Floating-Gate MOS Transistor with Dynamic Biasing as a Radiation Sensor

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Operating principle of floating gate MOS transistor

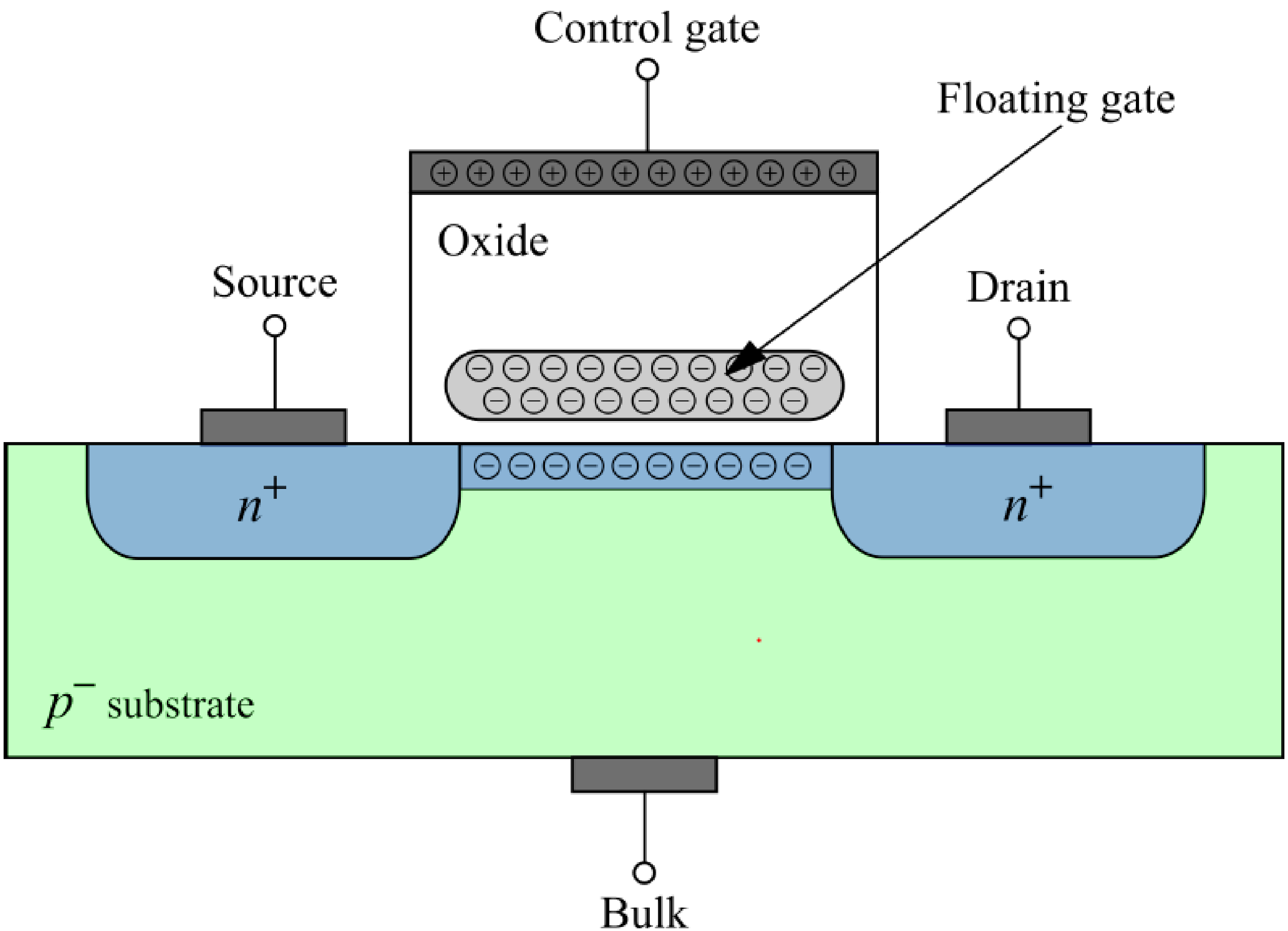

Figure 1. MOS transistor with the charged floating gate.

Reverse engineering of commercial floating gate structure

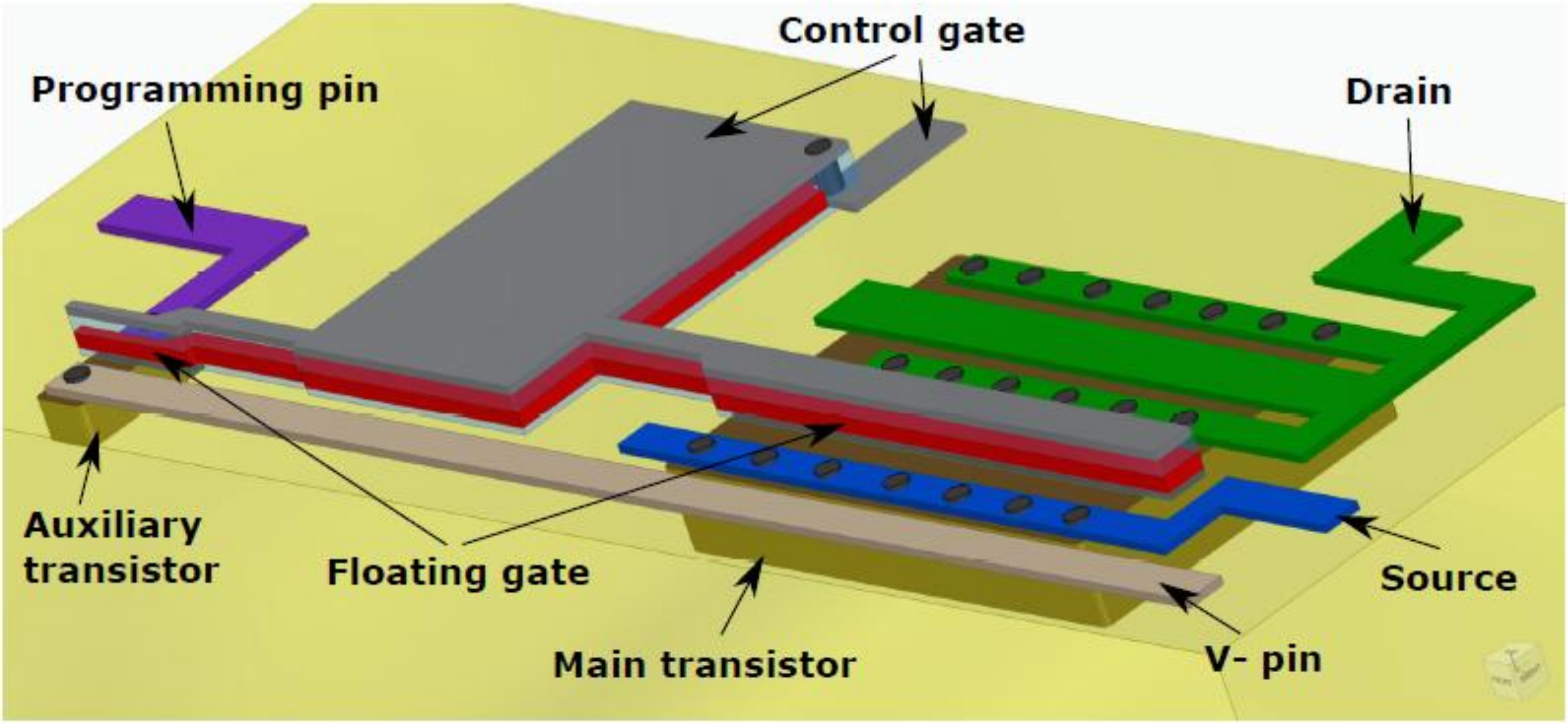

Figure 5. A simplified 3D representation of the EPAD structure.

New concept of dynamic bias during irradiation

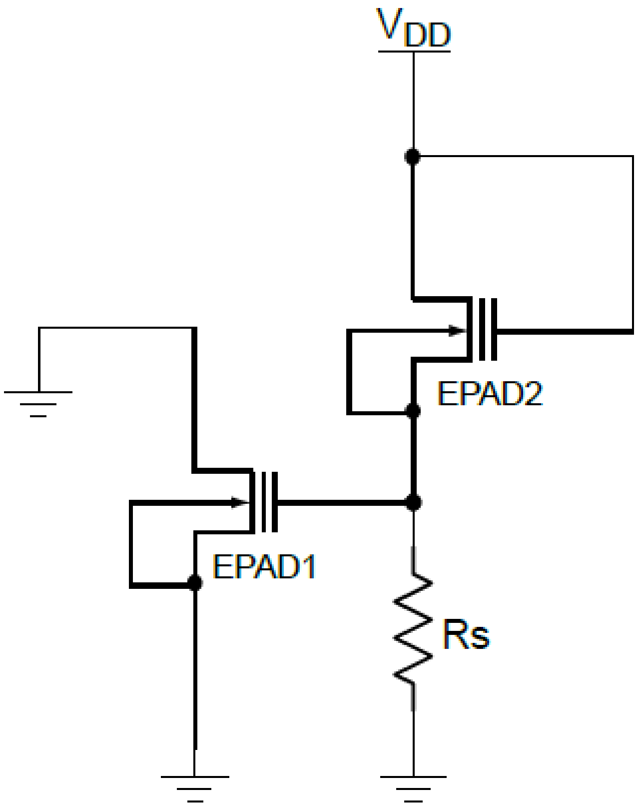

Figure 8. Idea of self-compensated dynamic biasing.

