KEK Inter-University Research Institute Corporation
High Energy Accelerator Research Organization

Feasibility Study on Neutron Dosimetry under Extreme Radiation Environments Using a Diamond Detector

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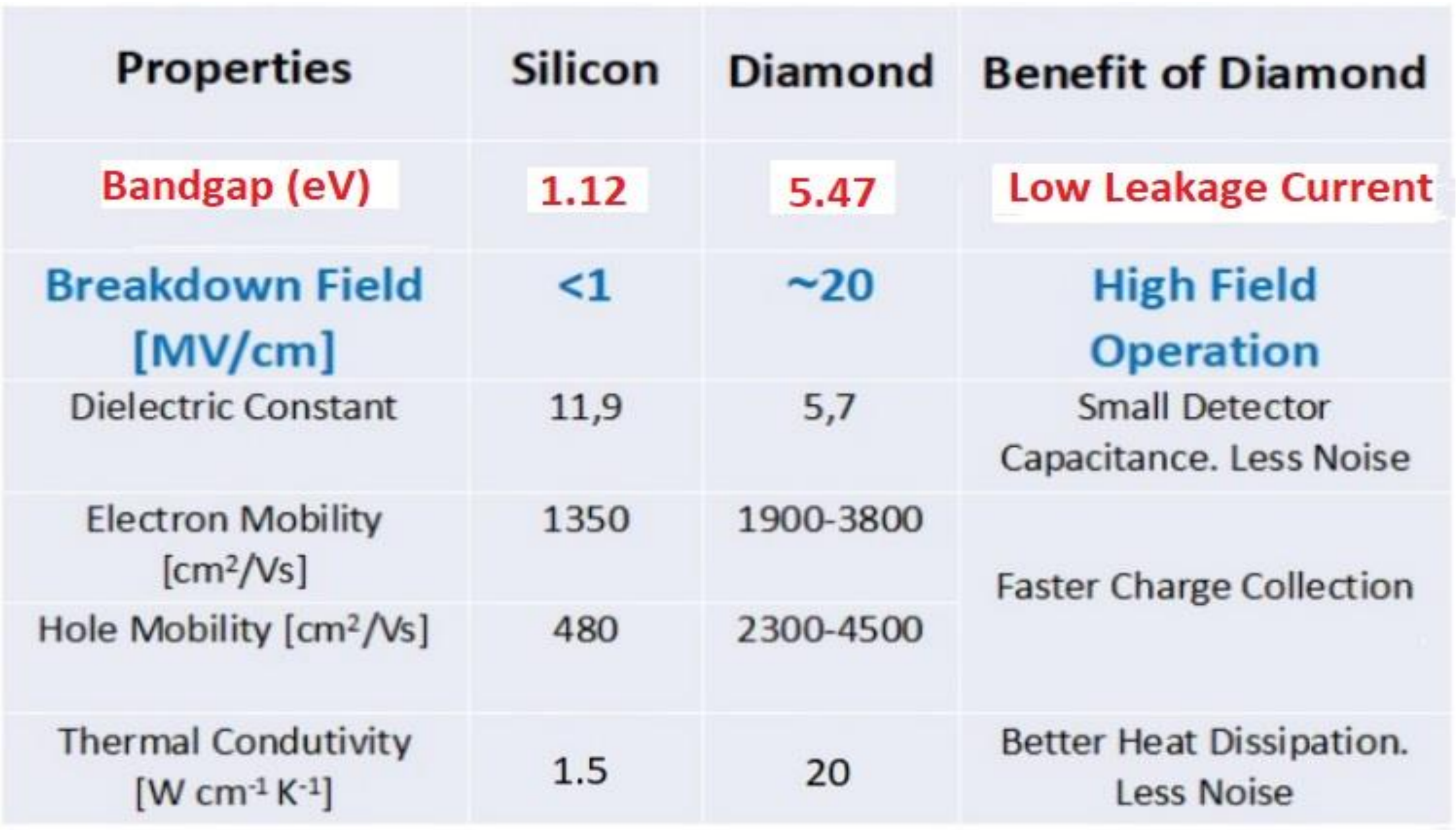
Motivation

- ☐ Since the application of neutron technology in a broad field, the neutrons dose are required to be monitored efficiently. Especially, some harsh environments including **Fukushima Daiichi nuclear power plant** and **high-intensity accelerators** such as **SuperKEKB** produce mixed radiation field.
- ☐ There is an urgent need to design a **neutron detector** that is resistant to **high-intensity radiation and can reject high levels of background rays.**

● **Advantage**：low leakage current，low capacitance，high electron–hole mobility，radiation resistance，excellent timing resolution .

