Response of HR-GaAs:Cr sensors to subnanosecond γ - and β - ray pulses

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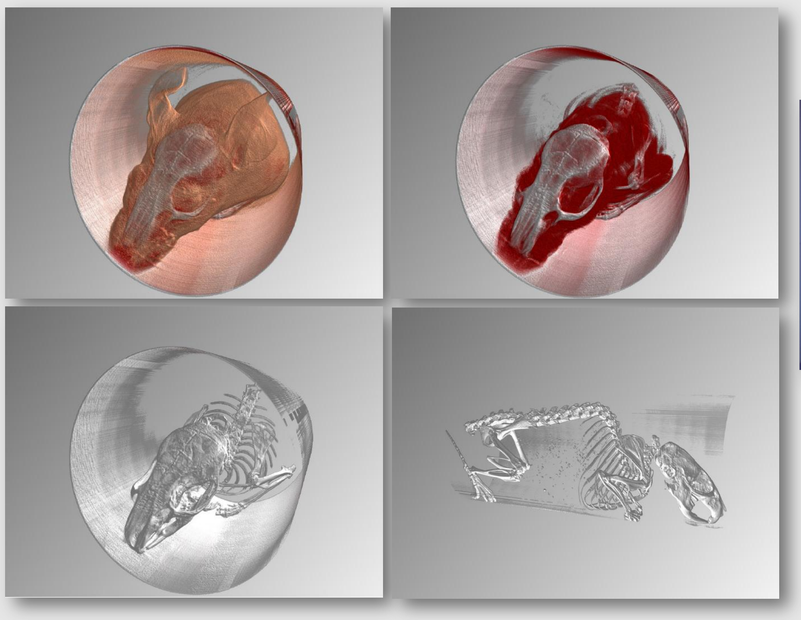
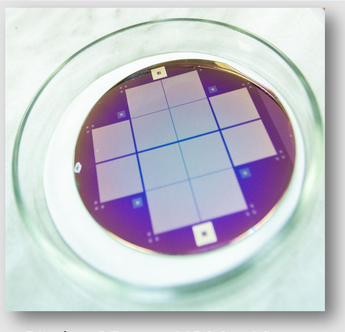
1. HR-GaAs:Cr sensors

Characteristics of HR-GaAs:Cr material:

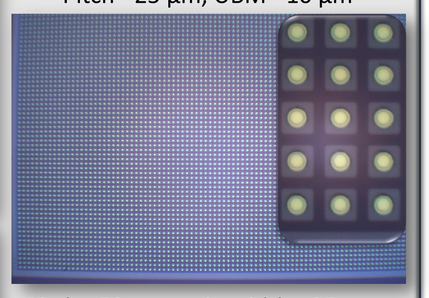
- ★ High resistive material: $\rho > 10^9$ Ω·cm;
- ★ High values of electron lifetime: τ_n > 100 ns;
- ★ Active layer thickness - up to 1 mm;
- ★ Diameter is up to 4 inches.



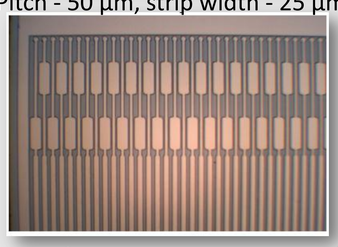
The image was obtained at Joint Institute for Nuclear Research



Pitch - 25 µm, UBM - 10 µm



Pitch - 50 µm, strip width - 25 µm



Application:

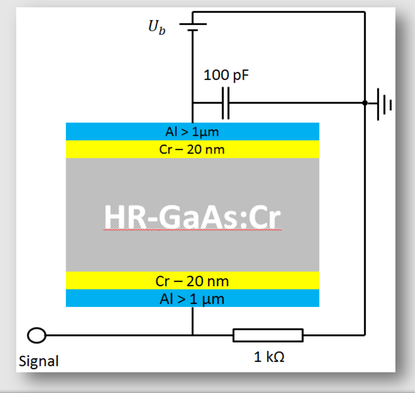
HR-GaAs:Cr sensors can be used for creation of X-ray imaging systems allowing to **register high speed processes** ~ 1ns (in physics, chemistry etc.).

2. Investigated structures

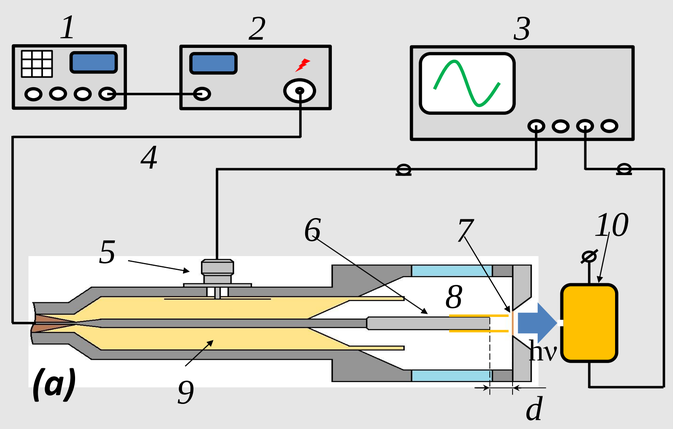
Contacts: Cr – 20 nm, Al – 1 µm
Active area of samples: 9 mm^2