Experimental setup

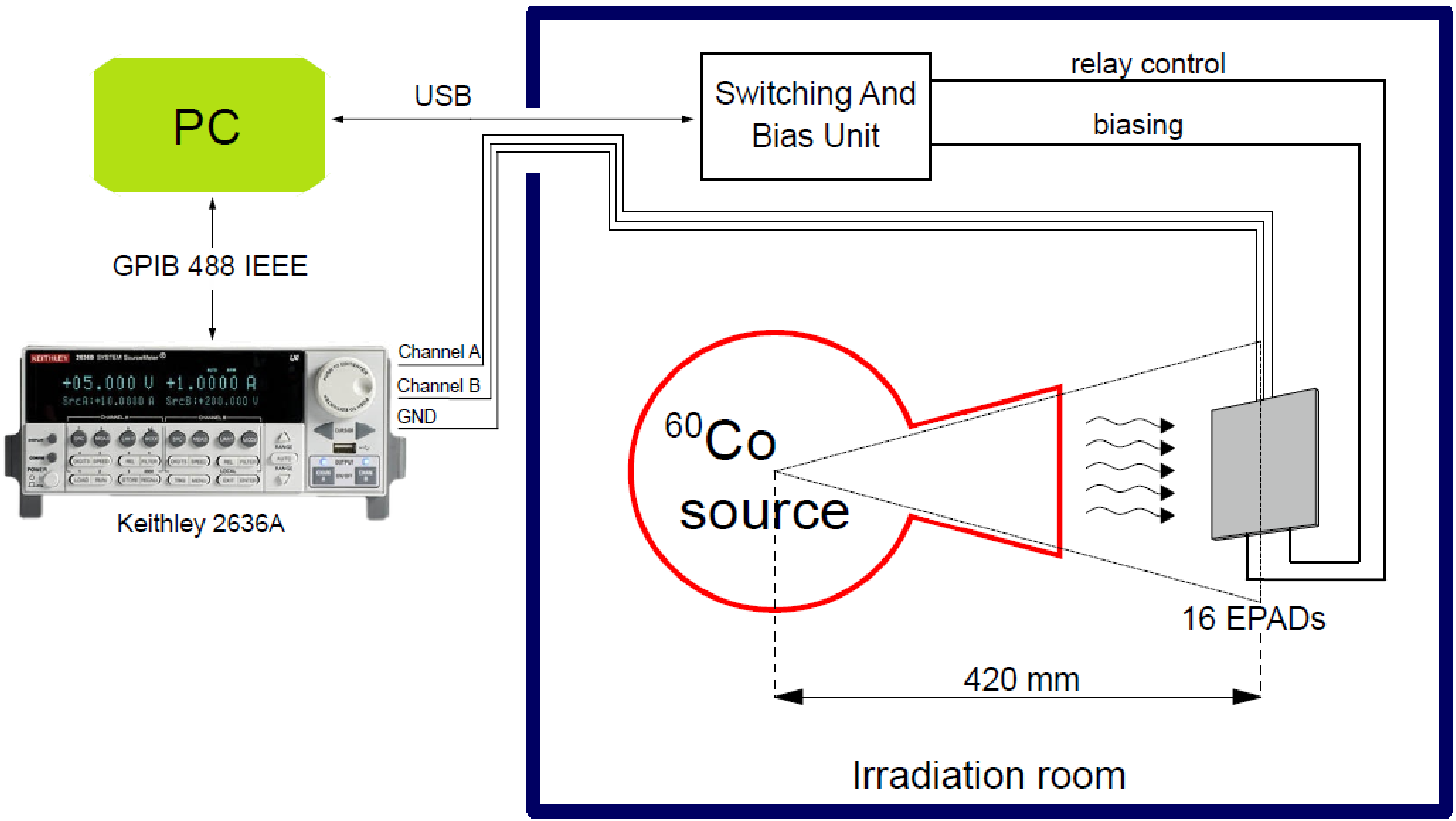

Figure 10. Experimental setup in irradiation room at Institute of Nuclear Sciences "Vinča".

Results

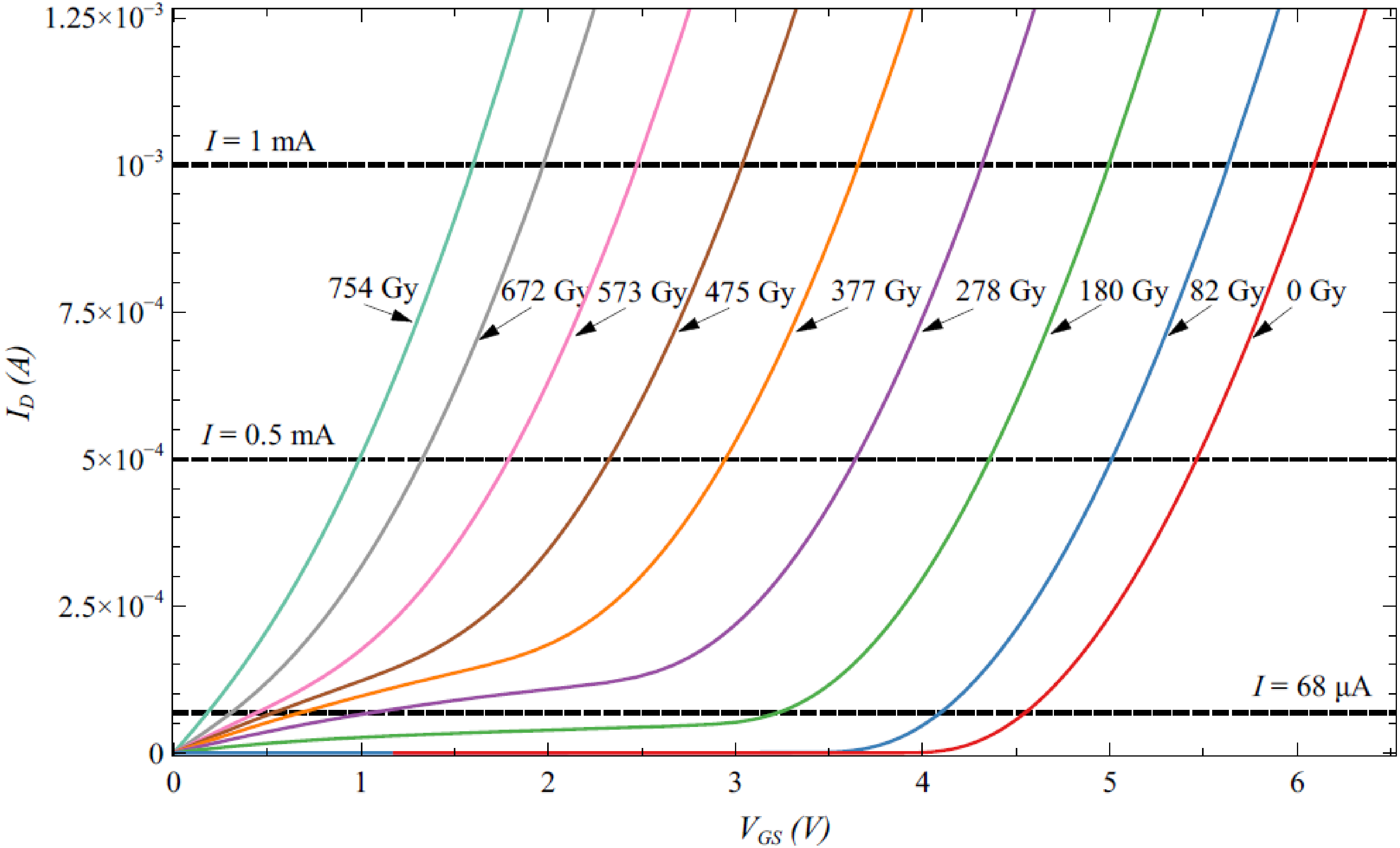

Figure 12. Degradation of transfer characteristic of EPAD with 10 V bias during irradiation.

