Passivated ion implanted planar silicon

PIPS detector

1.Overview

Passivated ion-implanted planar silicon PIPS detectors are modern semiconductor process products that have replaced silicon surface-site-barrier detectors (SSB) and diffuse junction-type detectors (DJ) in most applications.Passivated ion-implanted planar silicon PIPS detectors are fabricated using a planar semiconductor manufacturing process that utilizes photolithography to define the detector geometry. The formation of contact surfaces and contacts is precisely controlled by ion implantation, and the oxide passivation is precisely controlled, resulting in thinner incidence windows and lower leakage currents.

2.Advantages of PIPS detectors

PIPS detectors offer a number of advantages over SSB and DJ types of detectors

1. All structural edges are buried inside and do not require the use of epoxy sealers
2. Contacts are precisely formed by ion implantation for better energy resolution and are thinner
3. Ruggedized entry windows that can be easily cleaned and wiped down
4. Leakage currents are typically 1/8 to 1/100 of those of SSB detector or DJ detector
5. The incident window thickness is less than that of the corresponding SSB detector or DJ detector
6. Standard detectors can be baked to 100°C

SSB detectors have raw junction edges that are epoxy-sealed to achieve some degree of stability, whereas PIPS detectors have structural edges that are buried inside the detector

3.There are three main advantages by changing the package structure

1. The stability of the PIPS detector does not depend on the epoxy sealant
2. The risk of microplasma breakdown is small and does not affect the PIPS detector
3. Leakage currents are much smaller than SSB detector or DJ detector

Forming the contact surface of a PIPS detector by ion implantation minimizes the window thickness while maintaining the robustness, reliability and stability of the contact surface. This makes the window of the PIPS detector much thinner than that of a conventional SSB. This thin window improves the energy resolution of Alpha measurements and shows even greater improvement when detecting Alpha sources at close range. This is because Alpha is easily blocked, and the peak broadening in close proximity to the detector is due to the fact that the Alpha rays undergo a partial loss of energy at the entrance of the incidence window before entering the sensitive volume of the detector, resulting in a change in the measured Alpha energy. Thinner incident windows have less energy loss.

In addition PIPS detectors do not rely on metal contacts that are prone to evaporation like SSB Detectors, but rather on passivated implanted surfaces, which can therefore be touched by hand and cleaned with isopropyl alcohol-soaked cotton balls. Making it easier to develop applications, SSB detector or DJ detector are not comparable to PIPS detectors in terms of resolution or incident window thickness.

1.Overview

Passivated ion-implanted planar silicon (PIPS) detectors, primarily used in Alpha spectrometers, offer the advantages of reliability, ruggedness, stability, low noise, high resolution and high detection efficiency.The EP-FD series PIPS detector is a high resolution, high sensitivity and low background Alpha detector. To ensure high resolution, the energy deposition of Alpha rays in the sensitive volume must be maximized. The energy deposited in the sensitive volume deviates from the energy of the Alpha ray due to partial energy loss when charged particles interact with the material of the detector's incidence window. The can thin window on the detector surface reduces the loss of energy in the incidence window. In addition, a low level of leakage current reduces the contribution of electronic noise. These two attributes are required to have a high energy resolution. High energy resolution means high sensitivity and the ability to measure lower energy alpha rays. Low background can be achieved by careful selection of packaging materials, clean manufacturing and testing.

2.PIPS technology is characterized as follows

- 1 ········ Connection of ion-implanted junctions
- 2 ········ SiO2 Surface passivation
- 3 ········ Low leakage current
- 4 ········ Low noise
- 5 ········ Extremely thin incidence windows (≤500Å equivalent silicon)
- 6 ········ Rugged surface (wipeable)
- 7 ········ High temperature resistant baking (100 ℃)

3.Working principle

During the measurement process, particles are absorbed within the depletion region, creating electron-hole pairs. The energy required to form individual electron-hole pairs depends on the detector material and is essentially independent of the energy of the incident particle. Therefore, the number of electron-hole pairs produced is proportional to the energy of the particle. The electric field in the depletion region causes electrons and holes to be collected by two electrodes. From there, a current pulse is generated at the charge collection electrodes and amplified by a charge-sensitive preamplifier.

The thickness of the depletion region depends on the applied bias voltage, with higher bias voltages yielding thicker depletion layers and the ability to detect more energetic particles.

