Charge multiplication in CdZnTe Schottky barrier diode detectors at alpha-particles registration

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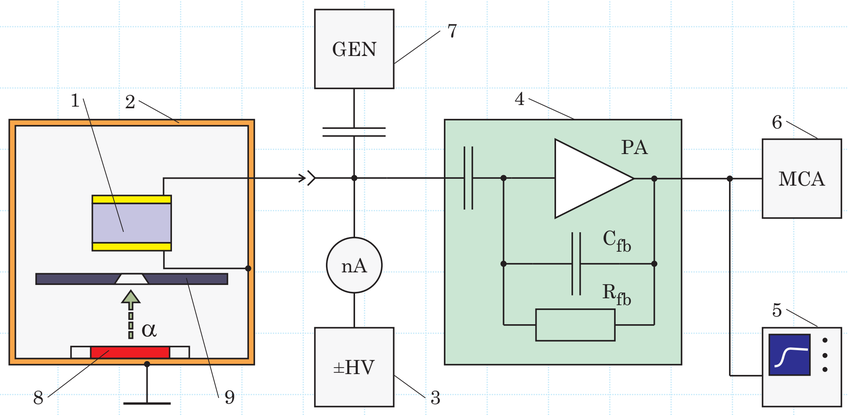
The planar detectors with Schottky barrier diode structure (Au/CdZnTe/In) were investigated using alpha-particle response characterization. At irradiation of a negative In contact by alpha-particles of 5.5 MeV slow pulses with extremely large amplitude, exceeding in tens times the amplitude of the pulses when operating at the reverse bias have been found. To study this phenomenon a special charge-sensitive preamplifier with low charge sensitivity and a large decay time constant has been used. Was found that the amplitude of the output pulses obtained with detectors having Schottky barrier diode structure at the forward biases exceed in many times the amplitude of output pulses obtained with planar conductive detector (Au/CdZnTe/Au) fabricated of the same crystal. Illumination of a negative contact of the conductive detector with a laser visible light (635 nm) leads to the similar effect.

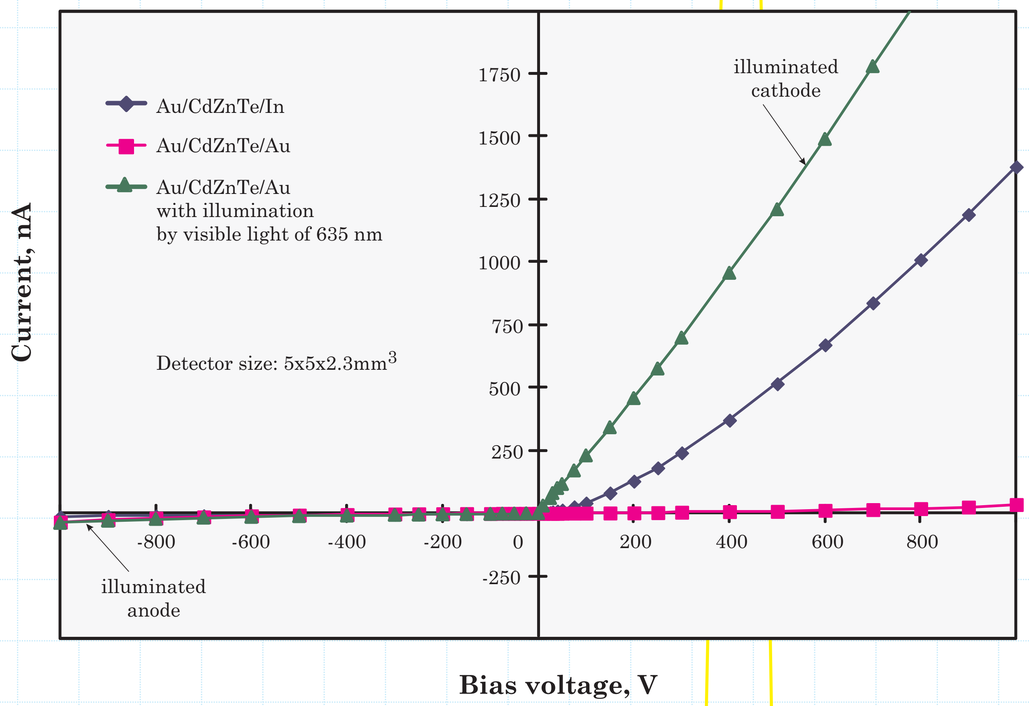
Schematic diagram of experimental setup for CdZnTe detectors characterization