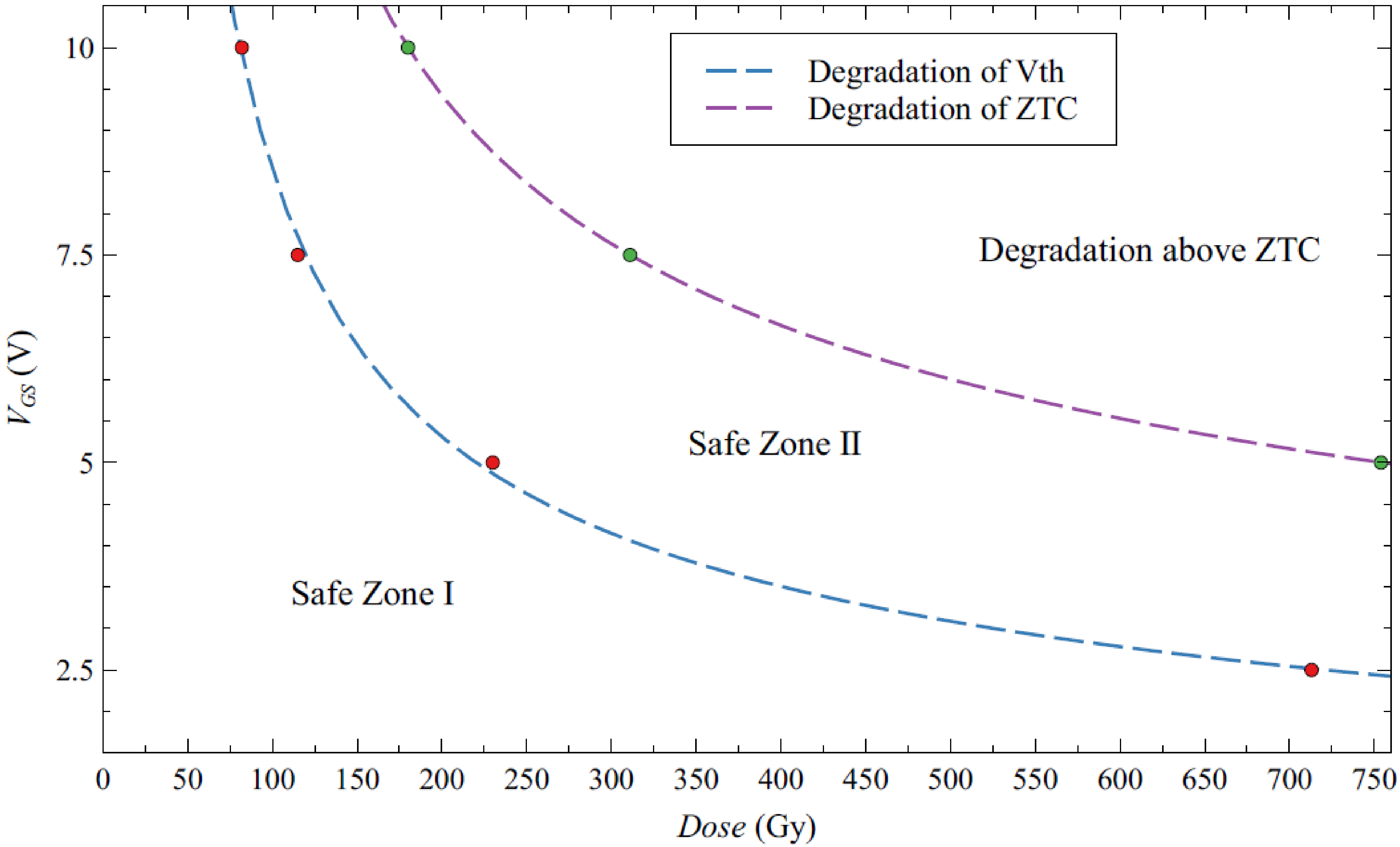

Figure 13. Safe Operating Area of EPAD. Red dots are representing the measured values for Vth ($I_D = 1\ \mu A$) and green dots for ZTC ($I_D = 68\ \mu A$) values.

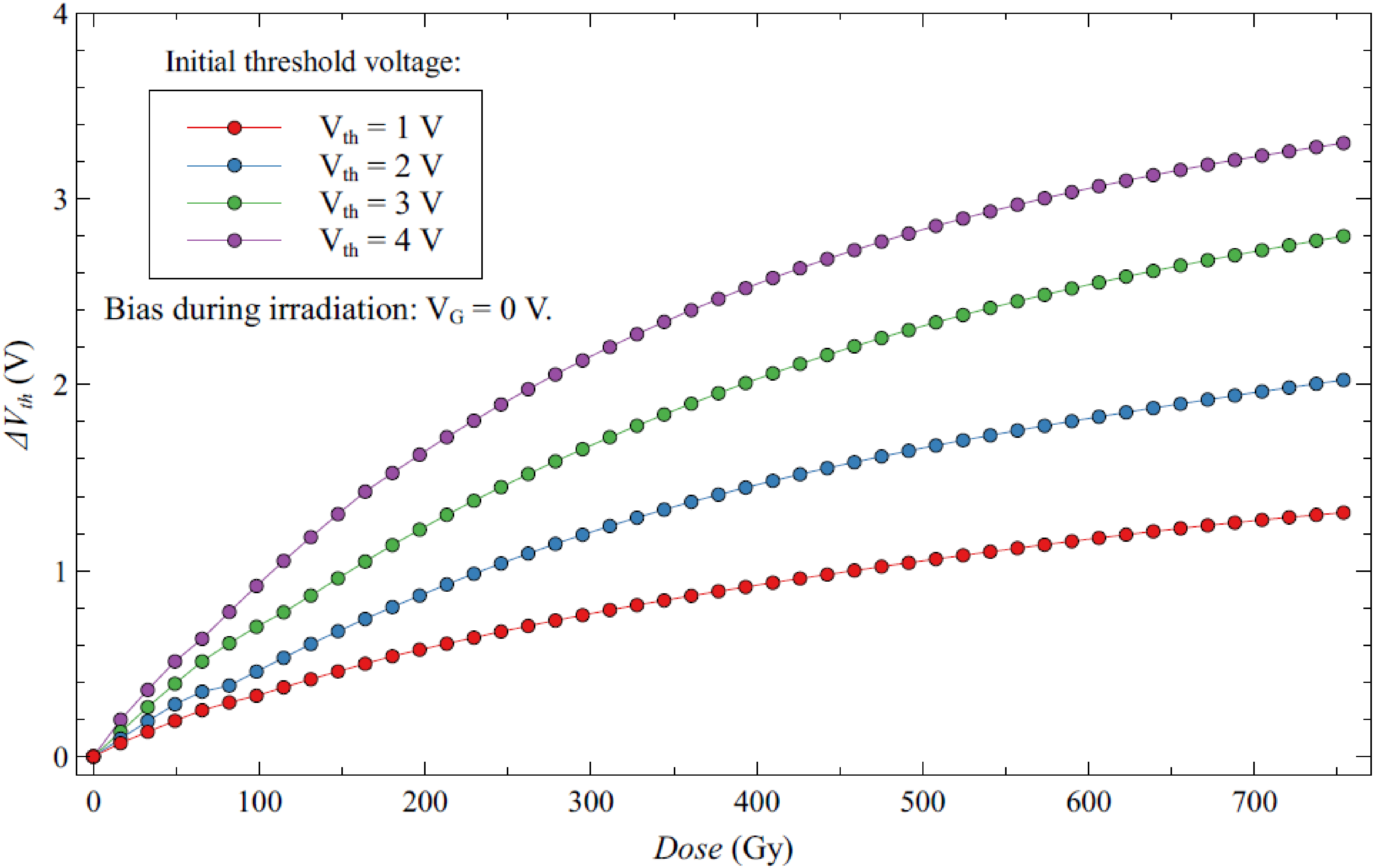

Figure 14. Threshold voltage shift for EPADs with zero bias during irradiation.