4.FD type PIPS are widely used in different scientific studies such as

- 1 ········ Radiochemical analysis
- 2 ········ Environmental research and monitoring
- 3 ········ Detection of nuclear radiation fields emitting actinides
- 4 ········ Geological and geomorphological studies

5.Detector specifications and operating characteristics of FD type PIPS detector

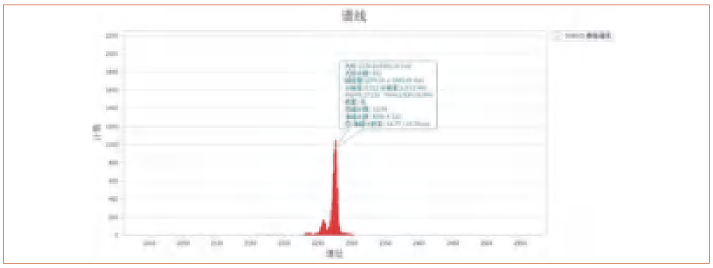
The main point to be made is that the energy resolution depends not only on the detector, but also on external factors such as source preparation, operating pressure, source-to-detector distance, and especially the overall performance of the preamplifier or spectrometer. At lower bias voltages and resistivities, the detector is partially depleted. The minimum depletion depth of the PIPS detector is 300 microns. This is sufficient to absorb particles up to 30 MeV, covering the full range of all Alpha radionuclides. Table 1 shows the detector specifications and operating characteristics of the FD-type PIPS detector.

Table 1 Detector specifications and operating characteristics of FD type PIPS detector

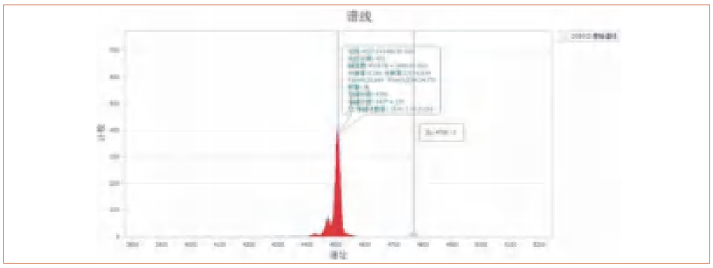
Product model	EP-300FD	EP-450FD	EP-600FD	EP-900FD	EP-1200FD	EP-2000FD
Effective area(mm^2)	314	475	600	940	1240	2000
Effective diameter(mm)	20	24.6	27.6	34.6	39.8	50.5
Thickness (min/max)	300/500 μm					
Bias voltage (min/max)	20/90 V					
Bias voltage (recommend)	30/70V					
Work temperature (min/max)	-40/+40 ℃					
Storage temperature (max)	+100 ℃					
20℃ Leakage Current (Typ/Max)	15/40 nA	20/40 nA	30/50 nA	40/70 nA	40/70 nA	70/100 nA
Energy resolution (keV)	18	20	25	25	35	40

1、The resolution is ^{241}Am@5.486MeV and the source distance detector is measured in equivalent diameter.
2、Beta resolution is typically 5 keV lower than Alpha resolution, approximating pulse line widths.
3、The diameter of the radioactive source is 25mm.

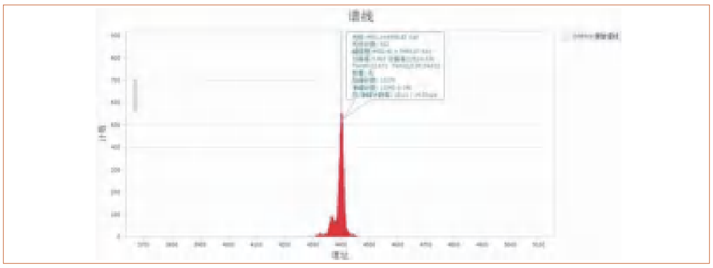
6.Application Testing



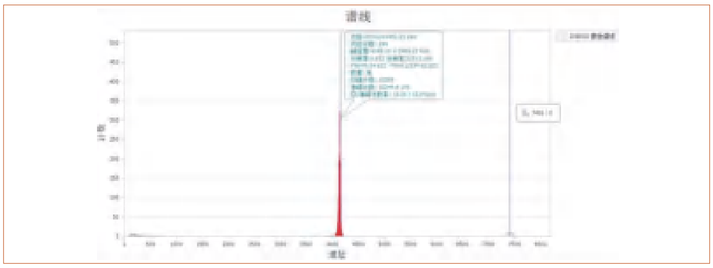
EP-300FD measured Alpha of ^{241}Am resolution: 17keV



