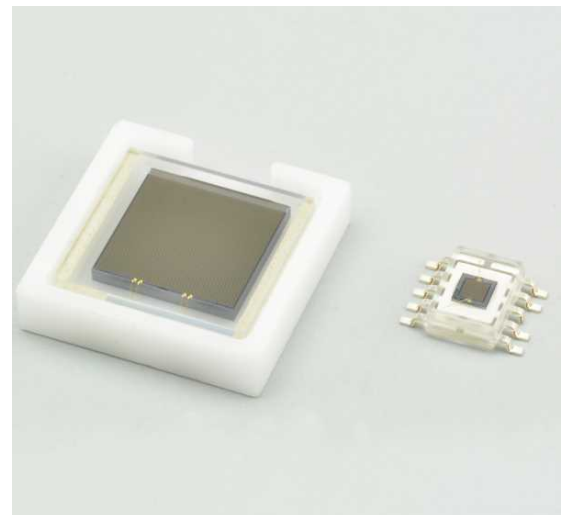
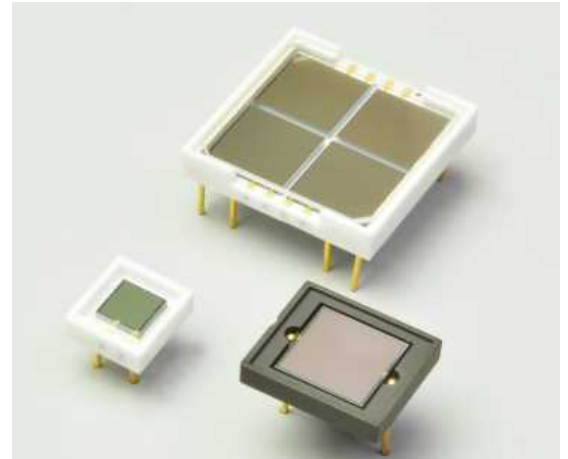


VUV-MPPC 4th generation (VUV4)

■ Overview

Hamamatsu Photonics K.K., a major manufacturer of a wide variety of silicon photodetectors including the Multi-Pixel Photon Counter (MPPC), has developed VUV-MPPCs that are capable of detecting light down to **120 nm**, covering scintillation wavelengths of liquid xenon and argon with cryogenically compatible, ultralow-RI packaging options.

We developed a 4th generation of **VUV-MPPC (VUV4)** for cryogenic physics experiments. In addition to diminished afterpulsing and inter-pixel trenches to suppress optical crosstalk, we have achieved improvement of VUV photosensitivity in this new MPPC through new modifications of the device structure. By achieving these results and continuing our MPPC improvements, we hope to make a valuable contribution to the physics community's efforts towards discovery of dark matter, the neutrinoless double-beta decay, and other cutting-edge research field.



■ Feature

- ✓ High sensitivity for VUV
- ✓ Stable for cryogenic temperature
- ✓ Suitable for detection of LXe or LAr scintillation light

■ LXe or LAr scintillator

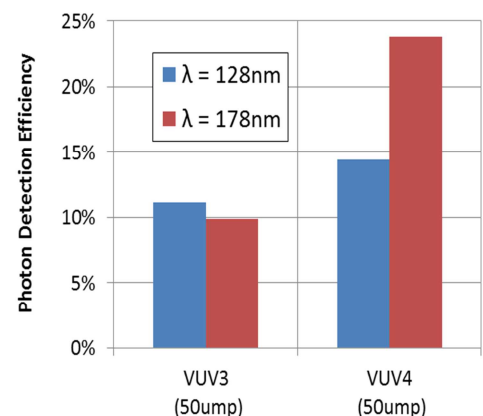
Liquid xenon (LXe) and liquid argon (LAr) are used as scintillators for **dark matter search** or **neutrinoless double-beta decay experiments**.