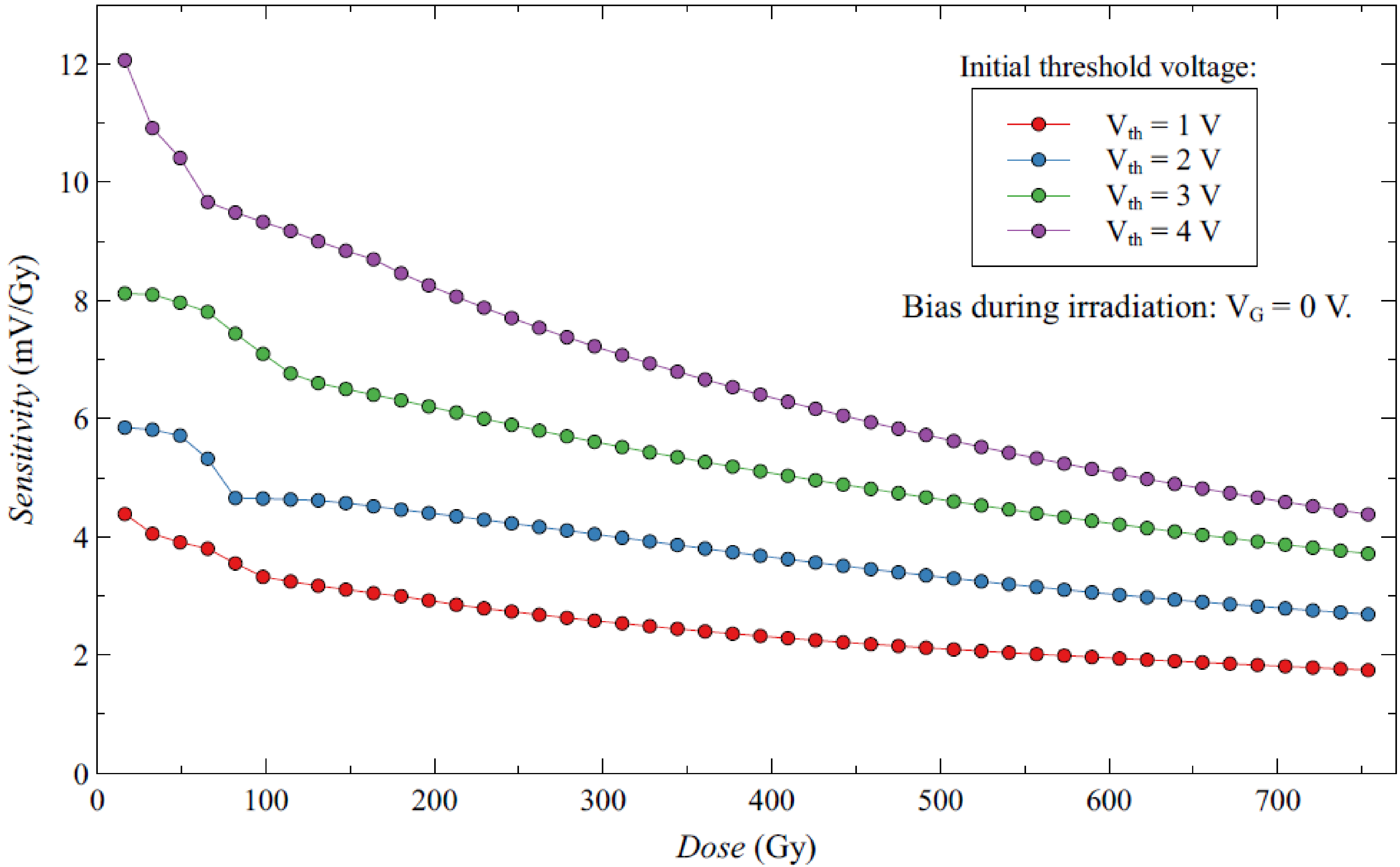

Figure 15. Sensitivity of EPADs with zero bias during irradiation.

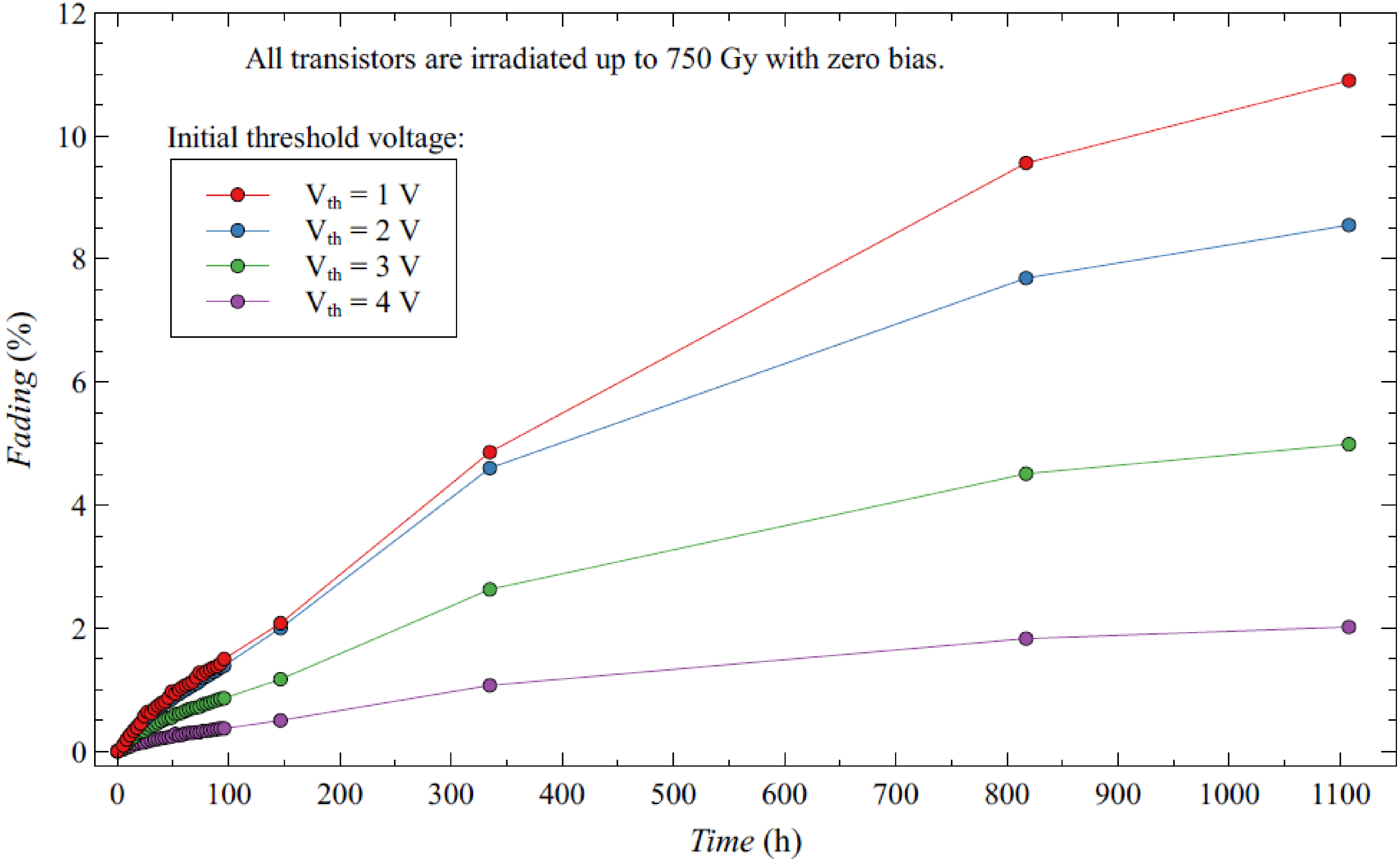

Figure 16. Fading of EPADs with zero bias during irradiation.