EP-600FD measured Alpha of ^{241}Am resolution: 20keV



EP-900FD measured Alpha of ^{241}Am resolution: 22keV



EP-2000FD measured Alpha of ^{241}Am resolution: 34keV

7.Factors affecting the impact and stability of pollution

The Alpha spectroscopy system uses a rotary vane vacuum pump to extract vacuum. When static conditions are established in the vacuum system (ultimate pressure has been reached) and there is not a significant flow of gas to the pump, oil particles may flow back into the spectrometer and deposit on the detector and source surfaces. The same can and will happen if the vacuum pump is turned off and the spectrometer draws air backwards through the air line connecting the two pumps. For this reason, it is recommended that a backflow filter be used between the pumps and the spectrometer tubing, or that a dry pump be used to prevent oil contamination.

Long-term stability

The influence of the environment on the detector will affect the long-term stability of the detector. Au-Si surface barrier detectors sometimes fail due to long exposure to indoor atmosphere, and sometimes fail when operating for a long time in high vacuum. This instability is caused by the epoxy edge package required for this type of detector. The junction of the PIPS detector is buried in silicon. Epoxy resin packaging is not required or used, so PIPS detectors have inherent long-term stability

EP-TCAM Series Continuous Air Monitoring

PIPS Detectors

1.Overview

The EP-TCAM series PIPS detector is a PIPS detector for continuous air monitoring in harsh conditions and is an enhanced version of the standard CAM detector.The EP-TCAM series detectors are micromanipulated with an inert coating of controlled thickness in the presence of a surface-thick aluminum layer. The coating provides excellent acid resistance and non-scratch properties. It is thinner than conventional aluminum layers, reducing the occurrence of conditions such as particle flashing. It is suitable for measurements in harsh conditions such as offshore applications or stack applications.Increasing demands on the safety of nuclear facilities require continuous detection of radioactive particles in the air in and around nuclear facilities, while potential nuclear accidents require worldwide monitoring of the atmosphere. Alpha and Beta levels need to be consistently below the prescribed limits, both instantly and as they accumulate over time. In order to better select a continuous air monitoring system, the impact of detectors on system performance should be understood.For off-line measurement of filter samples, standard PIPS detectors can be used under certain conditions. However, on-line measurements require the characteristics of the EP-TCAM series PIPS detectors, in particular: impermeability to light, moisture and corrosion.

2.PIPS technology is characterized as follows

- 1 ········ Can be operated in visible light
- 2 ········ Corrosion resistance (T-layer barrier protection)
- 3 ········ Moisture resistance (passivation protection)
- 4 ········ Low bias voltage (up to 70V)
- 5 ········ Alpha and Beta energies are clearly differentiated
- 6 ········ Wide operating temperature range (-40 to +50°C)
- 7 ········ Small leakage current
- 8 ········ High sensitivity (depletion thickness 500μm)

3.Working principle

Designed for continuous air monitoring, the EP-TCAM series of PIPS detectors are impervious to light and resistant to corrosion thanks to a special aluminum and inert coating.

Silicon detectors are essentially light sensitive. For Alpha spectrometers and low background Alpha, Beta meters, this can usually be ignored because both the source and the detector are placed in the same light-impermeable chamber. However, in continuous air monitoring, the detector is not protected by a chamber and light may reach the detector in some cases.The EP-TCAM series PIPS detectors have an aluminum coating on the front surface that blocks light. In addition, due to the nature of continuous air monitoring, detectors are often used in atmospheric environments such as humid or dusty environments filled with corrosive gases. In order to extend their service life, EP-TCAM series PIPS detectors are covered with an inert coating that provides mechanical and chemical resistance to abrasion, solvents and corrosion. The coating corresponds to a complementary absorption layer of about 0.5 μm silicon equivalent.The entrance window of the EP-TCAM series detectors is much thicker than that of the FD-type PIPS detectors, which results in an alpha resolution in vacuum that is about twice that of similarly sized FD-type PIPS detectors. However, we must take into account energy scattering and self-absorption of alpha particles in the air spacing between the filter and the detector as well as in the filter and the source itself, which makes scattering in the detector inlet window relatively unimportant.