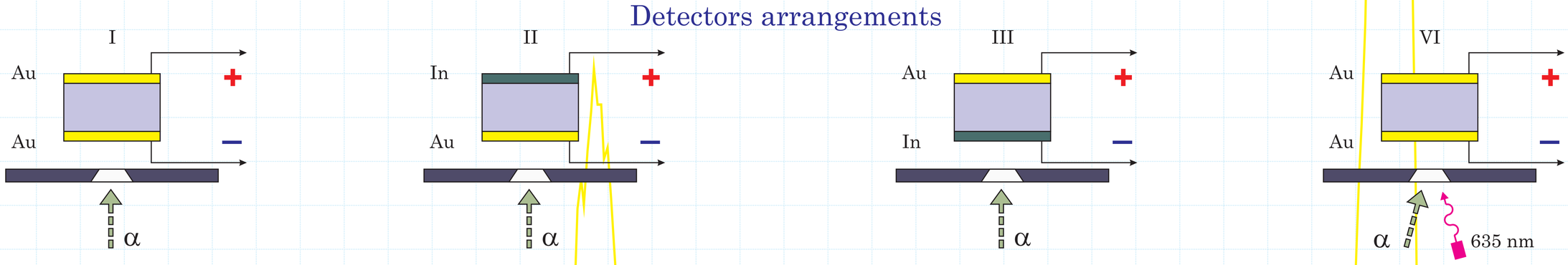
1 – CdZnTe detector (Au/CdZnTe/Au or Au/CdZnTe/In), 2 – measuring chamber, 3 – high voltage power supply (positive or negative) TENNELEC TC 953, 4 – charge sensitive preamplifier RITEC PA101C, 5 – digital oscilloscope Tektronix TDS 2012B, 6 – multi-channel analyzer with shaping amplifier, 7 – research pulser ORTEC 448, 8 – alpha-particle source ^{238}Pu (5.5 MeV), 9 – collimator.

Charge sensitive preamplifier parameters are: sensitivity (CdZnTe) - 1.5 mV/MeV; decay time constant ($\tau = R_{fb}C_{fb}$) - 7 ms; rise time - < 80 ns.