● **Drawback:** low Charge collection efficiency(CCE), low energy resolution.

Comparison of Diamond and Silicon Characteristic



Properties	Silicon	Diamond	Benefit of Diamond
Bandgap (eV)	1.12	5.47	Low Leakage Current
Breakdown Field [MV/cm]	<1	~20	High Field Operation
Dielectric Constant	11,9	5,7	Small Detector Capacitance. Less Noise
Electron Mobility [cm²/Vs]	1350	1900-3800	Faster Charge Collection
Hole Mobility [cm²/Vs]	480	2300-4500	
Thermal Condutivity [W cm⁻¹ K⁻¹]	1.5	20	Better Heat Dissipation. Less Noise

- ➢ The diamond detector is an ideal choice for monitoring neutron flux and dose in comparison to silicon detector.

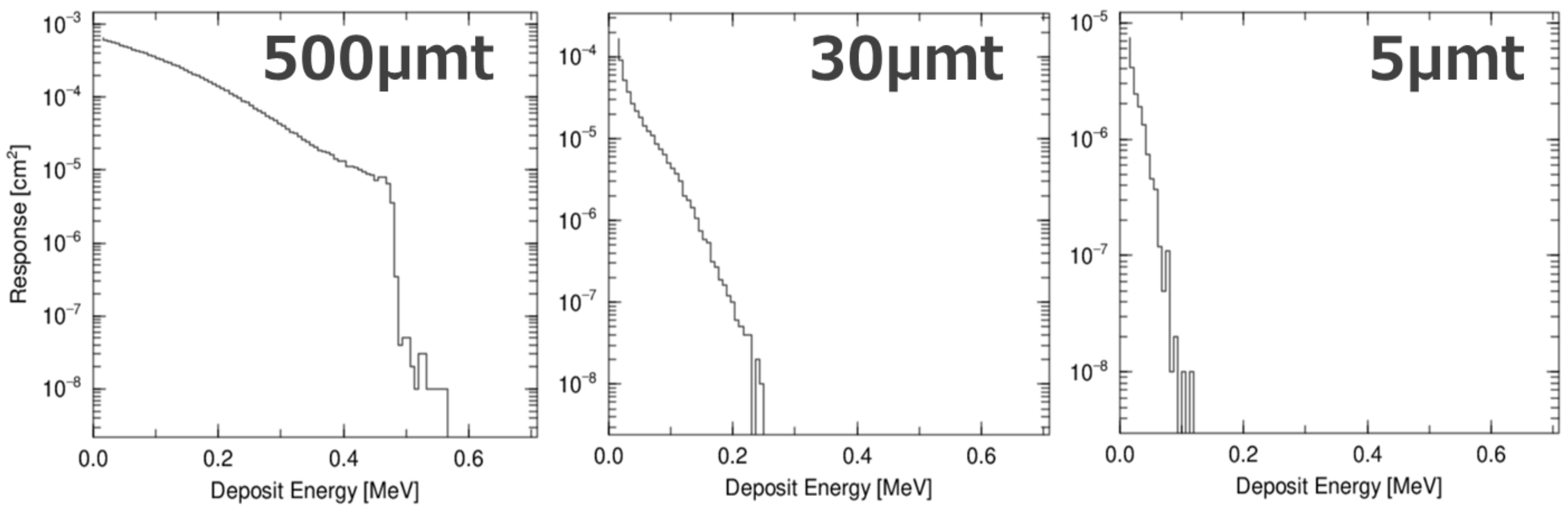
Simulation

PHITS(Particle and Heavy Ion Transport code System)

What it can do:

Transport and collision of nearly all particles over wide energy range

Transport	Collision of nearly all particles	Wide energy range
in 3D phase space with magnetic field & gravity	neutron, proton, meson, baryon electron, photon, heavy ions	10^{-4} eV to 1 TeV/u



The simulated deposition energies on diamond detectors with difference thickness for ^{137}Cs gamma-rays.