In normal continuous air measurements, there is no loss of efficiency due to the air separation between source and detector. Typical 5 MeV Alpha particles have a range of a few centimeters in air, while the air spacing is typically <1 cm. When the source-to-detector distance is 5 mm, the geometric efficiency of EP-TCAM series detectors of different areas varies little with source diameter, and large area detectors are much more efficient, regardless of the diameter of the source selected. The diameter of the radioactive source should not exceed the diameter of the detector.

The sum of the counts and the geometric efficiency are proportional to the total activity deposited on the filter. The latter depends on the pumping speed, which in turn is limited by the pressure drop through the filter. The pressure drop itself is proportional to the pumping rate and inversely proportional to the square of the filter diameter. Thus, a large detector permits the use of a larger filter and a higher air flow rate to obtain the same pressure drop, so that greater total activity can be deposited on the filter in a shorter time.

Table 1 shows the detector specifications and operating characteristics of the EP-TCAM series of PIPS detectors.

Table 1 The detector specifications and operating characteristics of the EP-TCAM series.

Product Model	EP-300TCAM	EP-450TCAM	EP-600TCAM	EP-900TCAM	EP-1200TCAM	EP-2000TCAM
Effective area (mm^2)	314	475	600	940	1240	2000
Thickness (min/max)	20	24.6	27.6	34.6	39.8	50.5
Effective diameter (mm)	500 µm					
Bias voltage (min/max)	15/90 V					
Bias voltage (recommend)	70V					
Work temperature (min/max)	-40/+50 ℃					
Storage temperature (max)	+100 ℃					
20℃ Leakage Current (Typ/Max)	15/40 nA	20/40 nA	30/50 nA	40/70 nA	40/70 nA	70/100 nA
α Energy resolution @15-24V(FWHM-keV)	36	38	42	45	55	80
α Energy resolution @70V(FWHM-keV)	34	35	37	40	45	65
β Energy resolution @70V(FWHM-keV)	15	17	20	22	25	37
β Shreshold @70V	18	20	25	25	30	40
Thresholds need to be considered when calculating β and γ efficiency						
The resolution is the α of 5.486MeV of 241Am in vacuum, and the forming time is 1us.						

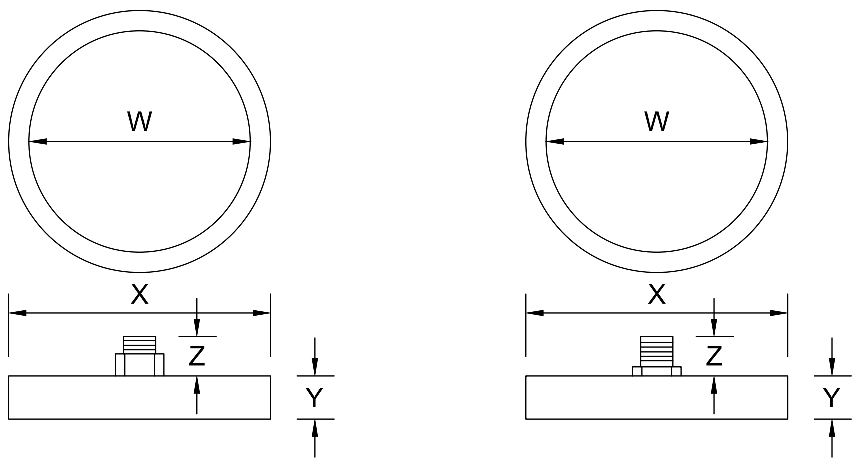
The leakage current of the detector is closely related to the ambient temperature. When the temperature increases by 5.5 to 7.5℃, the leakage current of the detector doubles. Because the high voltage bias resistance of the preamplifier is a source of noise contribution, the bias resistance must be high, usually 100m Ω. The typical leakage current of the PIPS detector is about 1 × 10 of that of the au-Si surface barrier detector. Therefore, the voltage drop on the bias resistance in the preamplifier is much smaller, so the obvious peak offset is not easy to occur at the temperature of 50 ℃.