✓ Liquid Xenon (LXe)

- Peak emission wavelength: **178 nm**
- Temperature: 165 K
- Directly detected by VUV photodetector

✓ Liquid Argon (LAr)

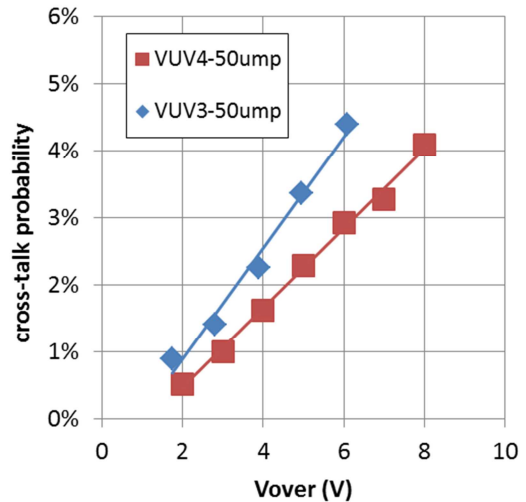
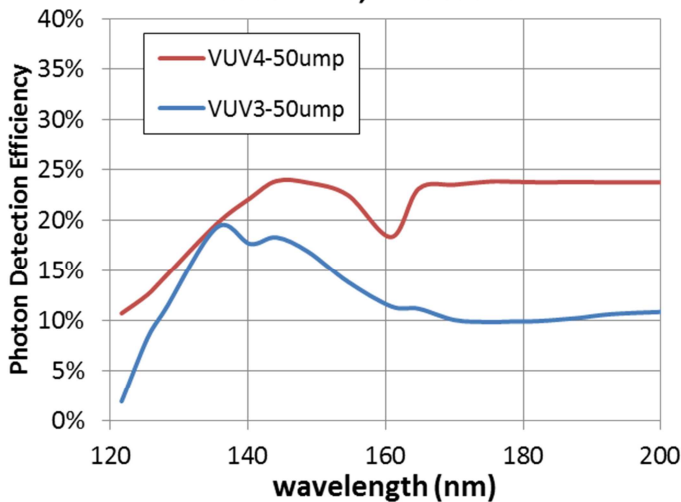
- Peak emission wavelength: **128 nm**
- Temperature: 87 K
- Directly detected by VUV photodetector or indirectly (after WL-shifter) by UV/blue photodetector (typically~420 nm)



■ **VUV-Sensitivity improvement**

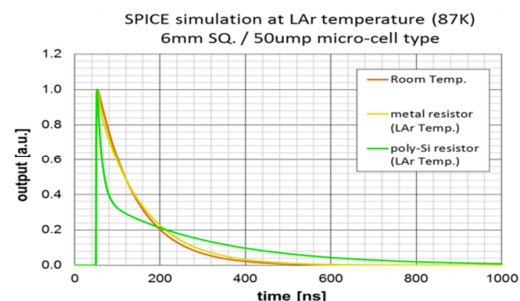
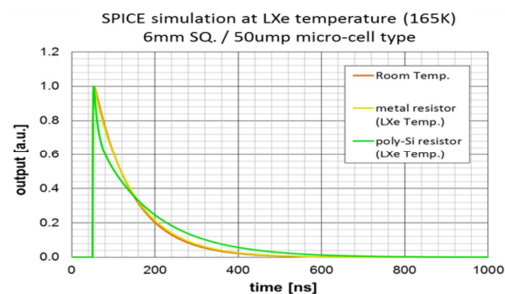
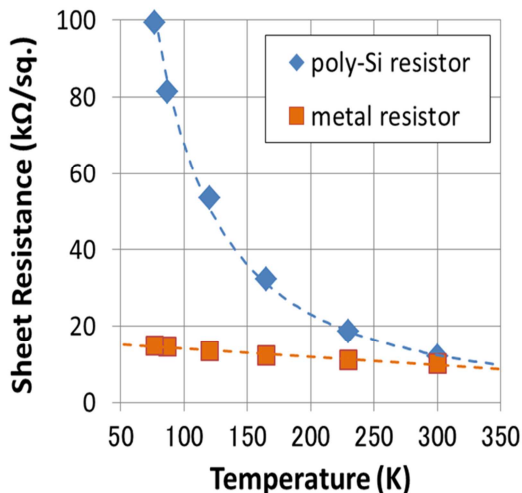
- ✓ VUV-MPPC has VUV-sensitivity down to 120 nm.
- ✓ The new 4th generation VUV-MPPC (VUV4) has improved photon detection efficiency, which becomes much higher than that of the 3rd generation VUV-MPPC (VUV3).
- ✓ Since optical crosstalk is suppressed by the inter-pixel trench structure, VUV4-MPPC has also improved signal-to-noise ratio

