SILICON MICRO-PIXELS AVALANCHE PHOTODIODES AND SCINTILLATION DETECTORS

F. Ahmadov[a.c], G. Ahmadov[a.c] , R. Madatov[c], Z. Sadygov[a.b], V. Shvetsov[a], S.Tiutiunnikov[a], Yu. Kopatch[a], V. Zhezher[a]

[a] Joint Institute for Nuclear Research, Joliot-Curie 6, 141980 Dubna, Russia,
[b] Institute of Physics-ANAS, H. Javid 33, AZ-1143 Baku, Azerbaijan,
[c] Institute of Radiation Problems-ANAS, B. Vaxabzade 9, AZ-1143 Baku, Azerbaijan

In this work was described the performance of new generation Micro-Pixel Avalanche Photodiode (MAPD) manufactured in collaboration with Zecotek Photonics Singapore Pte. Ltd. Micro-Pixel Avalanche Photodiode has the especial advances: gain can reach values of 10^5, photon detection efficiency is 30-35 % in a wide wavelength range and density of pixels is 15000pixels/mm^2.

We report the results of gamma-rays and alpha particle detecting measurements performed using lutetium fine silicate (LFS) scintillator crystal with MAPD. Energy resolution was 25% for ^{241}Am (59.6 keV), 11.5% for ^{137}Cs (662 keV) and 9% for 5.5MeV alpha particle from ^{241}Am source.

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INTRODUCTION

Nuclear and high-energy physics experiments often require photo-detectors which have low operating voltage, high gain, single optical-photon sensitivity with sub nanosecond timing characteristics, good radiation hardness, insensitivity to magnetic field and compact sizes [1, 2]. One of the best candidates between photo-detectors which respond conditions showed above is micro–pixel avalanche photo diode (MAPD) [3-5].

On the other hand, it is known that, scintillators with PMT are widely used as detector in many fields e.g. nuclear and high energy physics, medical imaging, diffraction, nondestructive testing, nuclear treaty verification and safeguards, and geological exploration [1]. Taking into account the properties of MAPD shown above, a replacement of PMT with MAPD is useful in many experiments [5-7]. Therefore, investigation of scintillation detectors based on MAPD attracts extensive attention.

1. MICRO-PIXEL AVALANCHE PHOTODIODE

MAPD consists of silicon substrate with n-type of conduction on the surface of which two 4 μm deep epitaxial layers with the same specific resistance of 7 Om·cm are grown. An array of highly doped regions with n+-type of conduction with a step from 5 to 15 μm, depending on implementation, is formed between the epitaxial layers. The distinguishing feature of the MAPD is that it does not have a common bias line and function of an individual quenching resistor is performed by directly biased p-n-junction located under each pixel. This allows increasing pixel density up to 40000 pixel/mm^2. Detail design and operation principle of the MAPD were described in [4, 8].