4.Installation and dimensions

Table 2 Mounting dimensions for different sizes of detectors
(The surface of the detector is 1.0mm from the surface of the package shell)

Detector area	W	Y	Microdot	SMA	BNC
(mm^2)	(mm)	(mm)	Z(mm)	Z(mm)	Z(mm)
314	20	12.3	7.2	7.1	18.5
475	24.6	12.3	7.2	7.1	18.5
600	27.6	12.3	7.2	7.1	18.5
940	34.6	12.3	7.2	7.1	18.5
1240	39.8	12.3	7.2	7.1	18.5
2000	50.5	12.3	7.2	7.1	18.5

Structure and dimensions of the PIPS detector



EP-AP Series Front Mounted

PIPS Detectors

1.Overview

The EP-FDAP and EP-CAMAP series of preamplified PIPS detectors integrate a PIPS detector and a low-noise charge-sensitive preamplifier in a package with a compact, ruggedized enclosure and a sophisticated internal design. The preamplifier can be easily connected directly to the back-end equipment. Depending on the subsequent instrumentation, a linear gain amplifier may be required. The overall power consumption of the detector is very low, making it ideal for use in portable equipment.

2.Product Applications

- 1 ········ α,β Energy spectrum measurement
- 2 ········ α,β Particle count
- 3 ········ Nuclide identification and measurement based on alpha decay
- 4 ········ Surface contamination meter

3.Preamplifier Specifications

- Power supply ········ ±12V
- Output Signal Dynamic Range ········ ±10mVmax
- Signal gain ········ 150mV/MeV
- Signal rise time ········ ＜60ns
- Signal-to-noise ratio ········ > 100 at room temperature
- Connector type ········ 7 pole Lemo connector

4.Specifications and operating characteristics

Table 1 Specifications and operating characteristics of EP-FDAP series

Product model	EP-450FDAP	EP-600FDAP	EP-900FDAP	EP-1200FDAP	EP-2000FDAP
Effective area（mm^2）	475	600	940	1240	2000
Effective diameter (mm)	24.6	27.6	34.6	39.8	50.5
Cathode height (mm)	30	30	30	30	30
Thickness (min/max)	300/500 μm				
Bias voltage (min/max)	15/90 V				
Bias voltage (recommend)	30/70V				
Work temperature (min/max)	-40/+40 ℃				
Storage temperature (max)	+100 ℃				
20℃ Leakage Current (Typ/Max)	20/40 nA	30/50 nA	40/70 nA	40/70 nA	70/100 nA
α Energy resolution (keV)	20	25	25	35	40

1、The resolution is ^{241}Am@5.486MeV and the source distance detector is measured in equivalent diameter.
2、Beta resolution is typically 5 keV lower than Alpha resolution, approximating pulse line widths.
2、The diameter of the radioactive source is 25mm.

Table 2 Specifications and operating characteristics of EP-CAMAP series

Product model	EP-450CAMAP	EP-600CAMAP	EP-900CAMAP	EP-1200CAMAP	EP-2000CAMAP
Effective area(mm^2)	475	600	940	1240	2000
Effective diameter (mm)	24.6	27.6	34.6	39.8	50.5
Cathode height (mm)	30	30	30	30	30
Thickness (max)	500 μm				
Bias voltage (min/max)	15/90 V				
Bias voltage (recommend)	70V				
Work temperature (min/max)	-40/+50 ℃				
Storage temperature (max)	+100 ℃				
20℃ Leakage Current (Typ/Max)	15/40 nA	20/40 nA	35/50 nA	40/70 nA	70/100 nA
α Energy resolution@15-24V(FWHM-keV)	38	42	45	55	80
α Energy resolution@70V(FWHM-keV)	35	37	40	45	65
β Energy resolution@70V(FWHM-keV)	17	20	22	25	37
β Shreshold@70V	51	60	66	75	110

Thresholds need to be considered when calculating β and γ efficiency

The resolution is the α of 5.486MeV of ^{241}Am in vacuum, and the forming time is 1us.

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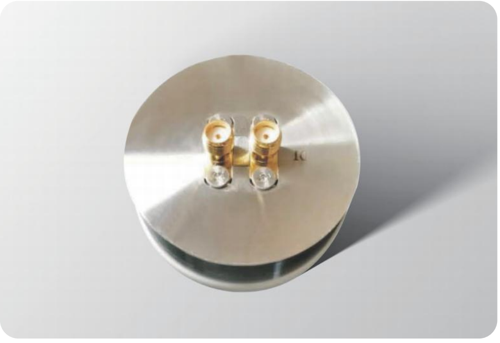
EP-CAMA Series Anti-Compliance

