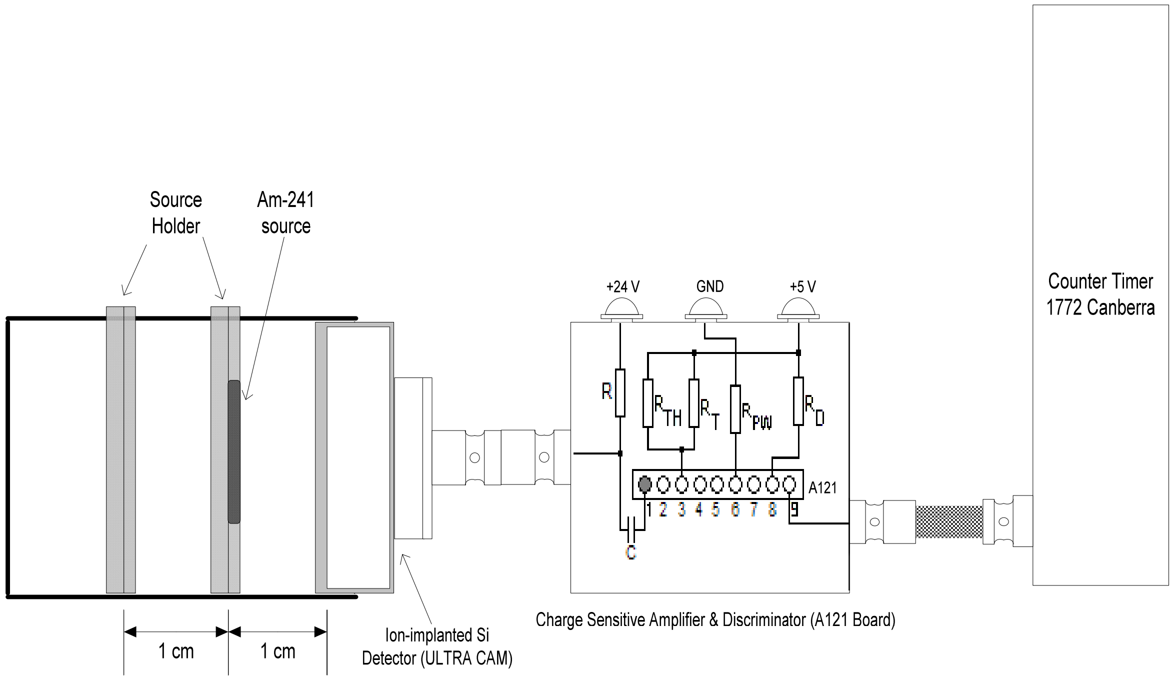

Figure 1. A block diagram of the experimental layout
(Şekil 1. Deneysel düzeneğin blok şeması)

A silicon detector collects charge generated by the traversal of an ion through the device's sensitive material. The charge collected is proportional to the energy deposited, as it requires 3.6 eV to generate an electron hole pair in silicon. A silicon detector produces very small output signals since there is no internal amplification in the detector. At the same time, the input stage of the amplifier must contribute little noise. Typically, charge sensitive preamplifier circuits are used to amplify the output pulses, in order to set the counting threshold, and to convert the pulses above the threshold to digital pulses. When these requirements are taken into consideration, we used A121 fast-high precision circuit device with amplifier, pulse shaping and discriminator. This circuit provides sufficient gain and low signal-to-noise ratio, and has effective detection efficiency for silicon detector. Measurements have been carried out in the optimized experimental setup at room temperature and bias voltage of the detector was chosen at 24 V.

Our experimental studies can be summed on two separate tests; electronic test and calibration. At electronic test procedure, we determined some basic parameters such as pulse width, deadtime and threshold of the discriminator for a given input pulses.

The output amplitude and width of the pulse were measured using Fluke 199C Scope meter and the test pulse by using Hung Chang Sweep Function Generator 9205C. To test the circuit, test pulses were applied through an integrated capacitor C_c=2 pF to charge sensitive amplifier input. During this test, charge sensitive amplifier performances have been verified. Thus, its response to well-known electronic pulses analogous to those produced in the detectors was checked. The output waveform and input voltage step are given in Figure 2.

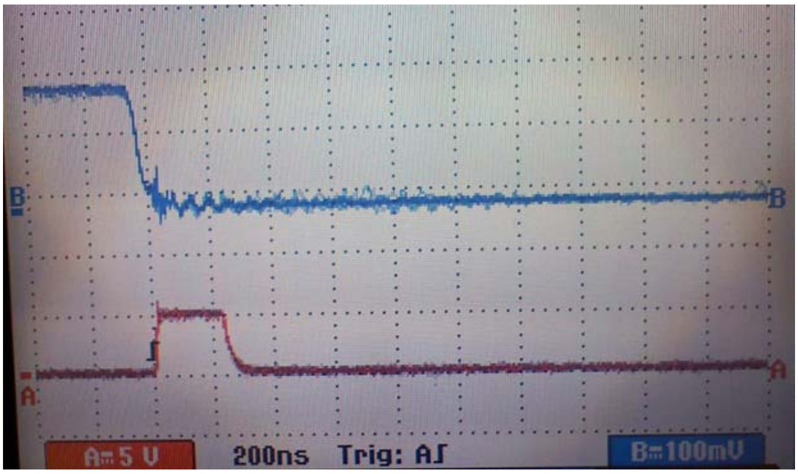

Figure 2. Oscilloscope screen dump depicting
(a) the output waveform and (b) the test voltage
(Şekil 2. Osiloskop ekran görünümü
(a)Çıkış dalga formu ve (b)test gerilimi)