PDE measurement data
Vover = 4V, in vacuum



■ **Cryogenic temperature stability**

- ✓ VUV-MPPC contains a metal quenching resistor to maintain its pulse shape at low temperatures. The metal resistor has 1/5 the temperature coefficient of the poly-Si resistor, so its resistance has excellent stability against temperature changes.
- ✓ SPICE simulation confirmed that there is a clear difference in pulse shapes between the metal and poly-Si resistors at lower temperatures.
- ✓ VUV-MPPC with metal quenching resistor maintains its pulse shape at both room and low temperatures, but MPPC with poly-Si resistor has longer pulse tails and recharge time at low temperatures.



■ S13370 series

S13370 series are basic VUV-MPPCs with 4th generation (VUV4).

Sensitivity for 128nm (Liq. Ar)	Sensitivity for 178nm (Liq. Xe)	Low RI
✓	✓	

■ Structure

Parameters	S13370				unit
	-3050CN	-3075CN	-6050CN	-6075CN	
Effective photosensitive area	3.0 x 3.0		6.0 x 6.0		mm ²
Pixel pitch	50	75	50	75	μm
Number of pixels / channels	3600	1600	14400	6400	-
Geometrical fill factor	60	70	60	70	%
Package	Ceramic				-
Window	Unsealed				-

■ Absolute maximum ratings

Parameters	Symbol	S13370 series	unit
Operating temperature ^{*1}	Topr	up to +60	°C
Storage temperature ^{*1}	Tstg	-20 to +80	°C
soldering condition	Tsol	350 °C or less, once, within 3 seconds	-

*1: No condensation

■ Electrical and optical characteristics (Typ. Ta=25 deg C, Over voltage=4.0V Unless otherwise noted)

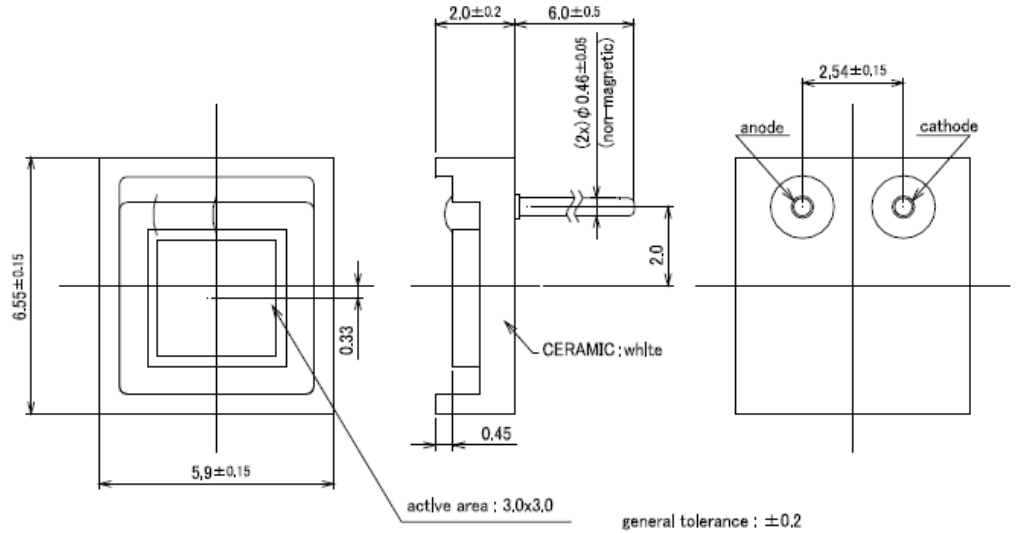
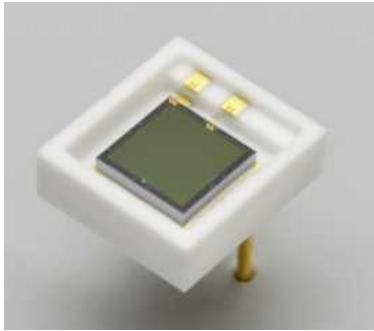
Parameters	Symbol	S13370				unit
		-3050CN	-3075CN	-6050CN	-6075CN	
Spectral response range	λ	120 to 900				nm
peak sensitivity wavelength	λp	500				nm
Photon detection efficiency at λp ^{*2}	PDE	35	40	35	40	%
Break down Voltage	VBR	53 +/-5				V
Recommended operating voltage ^{*3}	Vop	VBR + 4				V
Dark count	typ.	1.0		4.0		Mcps
	max.	3.0		12.0		
Crosstalk probability	-	3	5	3	5	%
Terminal capacitance	Ct	320		1280		pF
Gain	M	2.55x10 ⁶	5.8x10 ⁶	2.55x10 ⁶	5.8x10 ⁶	-
Temperature coefficient of recommended reverse voltage	ΔTVop	54 (around the room temperature)				mV/°C