I-V characteristics of CdZnTe detectors

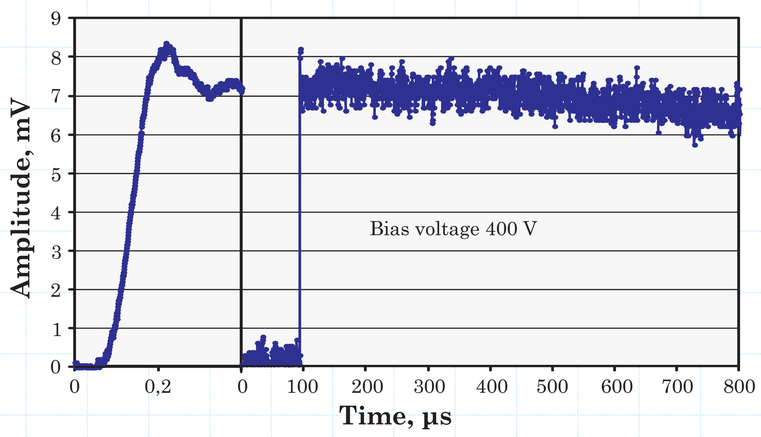


Detectors arrangements

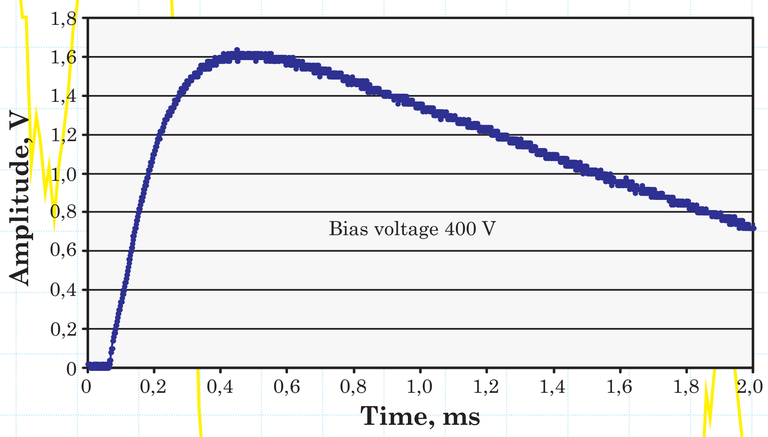


Output signal waveforms

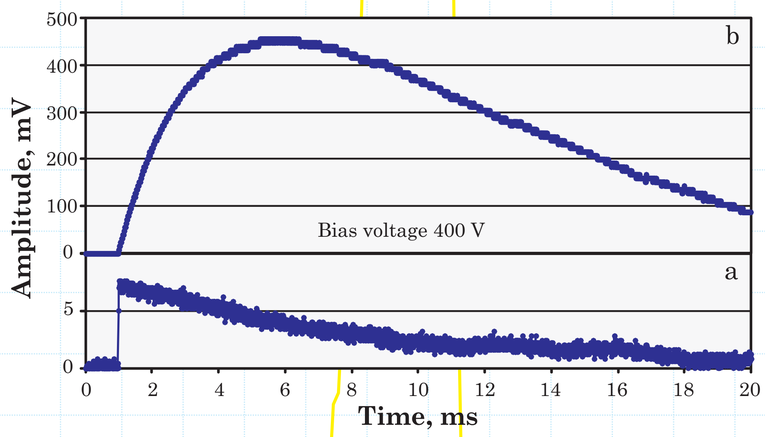
Detector arrangements I and II



Detector arrangement III



Detector arrangement IV
a - before illumination; b - with laser illumination



Output signals parameters from alpha-particles impinging on cathode

Detector arrangements / Parameter	I Au/CdZnTe/Au	II Au/CdZnTe/In Shottky diode reverse connecting ("-"at Au contact)	III Au/CdZnTe/In Shottky diode direct connecting ("-"at In contact)	VI Au/CdZnTe/Au under cathode illumination
Average amplitude at bias voltage of:	mV	mV	mV	mV
100 V	8	7	300-600	200-400
200 V	8	7,5	800-1000	
400 V	8	8	1000-1500	
800 V	8	8	1500-2000	
Average rise time at bias voltage of:	μs	μs	μs	μs
100 V	0,7	0,6	100-200	>1000
200 V	0,3	0,25	100-250	
400 V	0,18	0,14	200-500	
800 V	0,1	0,1	300-800	

Main results:

☑ The results show extremely large amplitude of the output signals during registration of alpha particles impinging on the cathode of the direct connected Schottky diode detector (Au/CdZnTe/In) or on the illuminated by red laser cathode of conductive detector (Au/CdZnTe/Au). We interpret this phenomenon as a "charge multiplication";

☑ Obtained gain of the "charge multiplication" reaches values about 250 for the direct connected Schottky diode detectors structure and more then 50 for the conductive detectors with illuminated cathode;

☑ "Charge multiplication" is obtained at very slow output signals rise times reaching values more then 1 ms for the conductive detectors with illuminated cathode.

The observed phenomenon may be explained by the presence of a space charge region, caused by a high level of carrier injection from the cathode under the influence of laser irradiation [1] or by high direct current of Schottky diode. In the region near the cathode due to a high concentration of injected charge carriers the conductivity is higher then in the bulk of the detector. In this region a charge trapping time may be longer than a dielectric relaxation time and this is a necessary condition of the "charge multiplication" obtained in [2].

1. G. Yang, A. E. Bolotnikov, G. S. Camarda, Y. Cui, A. Hossain, K. H. Kim, R. Gul, R. B. James, J. Electron. Mater., Vol. 40, No. 8, 2011.
2. D. C. Northrop, O. Simpson, Proc. Phys. Soc., Vol. 80, 1962.

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