PIPS Detectors

1.Overview



Nuclear power plants use reactor nuclear energy as a source of power, and in the event of an accident in which the integrity of the pressurized boundary of the first circuit is destroyed and a leak occurs, artificial radioactive aerosols will be rapidly released into the ambient atmosphere, causing radioactive contamination in the atmosphere. Monitoring the concentration of radioactive aerosols in the atmosphere inside a nuclear power plant will enable timely detection of reactor operation accidents in nuclear power plants and will be essential for ensuring the safety of nuclear power plant personnel.EP-CAMA series anti-conformity PIPS detector consists of 2 PIPS detectors placed in parallel, the front-end PIPS detector measures α,β rays emitted by aerosol particles and Gama rays from the environment and aerosol particles, and the back-end PIPS detector measures Gama rays from the environment and aerosol particles. the measurement data from the 2 detectors are processed by specialized algorithms to get the The specific activity of the radioactive aerosol is obtained after processing the data from the two detectors by a specialized algorithm. Therefore, the anti-conformal PIPS detector developed on the basis of the new PIPS semiconductor detector design is very suitable for the measurement of radioactive aerosols in terms of its performance characteristics.

Because of the existence of natural radioactive aerosols, the accurate measurement and rejection techniques of natural radioactive aerosol radon and thoron and their decay daughters in radioactive aerosol measurements are very critical and technically difficult.

The y-rays in the natural background and the y-rays emitted by radioactive aerosols also affect the accuracy of radioaerosol measurements to a certain extent, and need to be measured and rejected. Many international radioactive aerosol detectors are unable to accurately measure and reject natural radioactive aerosol radon and thoron, their decay daughters and y-rays due to the defects of their design principles or algorithms, and often have inaccurate measurement results or false alarms caused by natural radioactivity interferences in the process of use, which seriously affects the normal use of the equipment, and greatly weakens its ability to measure accurately. The new PIPS detector is an ion-adulterated PN junction semiconductor detector with a very thin sensitivity region, insensitive to Gama rays, fast output pulse signal and high energy resolution, which is very suitable for the measurement of α and β radioactivity. Based on the new PIPS semiconductor detector, the anti-compliant PIPS detector has been designed with efficient energy spectrum measurement capability, which can measure the energy spectrum of radioactive aerosol samples in real time, and can be processed by specialized stripping algorithms, which can strip out the natural radioactive radon, thoron and their substrate components in real time, and remove the interference of natural radioactivity. Thus, the artificial radioactive aerosol concentration with high accuracy is obtained.

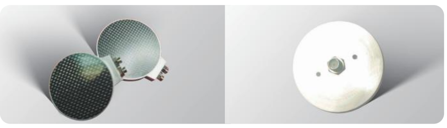
2.Specifications and operating characteristics

Table 1 Detectors and operating characteristics of EP-CAMA series.

Product Model	EP-300CAMA	EP-450CAMA	EP-600CAMA	EP-900CAMA	EP-1200CAMA	EP-2000CAMA
Effective area(mm^2)	310	470	600	940	1240	2000
Total area(mm^2)	620	940	1200	1880	2480	4000
Effective diameter（mm）	20	24.6	27.6	34.6	39.8	50.5
Shape diameter（mm）	30.8	36	41	48.5	55	66.5
Cathode height（mm）	17.1	17.1	17.1	17.1	17.1	17.1
Thickness (min/max)	500 µm					
Bias voltage (min/max)	15/90 V					
Bias voltage (recommend)	70V					
Work temperature (min/max)	-40/+50 ℃					
Storage temperature (max)	+100 ℃					
Interface Type	SMA					
20℃ Leakage Current(Typ/Max)	15/40 nA	20/40 nA	35/50 nA	40/70 nA	40/70 nA	70/100 nA
α Energy resolution@70V (FWHM-keV)	34	35	37	40	45	65
β Energy resolution@70V (FWHM-keV)	15	17	20	22	25	37
β Shreshold @70V	45	51	60	66	75	110
Thresholds need to be considered when calculating β and γ efficiency						
The resolution is the α of 5.486MeV of ^{241}Am in vacuum, and the forming time is 1us.						

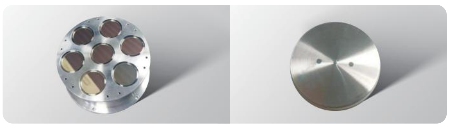
3.Customized PIPS detectors

In addition to the regular standard detectors, we can also provide customized services at the most suitable price according to the user's actual needs, including large-area detectors, arrays, and special structure detectors.



● Figure 1 Sample diagram 1.

● Figure 2 Sample diagram 2.



● Figure 3 Sample diagram 3.

● Figure 4 Sample diagram 4.

● Figure 5 Sample diagram 5.

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