*2: Photon detection efficiency does not include crosstalk and after pulse.

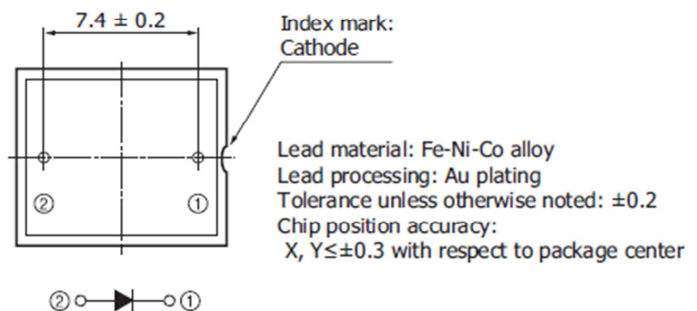
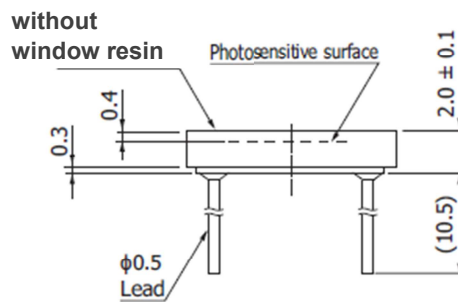
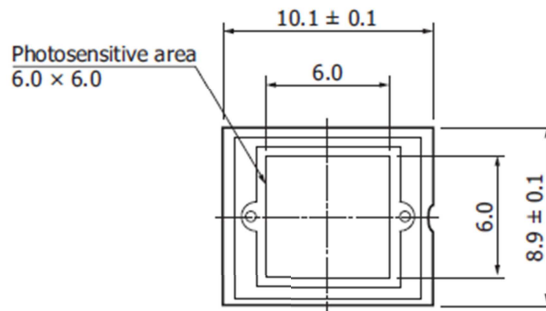
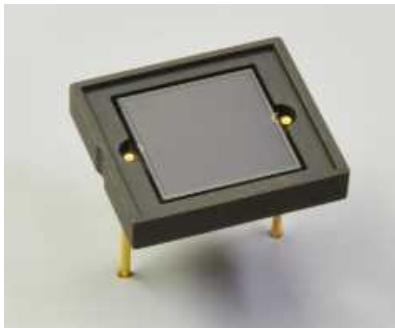
*3: Refer to the data attached for each product.

■ **Product outline**

<S13370-3050CN / S13370-3075CN>



<S13370-6050CN / S13370-6075CN>



■ S13371-6050CQ-02 <MPPC for MEG II experiment>

This MPPC will be installed in a γ -ray calorimeter to detect scintillation light from LXe.