It is quite clear that the output waveform has a square profile: the pulse height was ≈ 5 V and pulse width was ≈ 250 ns. An Amptek A121 model hybrid charge sensitive preamplifier – discriminator was developed for use in pulse counting mode with silicon detector. This circuit generates two outputs for every pulses received from detector. Analog output (pin 5) can be used to monitor detector gain variations by performing pulse height analysis. Other output (pin 9) provides a positive pulse capable of interfacing directly with CMOS and TTL logic [6]. During the test of A121, the following circuit elements are adjusted. Threshold setting was done by changing the voltage level on Pin 3. The voltage on pin 3 is defined by adding a R_{TH} and R_T. These resistors were added to raise the threshold sensitivity. Table 1 shows settings for threshold, pulse width and deadtime.

Table 1. Setting parameters
(Tanlo 1. Parametre ayarları)

Parameters	Settings
Threshold	R_{TH}= 27 KΩ R_T= 10 KΩ
Pulse width	R_{PW} = 7.5 KΩ
Deadtime	R_D= 12 KΩ

The second test consisted of the calibration of silicon detector and its corresponding electronics chain with ^{241}Am source emitting 5.485 MeV alpha particles. The α particles were collimated through a hole of 2 cm in diameter and 1 or 2 cm in length. The absolute counts are calculated by substraction of the background counts by using Canberra Counter/Timer Model 1772. The calibration of the system was performed at different distances and time periods. It was seen in early testing that the charge sensitive preamplifer circuit was extremely sensitive and it required voltage sources in order to avoid being swamped with the noise coming from power sources. Best results so far have been achieved by isolating the preamplifier board inside an aluminum box.

4. RESULTS (SONUÇLAR)

All the measurements were made with the identical settings of the bias voltage and the threshold. The measurement results refer to the behavior of the detectors when using the 5.48 MeV alpha particles from a Am-241 source. Thus, the count rate was adjusted to keep the detector below the high limit of the linearity range. The calibration experiment measurements were performed from 1 to 10 minutes and then, counting signals were recorded. The background signals were substracted from the radon signal. The results obtained were shown in Fig.3, Fig.4 and Fig.5.

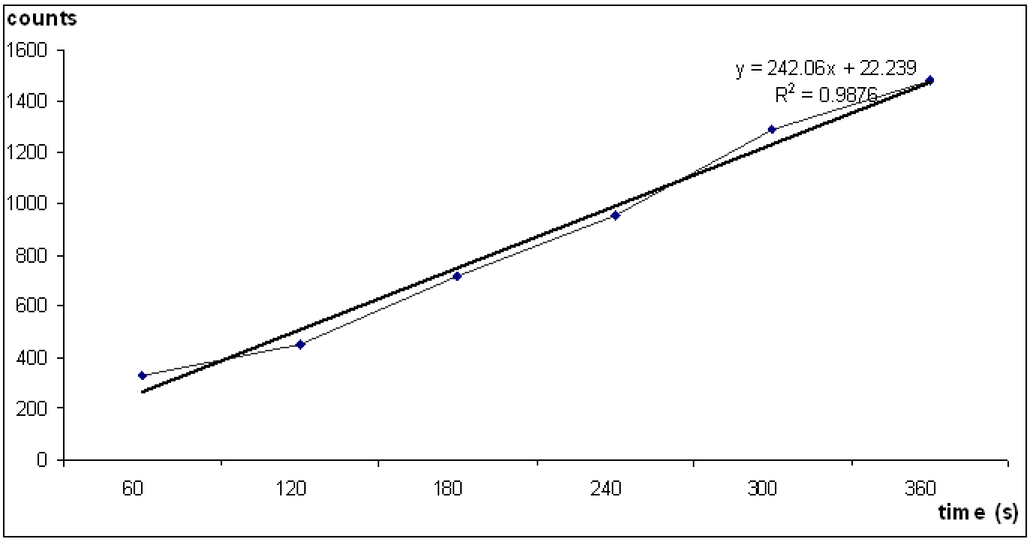

Figure 3. The counts with Am-241 source
(Detector-source distance: 1 cm)
(Şekil 3. Am-241 kaynaklı sayımlar (Detektör-kaynak mesafesi: 1 cm)

The radioactive source was placed at 2.0 cm and 1.0 cm distances from the detector, the best efficiency was achieved at 24 V bias supply, being adjusted R_{TH} and R_T.