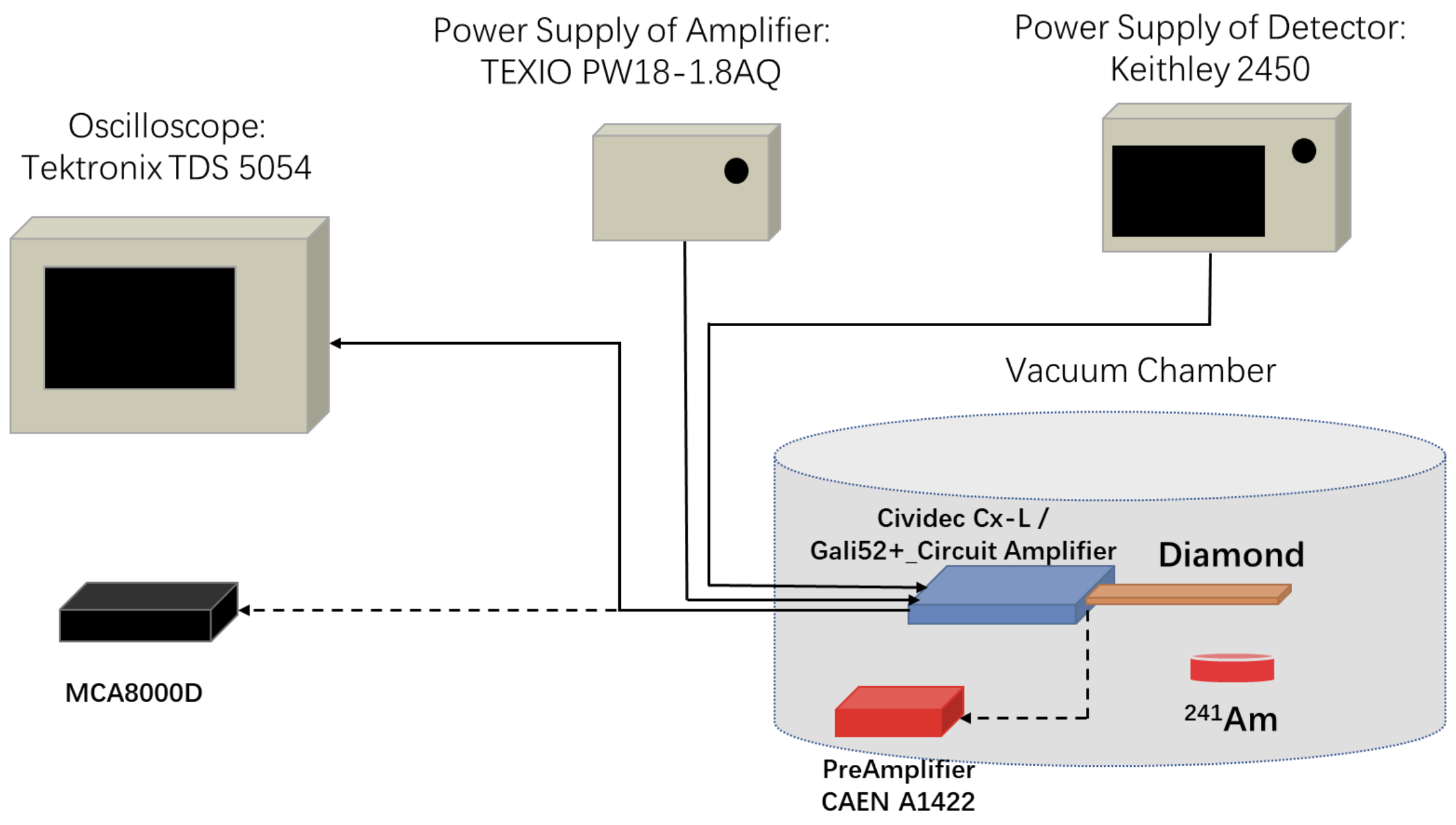
- ➢ **The sensitivity and deposit energy** decreased with decreasing the detector **thickness**.
- ➢ The **pile-up events** will be less impact.
- ➢ **The maximum deposition energies** were significantly **less** than the expected deposition energies from the neutron-induced ^{6}Li(n,t)α reaction: Et= 2.73 MeV, Eα= 2.05 MeV.