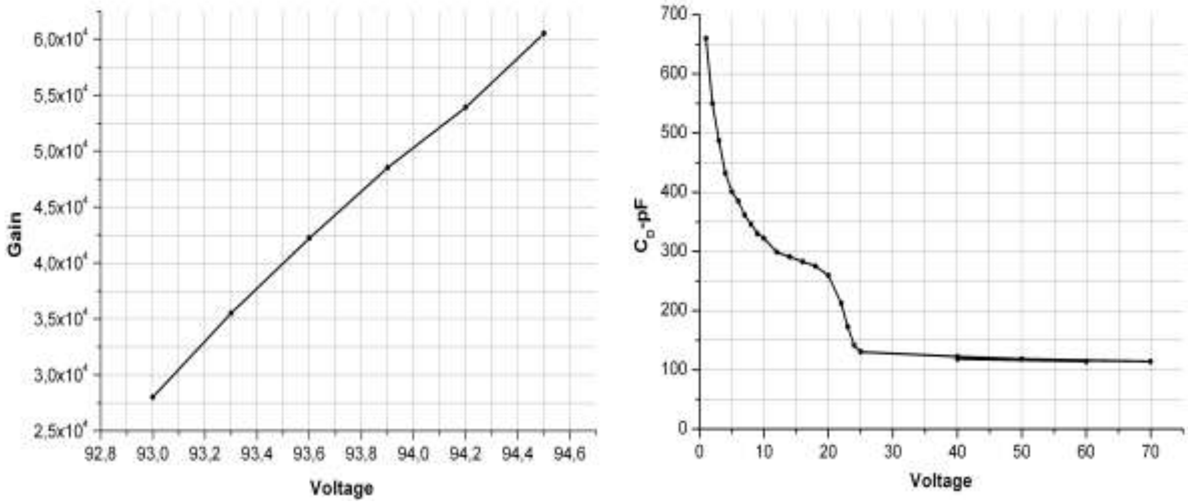

Fig.1. Gain-voltage (left) and capacitance-voltage (right) characteristics of MAPD-P

In Fig.1 is shown gain-voltage (left) and capacitance-voltage (right) characteristics of MAPD-P at room temperature. Gain of the diode reaches $5.5*10^4$. As shown in Fig.1 (right), capacitance of diode reaches 120pF. Maximum PDE is more than 30% around 450-525nm [6]. Dark current is 77nA around operation voltage.

2. EXPERIMENTAL DETAILS AND RESULTS

Gamma rays and alpha particle detecting studies were done on MAPD-P of 3 mm x 3 mm^2 size, consisting of 135000 pixels, respectively. For detecting gamma-ray and alpha particle were used LFS-3 and LFS-8 scintillator. Properties of LFS scintillators were showed in Table 1. In the experiment were used two different size LFS scintillator (LFS-3: $2x2x10mm^3$ and LFS-8: 3 x 3 x $0.5mm^3$) [8].

Table 1. Essential properties of LFS scintillators

Crystal	LFS-3	LFS-8
Density, g/cm^3	7.35	7.4
Decay constant, ns	25-33	12-27
Max emission, nm	425	422
Light yield (NaI=100%)	80-85	80-85
Refractive index	1.81	1.81

LFS-3 scintillator was used to detect gamma-rays from ^{137}Cs gamma source. However, LFS-8 scintillator was used to detect gamma-rays and alpha particle from ^{241}Am. Distance between LFS-8 crystal and alpha sources was 1 cm.

Block diagram of the experimental setup was shown in Fig. 2. Keithley 6487 voltage source was connected to MAPD-P through RC-filter. Signals were read out from 1kOm load resistor through a coupling capacitor and a line amplifier (K=12 for ^{137}Cs and K=60 for ^{241}Am). After the amplifier, the signal was fed into LeCroy 2249A ADC. CAEN N-48 shaping discriminator was used to form a gate signal for the ADC. Digitized signal was read out by a personal computer. Peak positions and their full width at half maximum (FWHM) were obtained from Gaussian fit.

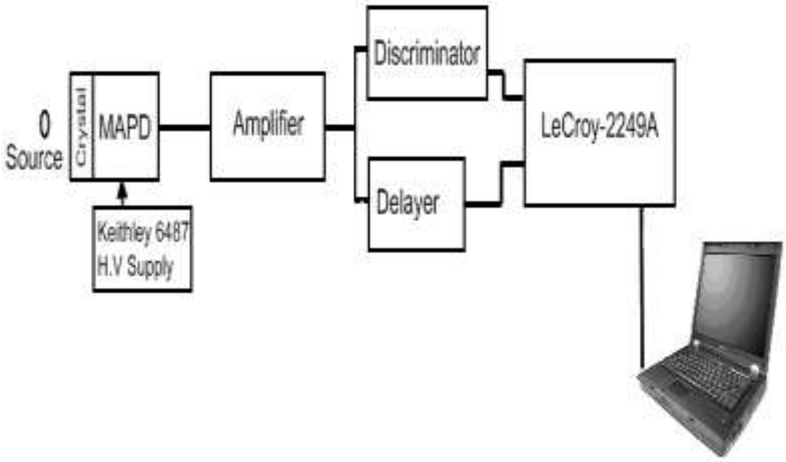

Fig.2. Block diagram of the experimental setup

The LFS crystal was coated with aluminum tape and coupled to the MAPD-P with silicone optical grease. In Fig.3 and Fig.4 were illustrated ^{137}Cs gamma and ^{241}Am alpha spectra measured by the MAPD-P in combination with the LFS scintillator, respectively.