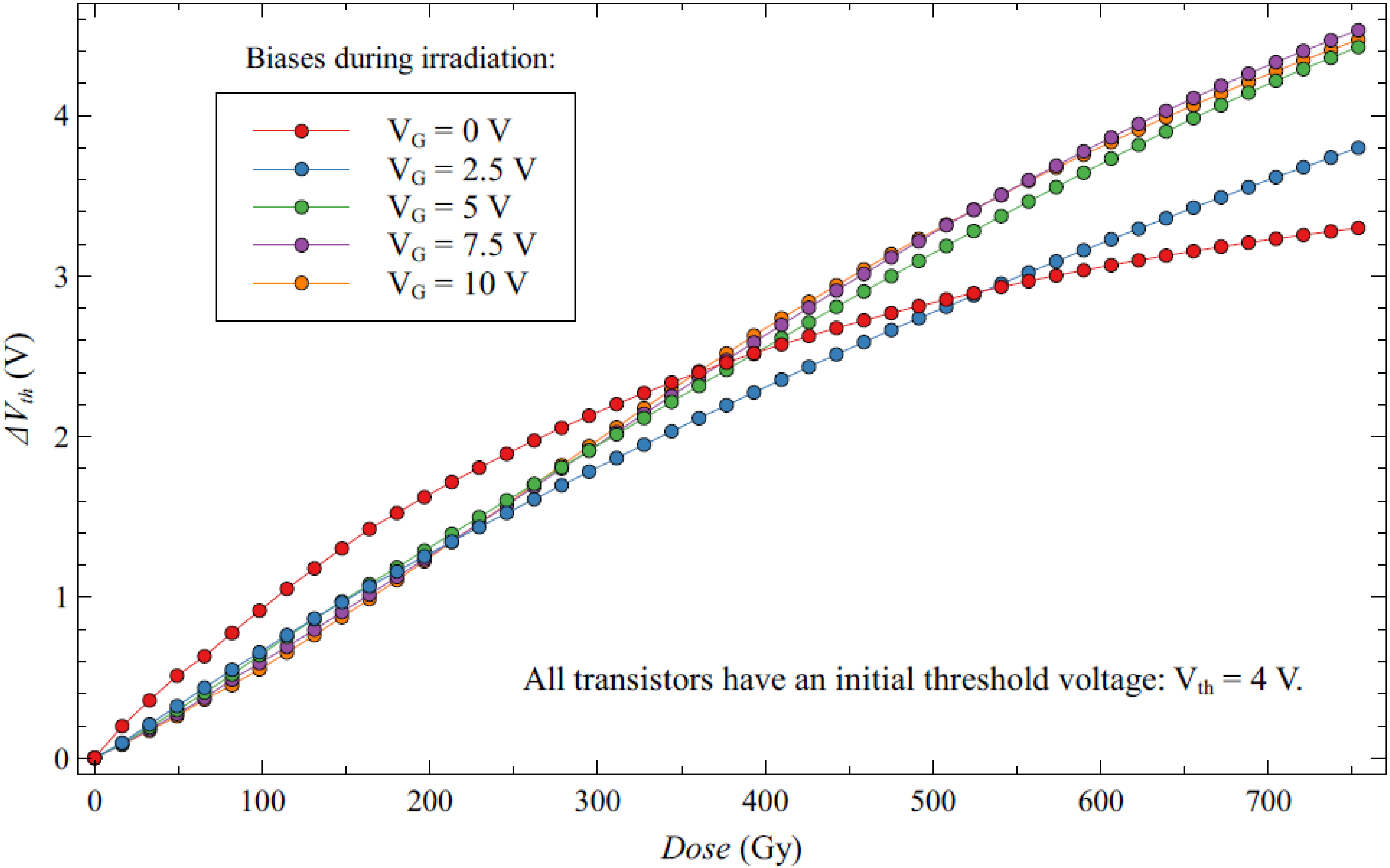

Figure 17. Threshold voltage shift for EPADs with static bias during irradiation.

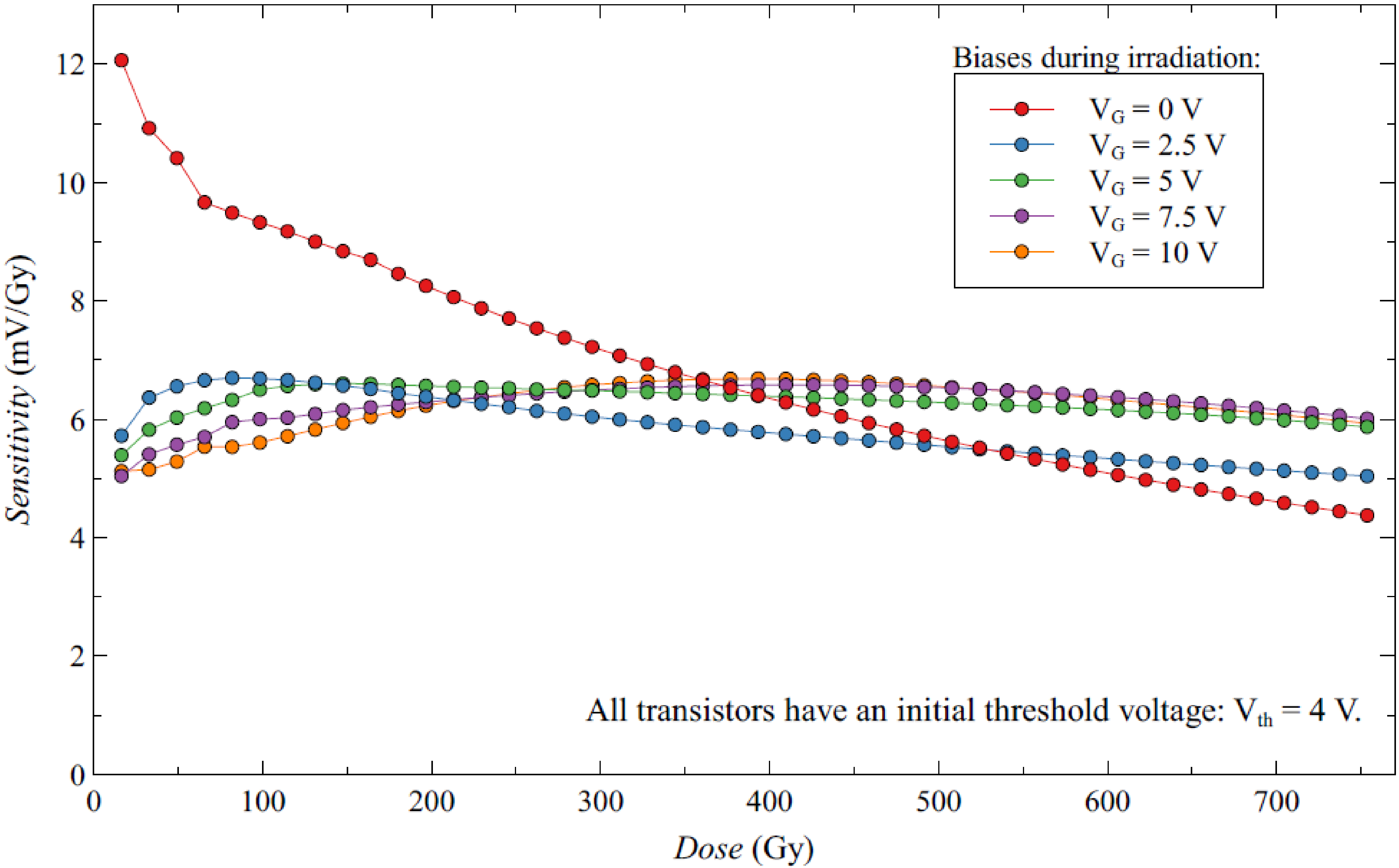

Figure 18. Sensitivity of EPADs with static bias during irradiation.