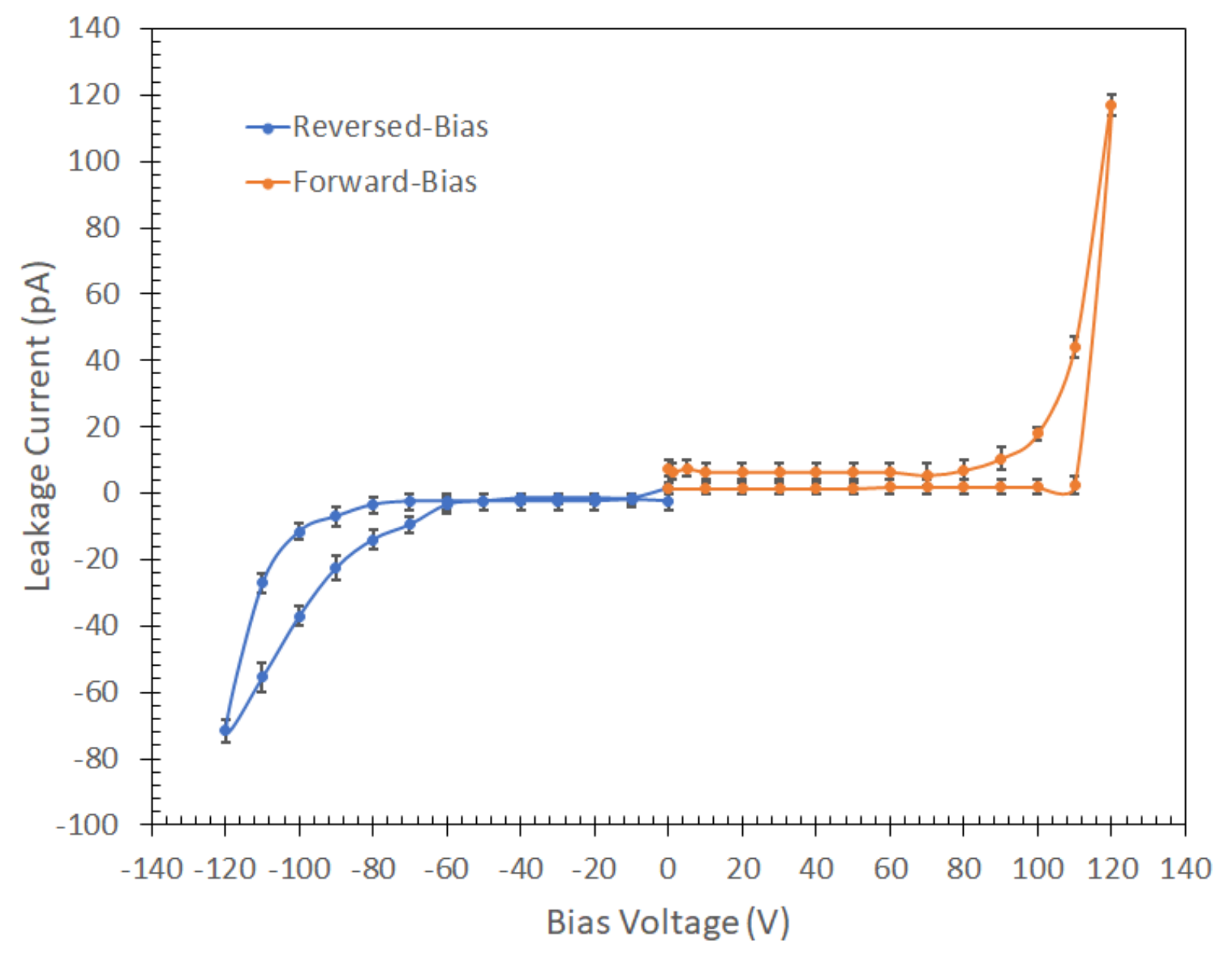
Experimental Setup and Result

Diamond Detector:

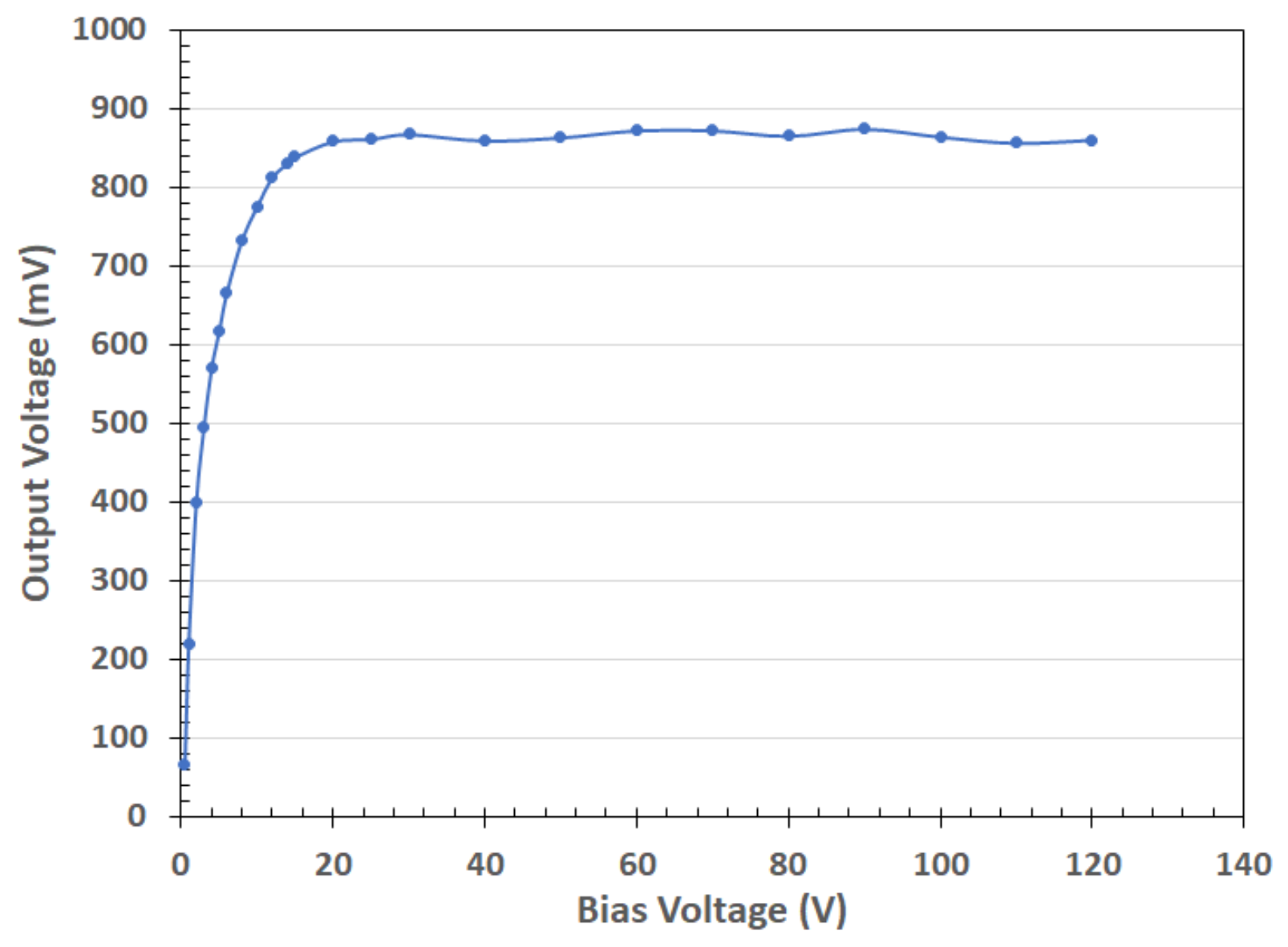
- ➢ Material: sCVD diamond
- ➢ Size: 4.5 mm x 4.5 mm
- ➢ Thickness: 140 μm
- ➢ Thermal-neutron converter: ^{6}LiF (95% enrichment)
- ➢ Active area: 10 mm^2