Sensitivity for 128nm (Liq. Ar)	Sensitivity for 178nm (Liq. Xe)	Low RI
	✓	

■ Structure

Parameters	S13371-6050CQ-02	unit
Number of channel	4(2x2)	
Effective photosensitive area	5.95 x 5.85	mm ²
Pixel pitch	50	μ m
Number of pixels / channels	13,923	-
Geometrical fill factor	60	%
Package	Ceramic	-
Window	Quartz	-

■ Absolute maximum ratings

Parameters	Symbol	S13371-6050CQ-02	unit
Operating temperature ^{*1}	Topr	up to +60	°C
Storage temperature ^{*1}	Tstg	-20 to +80	°C
soldering condition	Tsol	350 °C or less, once, within 3 seconds	-

*1: No condensation

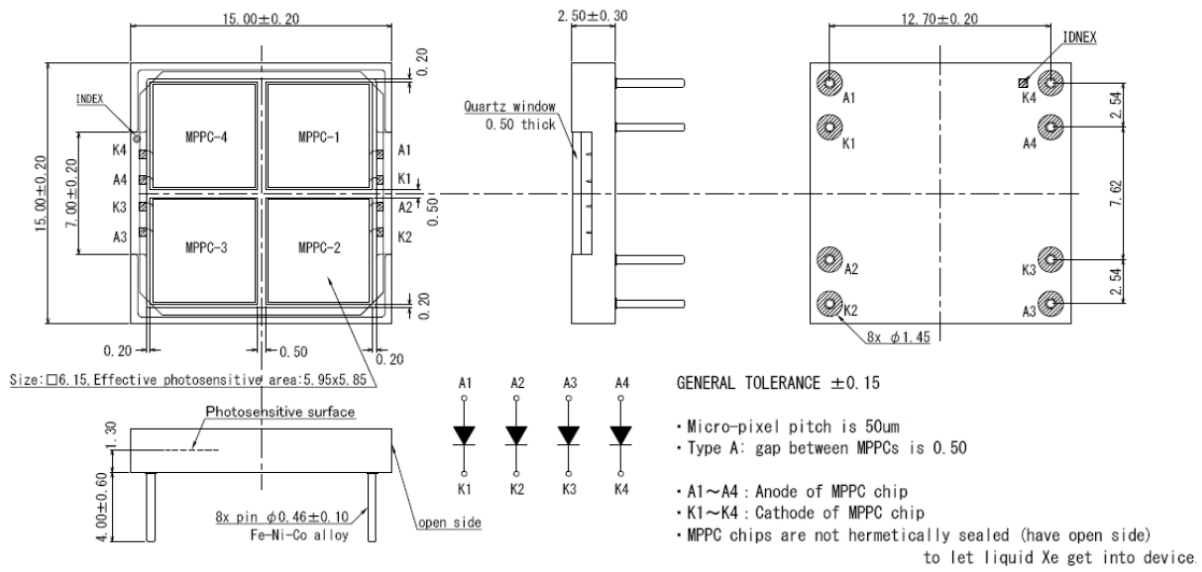
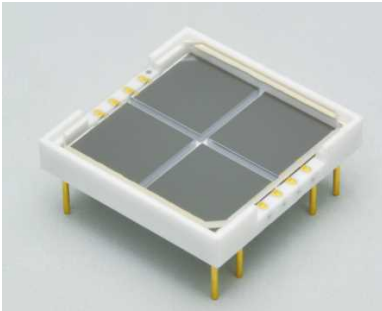
■ Electrical and optical characteristics (Typ. Ta=25 deg C, Over voltage=4.0V Unless otherwise noted)

Parameters	Symbol	S13371-6050CQ-02	unit
Spectral response range	λ	155 to 900	nm
Photon detection efficiency at 175nm in vacuum condition ^{*2}	PDE	24	%
Break down Voltage	VBR	53 +/-5	V
Recommended operating voltage ^{*3}	Vop	VBR + 4	V
Vop variation	typ.	0.15	V
between channels (+/-)	max	0.4	
Dark count/ch.	typ.	4.0	Mcps /ch.
	max	12.0	
Crosstalk probability	-	3	%
Terminal capacitance/ch.	Ct	1200	pF
Gain	M	2.55x10 ⁶	-
Temperature coefficient of recommended reverse voltage	Δ TVop	54	mV/°C

*2: Photon detection efficiency does not include crosstalk and after pulse.