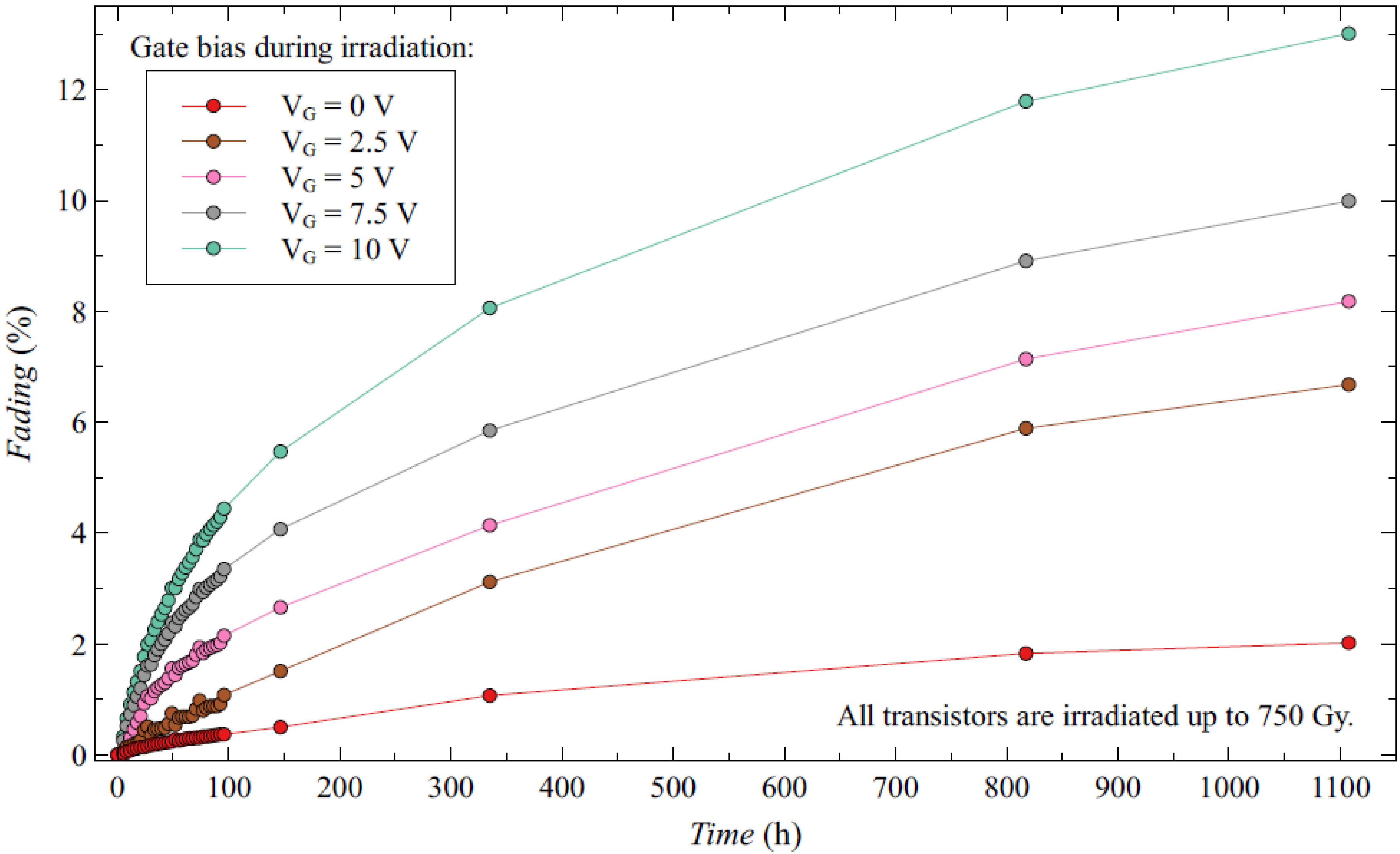

Figure 19. Fading of EPADs with static bias during irradiation.

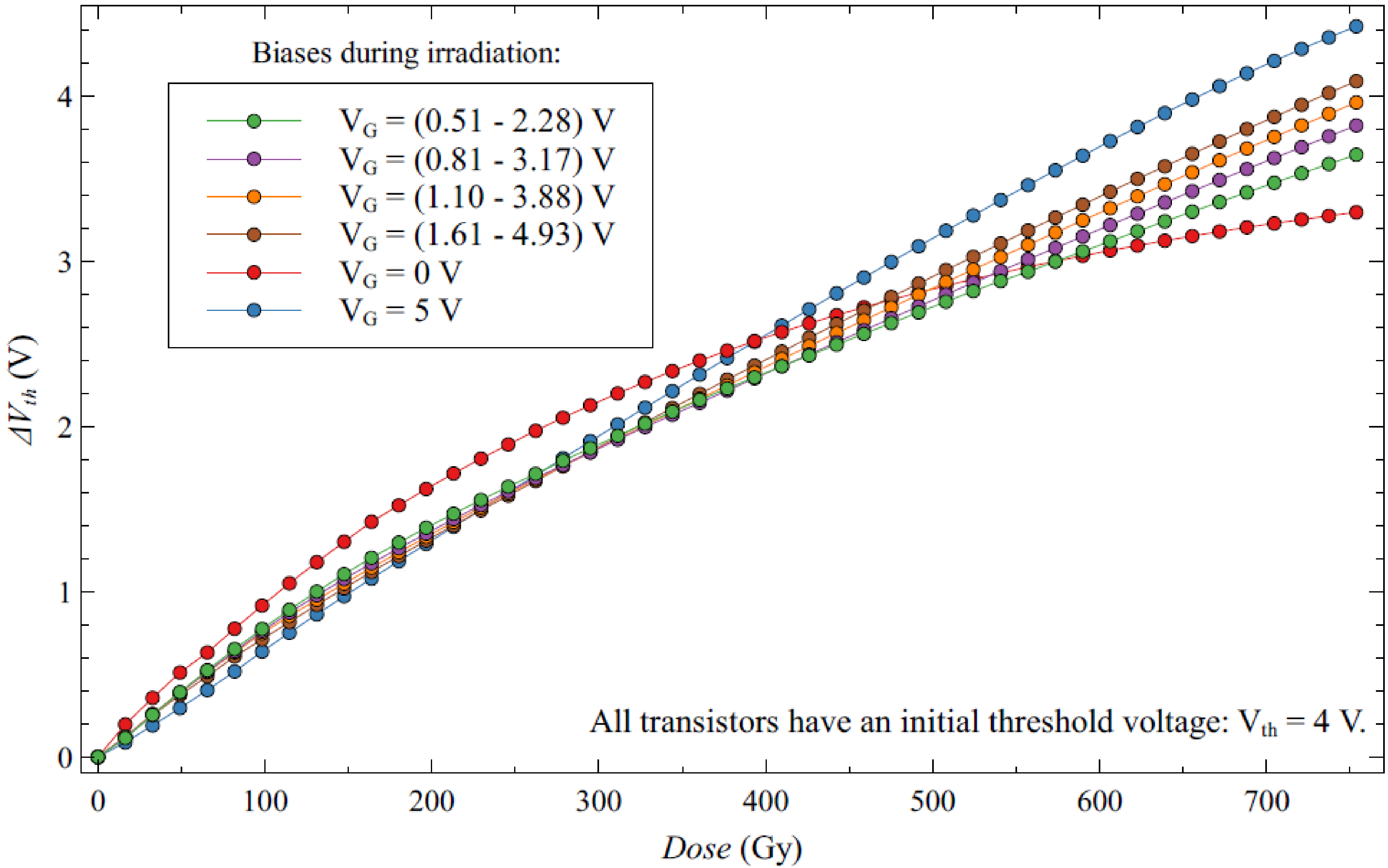

Figure 20. Threshold voltage shift for first subgroup of EPADs with dynamic 6 V bias during irradiation.

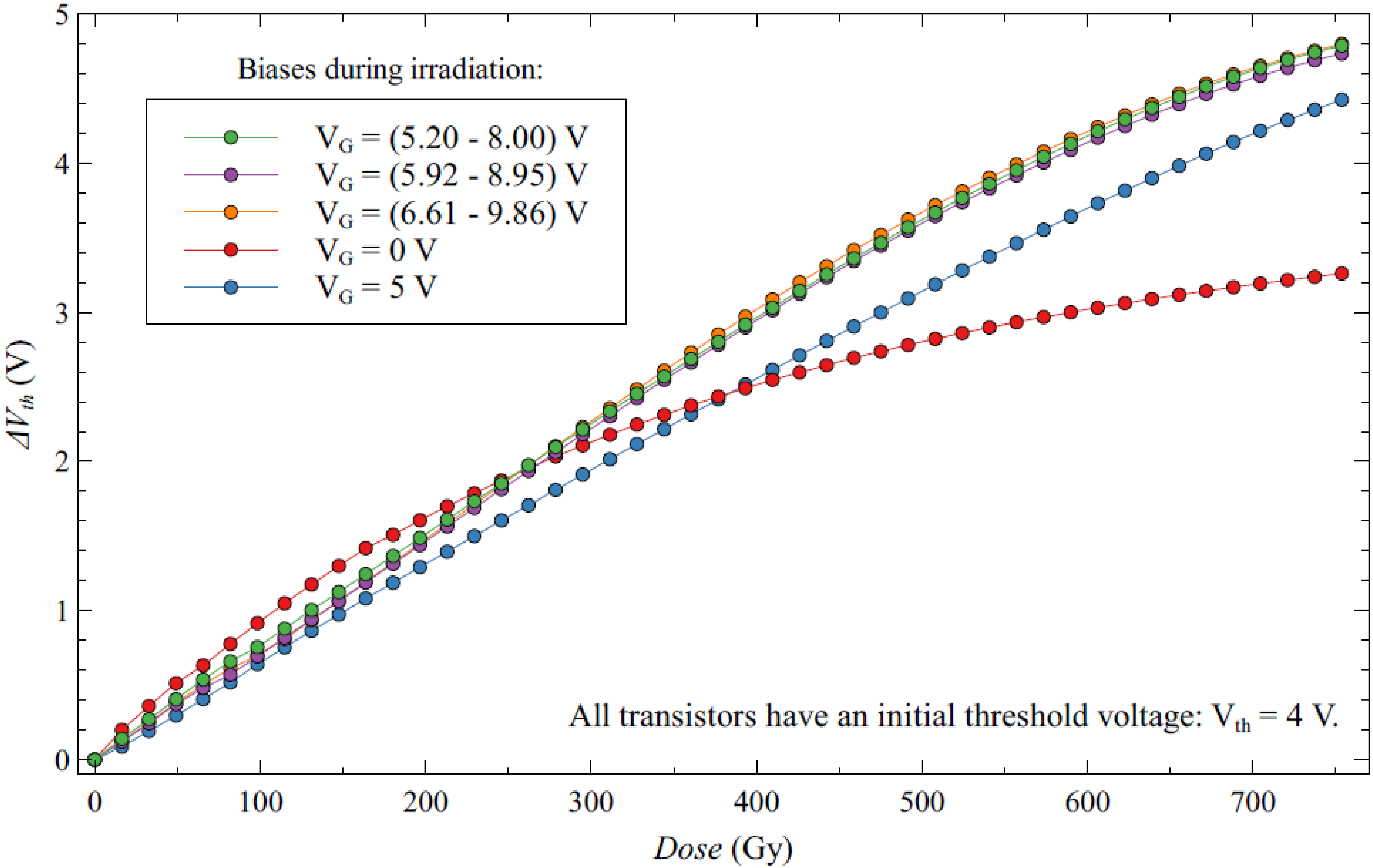

Figure 21. Threshold voltage shift for second subgroup of EPADs with dynamic 12 V bias during irradiation.