Structure	Thickness, µm
HR-GaAs:Cr	500
	250
	200
VPE HR-GaAs:Cr	145

Link-up circuit of the samples



3. Experimental setup



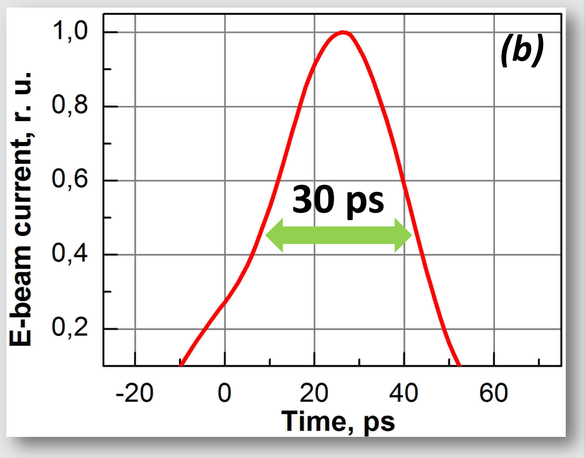


Figure 1. Experimental setup ***(a)***: 1 – trigger generator, 2 – HV generator, 3 – oscilloscope, 4 – 75-Ω cable, 5 – capacitive voltage divider, 6 – HV electrode, 7 – Cu 25 µm, 8 – window, 9 – 75-Ω transmission line, 10 – HR-GaAs:Cr sensor; Time response characteristic of X-ray tube ***(b)***

4. Pulse characteristics of HR-GaAs:Cr sensors

4.1 γ - radiation. Pulse characteristic of sensors exposed to subnanosecond γ - radiation with energy of 28, 38, 52 keV was obtained (Figure 2). The use of structure with thickness from 500 to 250 µm leads to an increase of response speed of sensor. Further decrease of sensors thickness leads to an increase of output pulse duration.

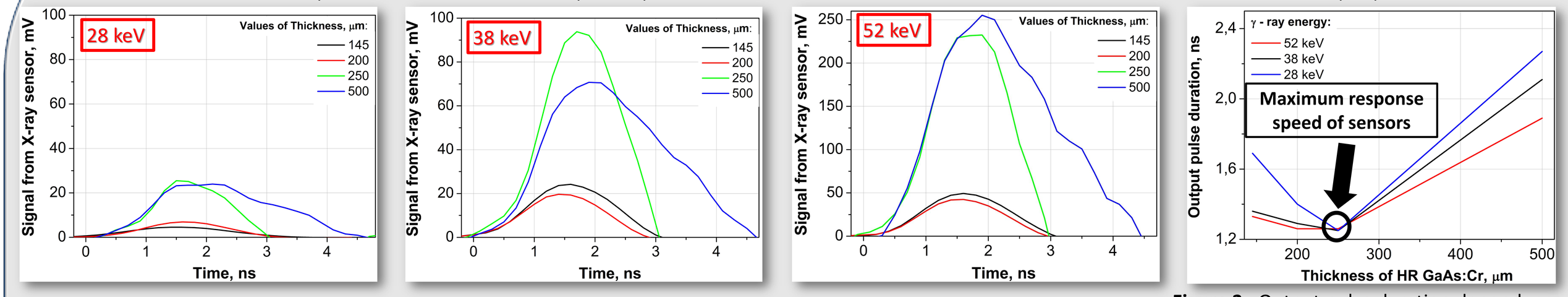


Figure 2. Pulse characteristic of sensors under γ - radiation (28, 38, 52 keV)

Figure 3. Output pulse duration dependence on sensor thickness

4.2 Experimental data vs. theoretical calculation

Influence of electric field on speed response of HR-GaAs:Cr sensors with thickness of 500 µm was assessed. Empirical and theoretical data are shown in Figure 4. The calculations were made by using Duhamel's integral, taking into account electrophysical characteristics of sensors. The output duration of signal was **12-14 ns** under bias voltage 50 V. When bias voltage is over 150 V, a slow increase of response speed (up to **2-4 ns**) is observed. This can be caused by the saturation of electron drift mobility.