*3: Refer to the data attached for each product.

■ **Product outline**

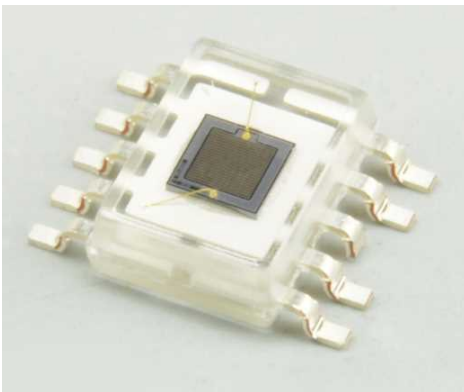


■ Ultra-low RI MPPC

- ✓ For rare event search experiments that require a low-noise background, MPPC must have reduced radioisotope (RI) content in its constituent materials.
- ✓ We measured the RI level of each package material candidate and developed the ultralow-RI MPPC.

➤ S13372 series Ultralow-RI MPPC for indirect VUV detection

Sensitivity for 128nm (Liq. Ar)	Sensitivity for 178nm (Liq. Xe)	Low RI
		✓



RI level of package component

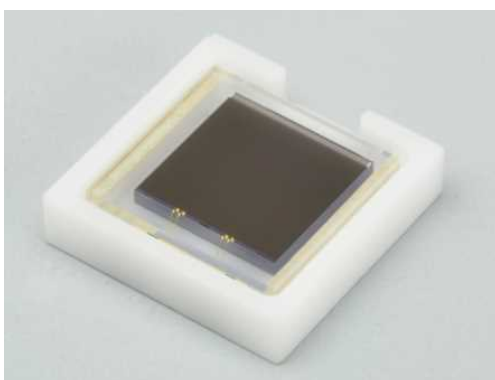
Unit:[mBq/unit]	MPPC chip	die bonding resin	molding resin	lead frame
U-chain	Pa-234m	<1.8	<1.7	<41
	Pb-214	<0.019	<0.019	<0.425
	Bi-214	<0.031	<0.018	<0.51
Th-chain	Ac-228	<0.055	<0.041	<0.92
	Pb-212	<0.013	0.014±0.004	<0.27
	Bi-212	<0.14	<0.12	<2.5
Other	Tl-208	<0.031	<0.03	<0.75
	U-235	<0.011	<0.011	<0.19
	K-40	<0.084	<0.072	<2.99
	Cs-137	<0.006	<0.005	<0.13
	Co-60	<0.005	<0.006	<0.12

Measured by GeLatuca (Radiopurity Service of Laboratorio Subterráneo de Cabfranc), IFIC INST. FISICA CORPUSCULAR UNIV. VALENCIA CSIC, NEXT group.

Package type	: Plastic mold (active area: 1 mm sq)
Application	: Indirect detection of scintillation photons by using a wavelength shifter (WLS)
Spectral response range	: 320 to 900 nm
RI level	: Only ²¹² Pb has been quantified from die bonding resin, but other radioisotopes in the Th-chain are below the detection limit.

➤ S13374 series Ultralow-RI MPPC for direct VUV detection

Sensitivity for 128nm (Liq. Ar)	Sensitivity for 178nm (Liq. Xe)	Low RI
✓	✓	✓



RI level of package component

Unit:[mBq/unit]	MPPC chip	die bonding resin	Pure Ceramic
U-chain	Pa-234m	<99	<211
	Pb-214	<1.1	<6.8
	Bi-214	<1.7	<13
Th-chain	Ac-228	<3.1	<6.4
	Pb-212	<0.74	<2.1
	Bi-212	<7.6	<89
Other	Tl-208	<1.7	<5.6
	K-40	<4.7	<22
	Cs-137	<0.33	<2.3
	Co-60	<0.27	<1.8

Measured by Hamamatsu Photonics (on ground equipment)

Package type	: Ceramic (active area: 6 mm sq)
Window	: Bare, quartz (for LXe), MgF ₂ (for LAr)
Application	: Direct detection of scintillation photons
Spectral response range	: 120 to 900 nm
RI level	: No radioisotopes could be quantified by the measurement setup.