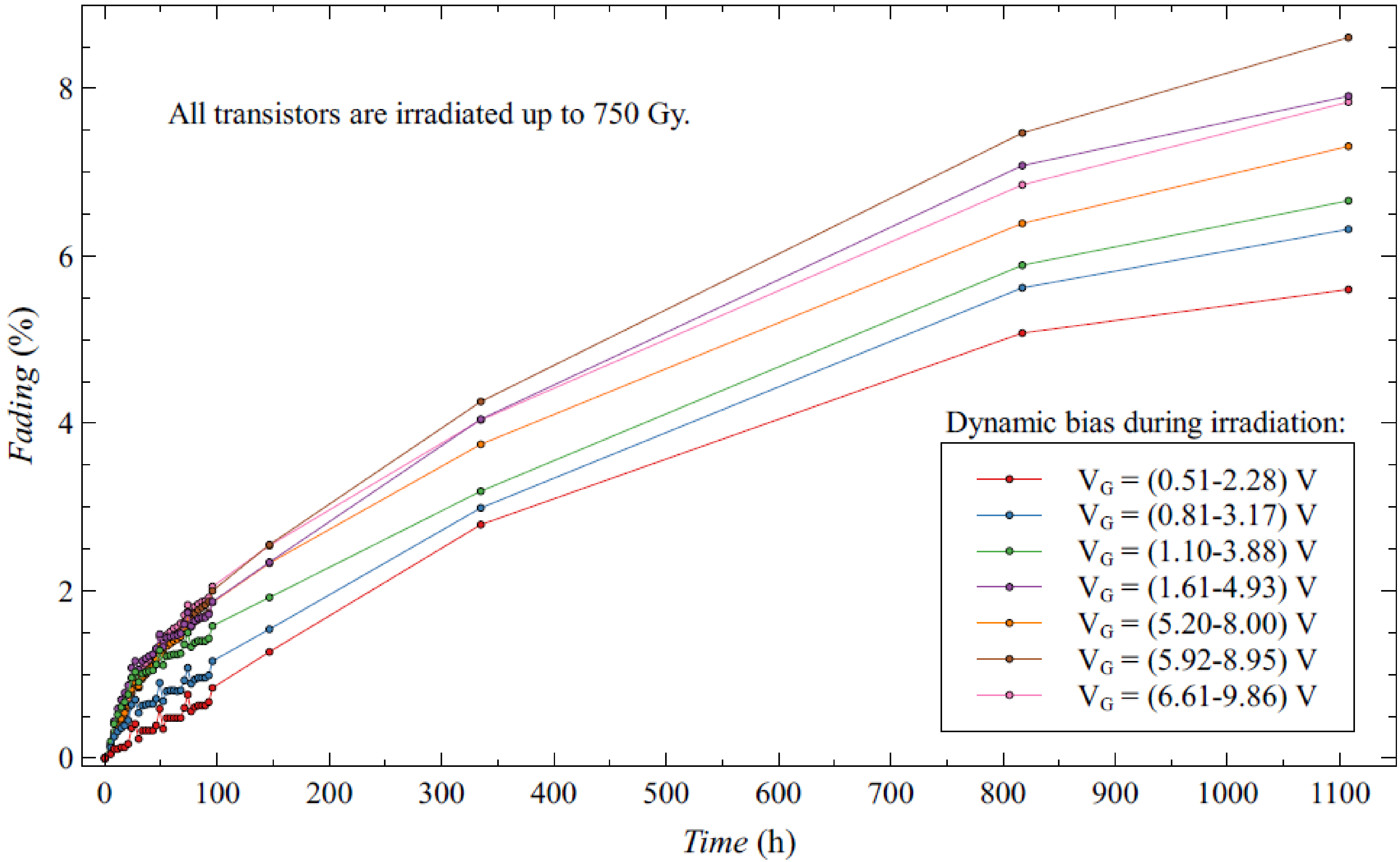

Figure 22. Fading of EPADs with dynamic bias during irradiation.

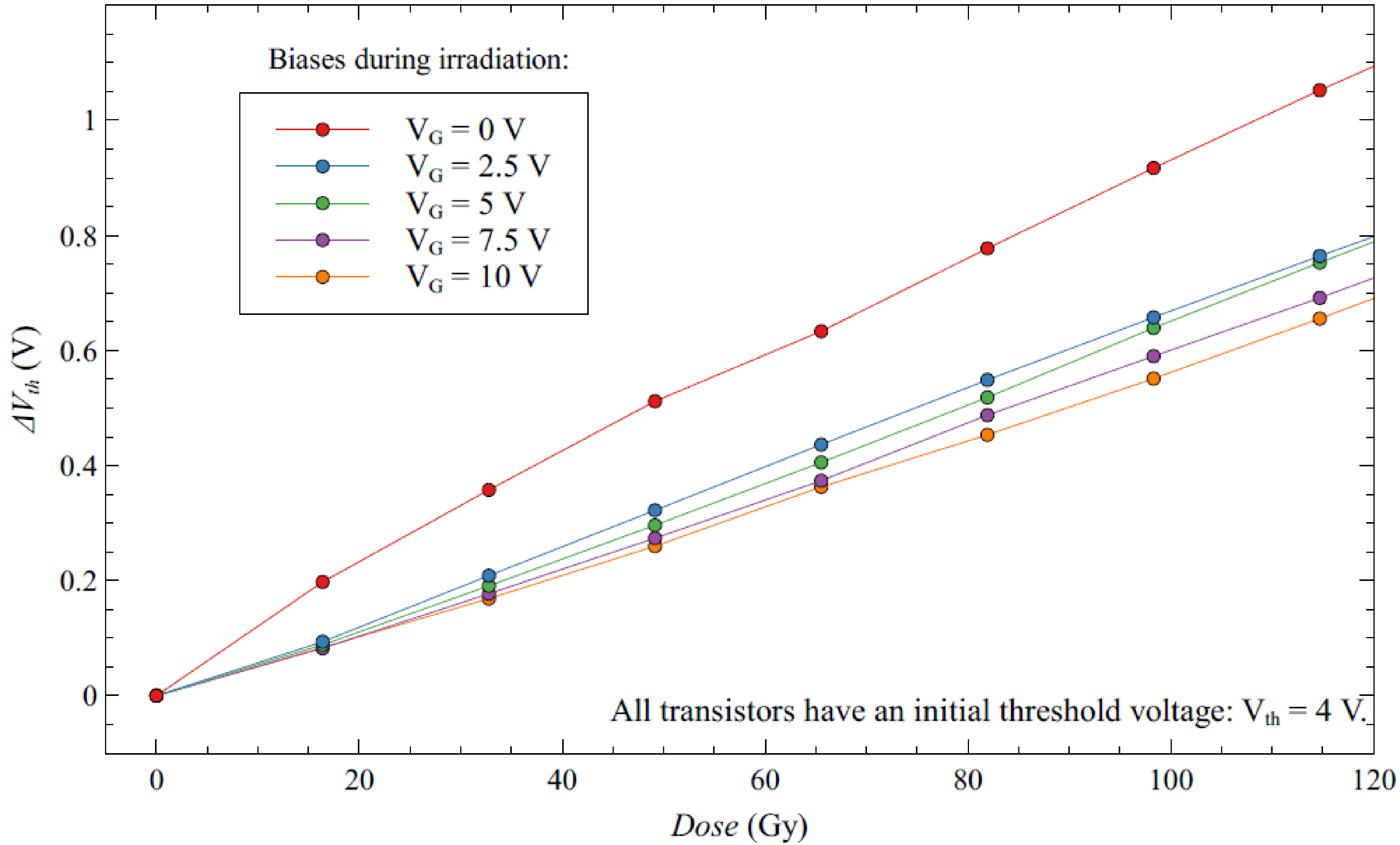

Figure 23. Interesting phenomenon of higher sensitivity with zero-biased floating-gate MOS transistor.