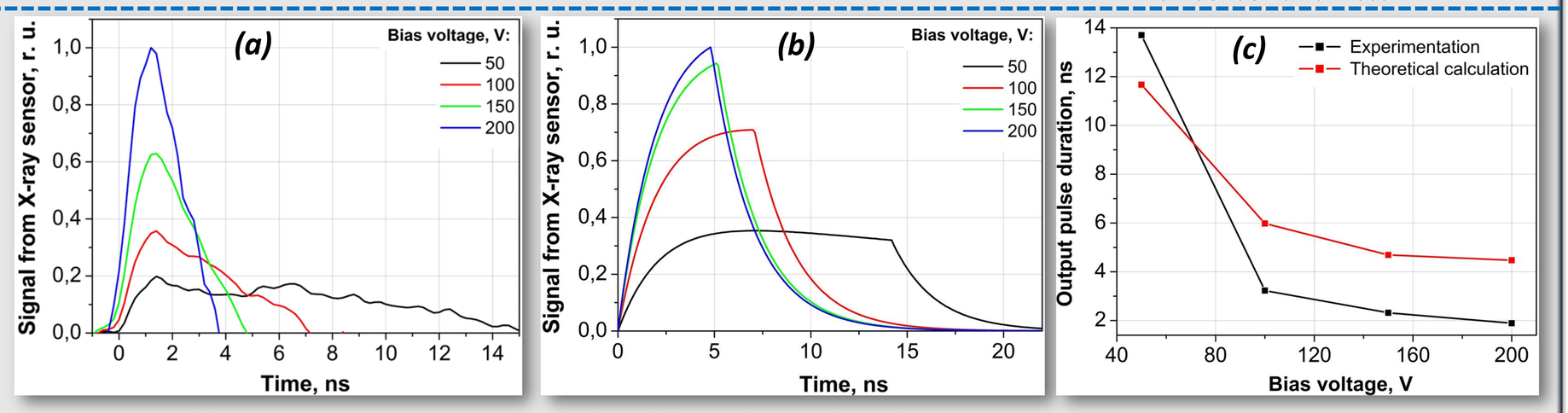


Figure 4. Signal from HR-GaAs:Cr sensor exposed to different bias voltage (Experimental data ***(a)*** and theoretical calculation ***(b)***); Output pulse duration dependence on bias voltage ***(c)***

4.3 β - radiation

Pulse characteristics of HR-GaAs:Cr sensors of different thicknesses exposed to 52 keV β-ray are shown in Figure 5. The dependencies of output duration of signal on sensor thickness under γ - and β - ray are correlated. For 500 µm sensor the essential difference in speed response is observed (**1.9 ns** for γ - pulses and **3.6 ns** for β - pulses, respectively).

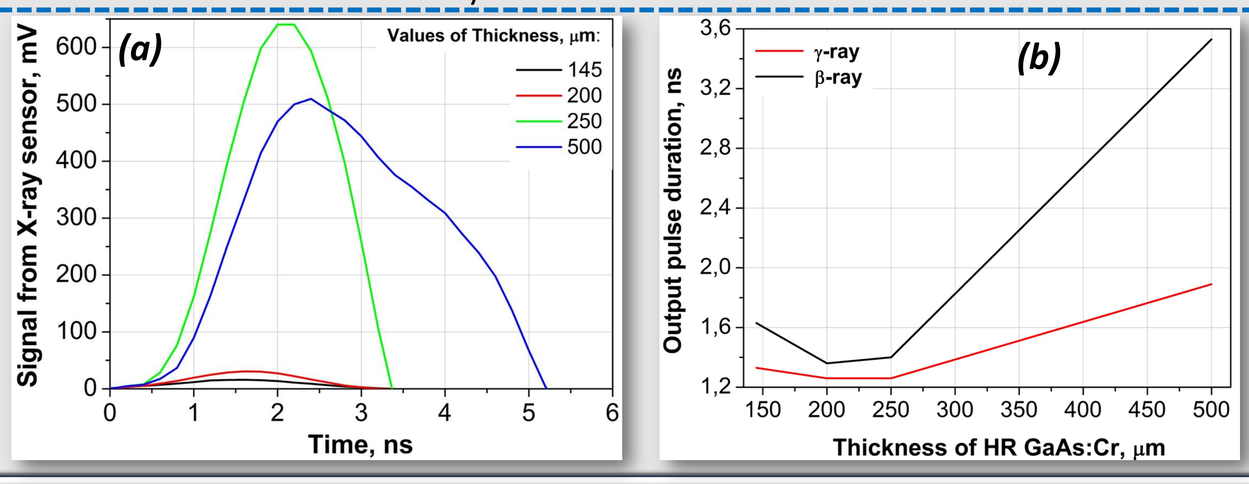


Figure 5. Pulse characteristic of sensors exposed to β - radiation ***(a)***; output pulse duration dependence on sensor thickness ***(b)***

5. Conclusion

- The sensor with optimal thickness of 250 µm, exposed to subnanosecond γ - and β - ray pulses, allows to obtain speed response 1 ns. Further decrease of sensor's thickness leads to increase of capacity up to critical value. This restricts speed response of the system.
- The signal in 500 µm HR-GaAs:Cr sensors was calculated, when bias voltage is 50-200 V and γ - pulses are applied. Theoretical data are coherent with empirical data.

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