Experimental Setup:

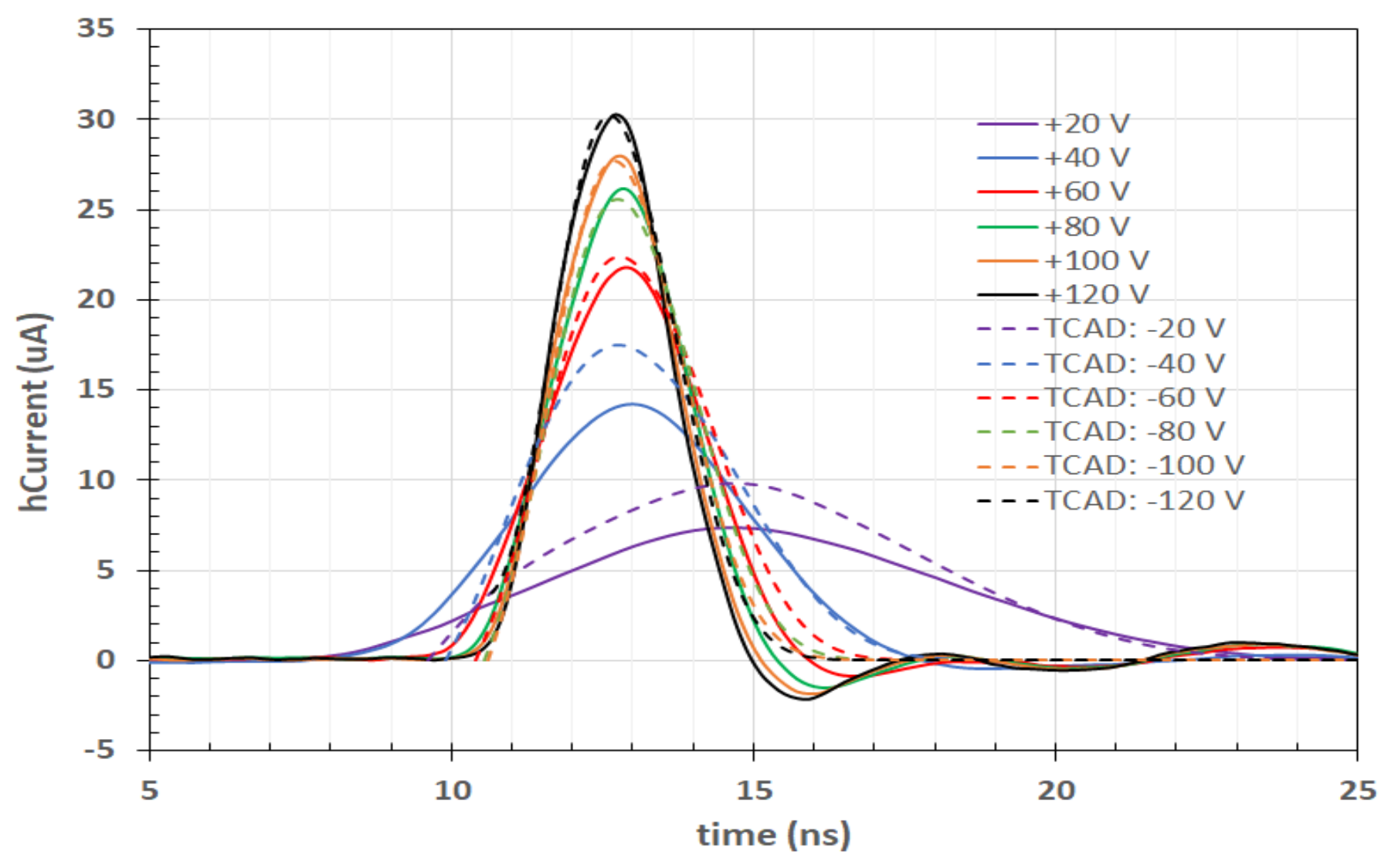




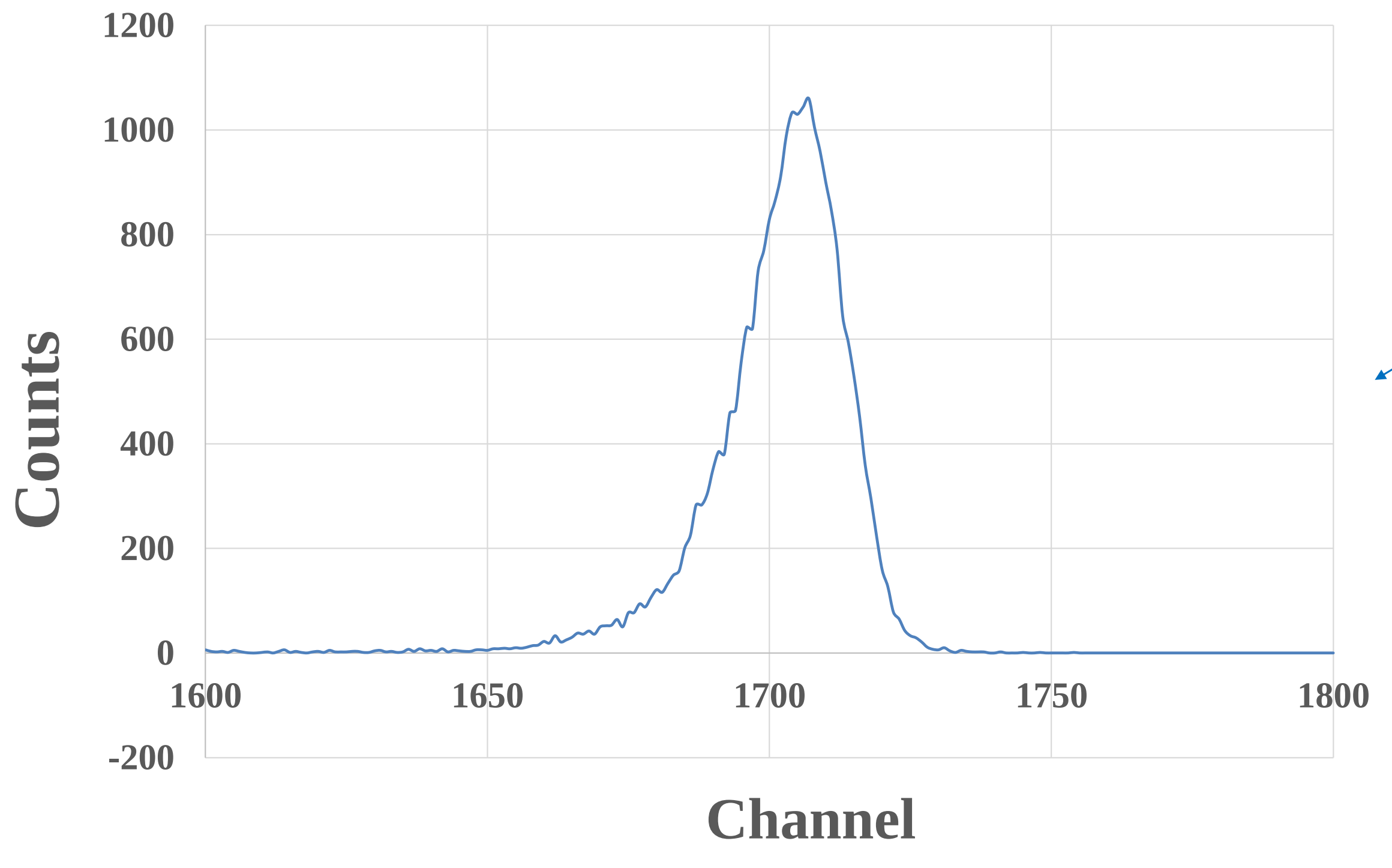
I–V characteristic of the sCVD diamond detector.



CCE of the sCVD diamond detector.



TCT pulse for charge carrier in diamond



Pulse height distribution of Diamond

α source：^{241}Am Energy：5.486 MeV

Conclusion

❖The **deposition energies** on diamond detectors with difference thickness for ^{137}Cs gamma-rays were simulated.

❖we did **performance tests** on the diamond detector.

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