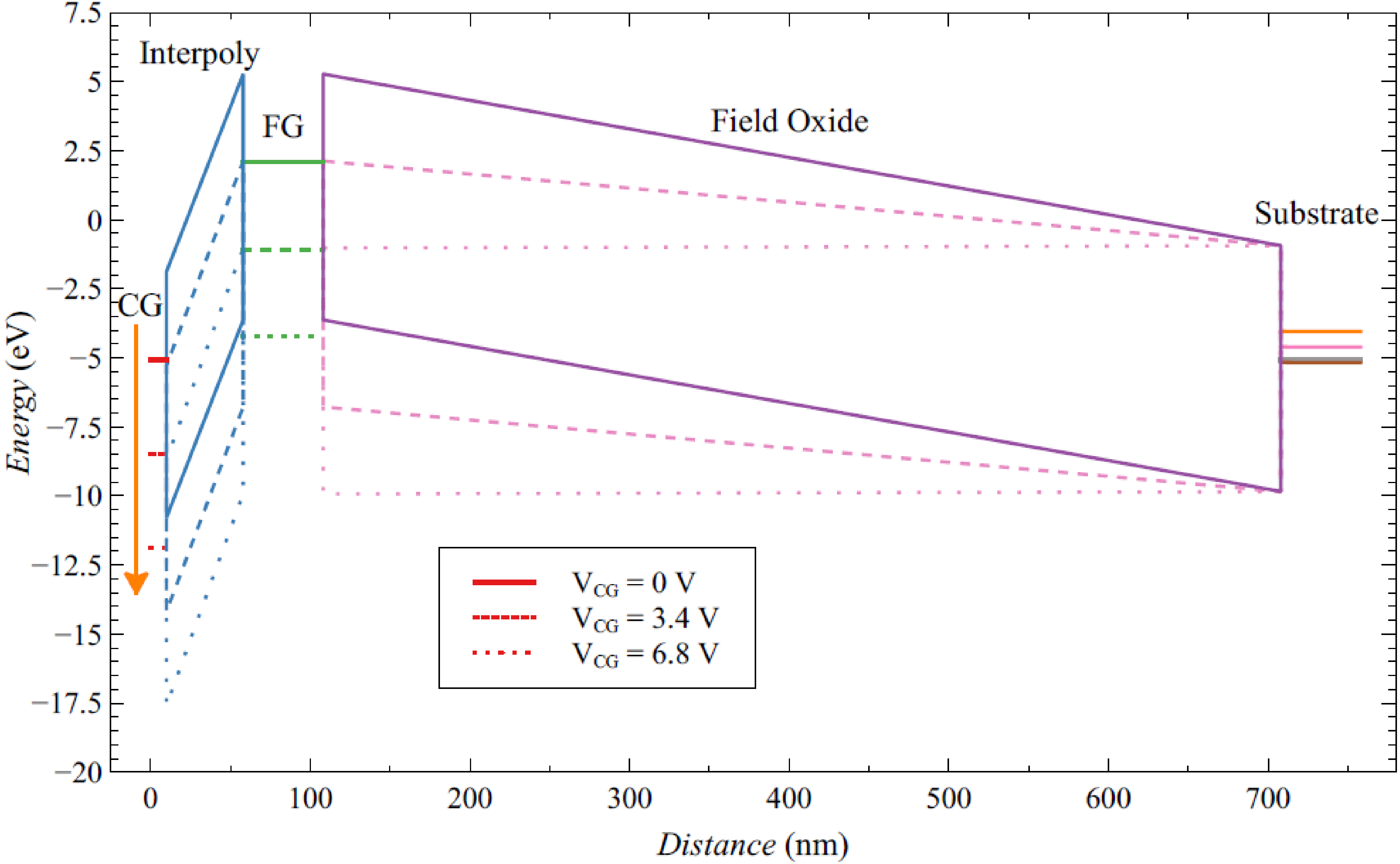

Figure 24. Energy band diagram of EPAD structure.

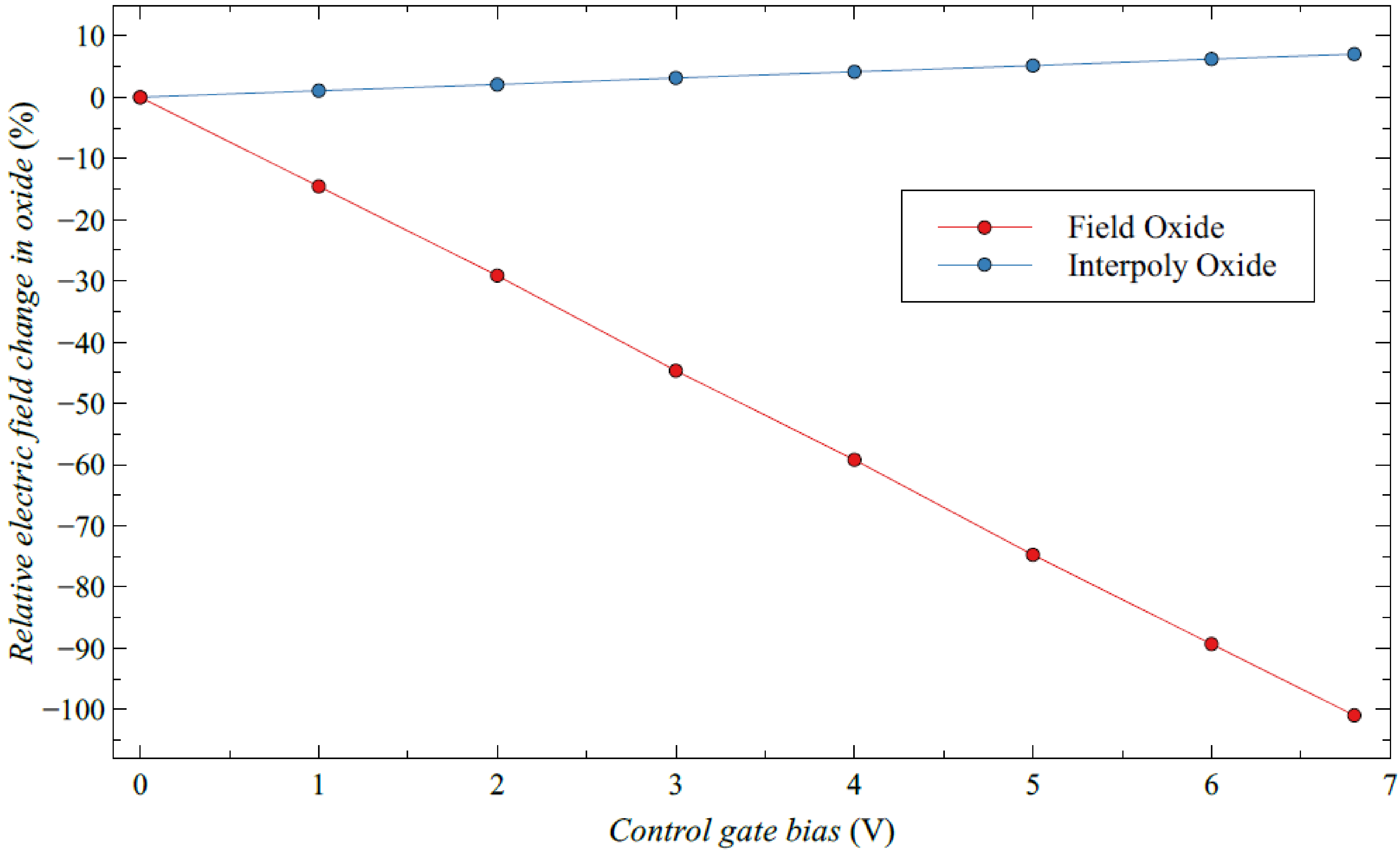

Figure 25. Electric field in field and interpoly oxide.

Conclusion

Electrically Programmable Analog Device is a commercial NMOS floating-gate transistor designed for totally different purposes, this paper describes the possibility of using that transistor as a radiation sensor. An experiment was performed at the “Vinča” Institute of Nuclear Sciences with the gamma radiation source. Highlighting the main results, we concluded that a higher bias does more damage to the EPAD structure. EPAD with zero bias and 4 V initial threshold voltage shows the lowest fading and the highest sensitivity in the 300 Gy dose range. The interesting phenomenon that zero-biased floating-gate MOS transistor has higher sensitivity compared to static-biased transistors was explained with the energy band diagram. The idea of the dynamic bias of the control gate during irradiation was presented for the first time. This dynamic method achieved very good results, showing that some EPADs with dynamic bias have higher sensitivity and better linearity than static-biased EPADs with higher values of biasing. Further work is needed on its implementation. Due to the degradation of the transfer characteristics of EPAD during irradiation, a function of the safe operation area has been found that determines the maximum voltage at the control gate for the desired dose, which will not lead to degradation of the transistor. The dosimetric characteristics of EPAD, such as sensitivity, linearity, fading, are promising, but some changes in design need to be made to make this component to operate as a radiation sensor.