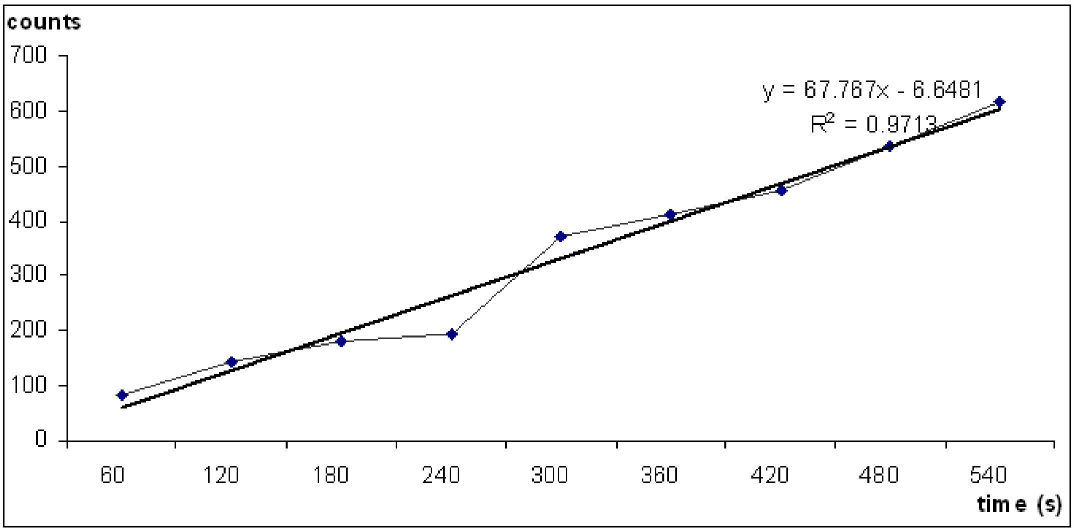

Figure 4. The counts with Am-241 source
(Detector-source distance: 2 cm)
(Şekil 4. Am-241 kaynaklı sayımlar (Detektör-kaynak mesafesi: 2 cm)

As seen in figures, it has been found that the counts measured for different distances from ^{241}Am-source increased with time. Another detector was used to check the counts of Si-detector. Fig.5 shows the counts with spectroscopic system by using silicon surface barrier detector. According to these results, the counts between spectroscopic system and ion-implanted Si detector were observed to give a positive correlation (Fig.5).

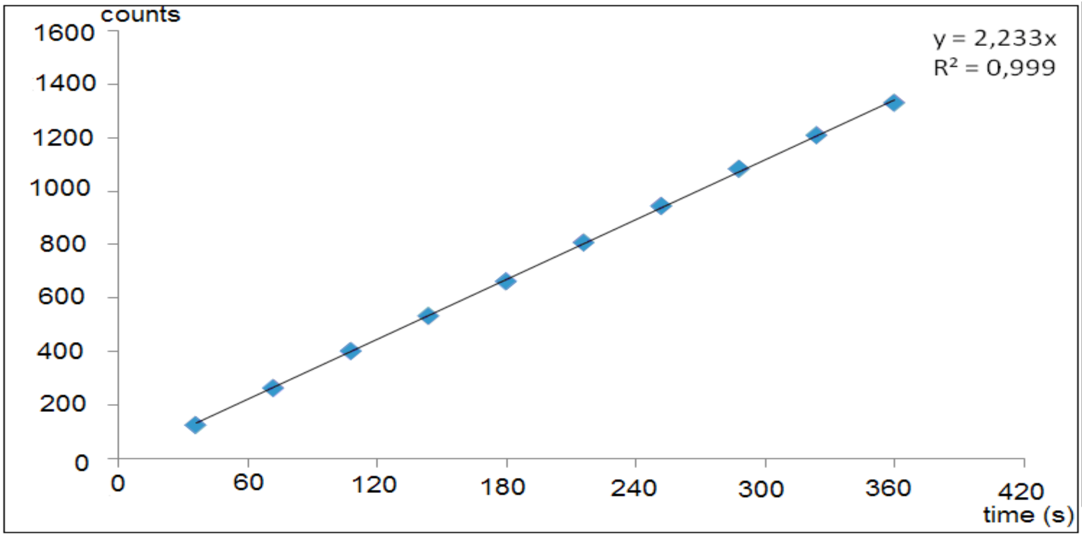

Figure 5. The counts with Am-241 source using alpha spectroscopic system (detector-source distance: 1 cm)
(Şekil 5. Alfa spectroskopik sistem kullanılan Am-241 kaynaklı sayımlar (Detektör-kaynak mesafesi: 1 cm)

5. CONCLUSION (TARTIŞMA)

The Si-detector for the continuous monitoring system has been tested successfully under controlled conditions in the laboratory, as well as in working conditions in a normal environment. The performance of the system will allow us to obtain real time measurements of radon in the environment studies. The applications of continuous radon monitoring system could be extended to the other environmental measurements such as radon on air and in water. In addition, the system, which is expandable from single channel up to multi channels, is able to collect data from a number of various detector types. Further study is ongoing to increase the sensitivity to the detection of alpha particles while adding some other parameters such as temperature, humidity, and pH of soils.

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