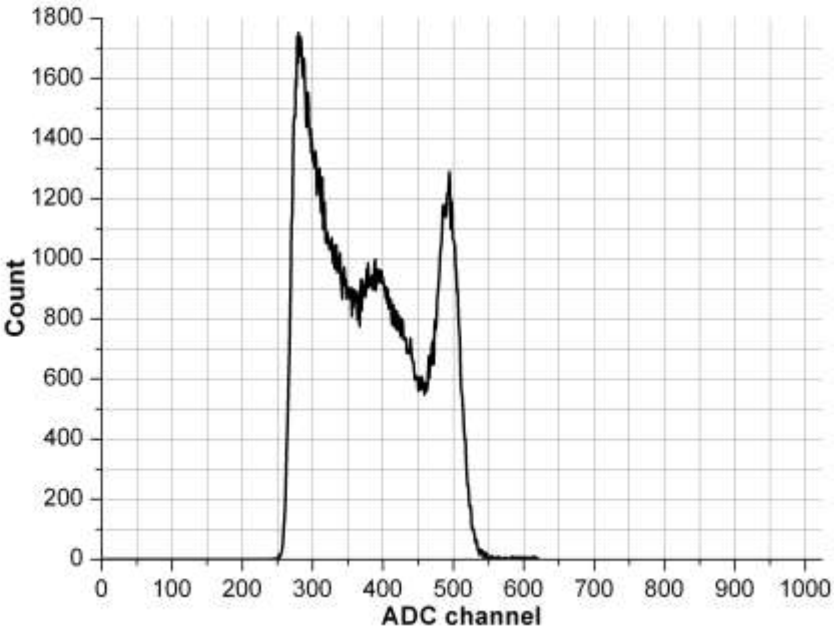

Fig.3. Amplitude spectra obtained with MAPD-P at detection ^{137}Cs source with LFS scintillator

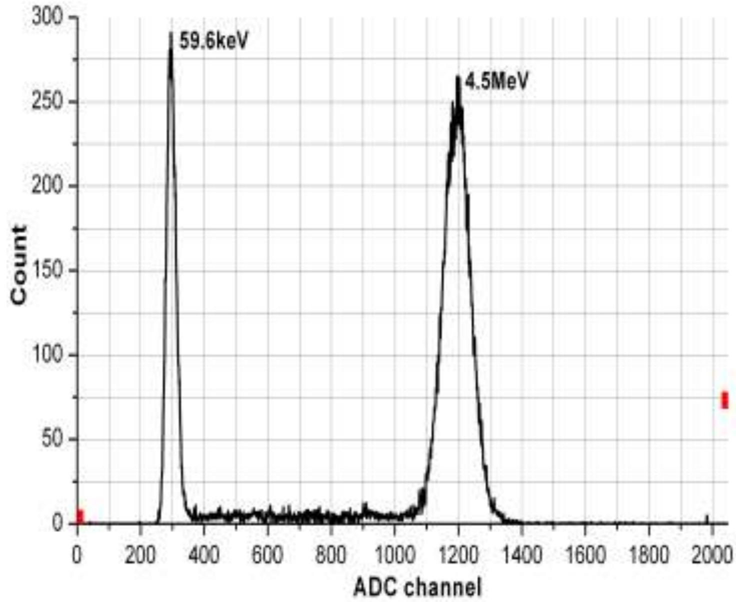

Fig.4. Amplitude spectra obtained with MAPD-P at detection ^{241}Am source with LFS scintillator

There are two peaks in the spectrum of ^{241}Am source. The first peak accorded with 59.6keV gamma ray and the second belonged to 4.5MeV alpha particle. Measured energy resolution for 59.6keV and 662keV gamma rays were 25% and 11.5%. Obtained energy resolution for 4.5MeV alpha particle was 9%.

CONCLUSION

The performance of the MAPD-P together with LFS crystals was investigated for alpha and gamma sources. The obtained results allow using these kinds of detectors for monitoring radioactive contamination in various environments and public security (Associated Particle Imaging for explosives and drugs detection) [7, 9].

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