



Standard Test Method for Separating an Ionizing Radiation-Induced MOSFET Threshold Voltage Shift Into Components Due to Oxide Trapped Holes and Interface States Using the Subthreshold Current–Voltage Characteristics¹

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1. Scope

1.1 This test method covers the use of the subthreshold charge separation technique for analysis of ionizing radiation degradation of a gate dielectric in a metal-oxide-semiconductor-field-effect transistor (MOSFET) and an isolation dielectric in a parasitic MOSFET.^{2,3,4} The subthreshold technique is used to separate the ionizing radiation-induced inversion voltage shift, ΔV_{INV} into voltage shifts due to oxide trapped charge, ΔV_{ot} and interface traps, ΔV_{it} . This technique uses the pre- and post-irradiation drain to source current versus gate voltage characteristics in the MOSFET subthreshold region.

1.2 Procedures are given for measuring the MOSFET subthreshold current-voltage characteristics and for the calculation of results.

1.3 The application of this test method requires the MOSFET to have a substrate (body) contact.

1.4 Both pre- and post-irradiation MOSFET subthreshold source or drain curves must follow an exponential dependence on gate voltage for a minimum of two decades of current.

1.5 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:⁵

[E666 Practice for Calculating Absorbed Dose From Gamma or X Radiation](#)

[E668 Practice for Application of Thermoluminescence-Dosimetry \(TLD\) Systems for Determining Absorbed Dose in Radiation-Hardness Testing of Electronic Devices](#)

[E1249 Practice for Minimizing Dosimetry Errors in Radiation Hardness Testing of Silicon Electronic Devices Using Co-60 Sources](#)

[E1894 Guide for Selecting Dosimetry Systems for Application in Pulsed X-Ray Sources](#)

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 *anneal conditions*—the current and/or voltage bias and temperature of the MOSFET in the time period between irradiation and measurement.

3.1.2 *doping concentration*—*n*- or *p*-type doping, is the concentration of the dopant in the MOSFET channel region adjacent to the oxide/silicon interface.

3.1.3 *Fermi level*—this value describes the top of the collection of electron energy levels at absolute zero temperature.

3.1.4 *intrinsic Fermi level*—the energy level that the Fermi level has in the absence of any doping.

3.1.5 *inversion current*, I_{INV} —the MOSFET channel current at a gate-source voltage equal to the inversion voltage.

¹ This test method is under the jurisdiction of ASTM Committee F01 on Electronics and is the direct responsibility of Subcommittee F01.11 on Nuclear and Space Radiation Effects.

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² McWhorter, P. J. and P. S. Winokur, “Simple Technique for Separating the Effects of Interface Traps and Trapped Oxide Charge in MOS Transistors,” *Applied Physics Letters*, Vol 48, 1986, pp. 133–135.

³ DNA-TR-89-157, Subthreshold Technique for Fixed and Interface Trapped Charge Separation in Irradiated MOSFETs, available from National Technical Information Service, 5285 Port Royal Rd., Springfield, VA 22161.

⁴ Saks, N. S., and Anaconda, M. G., “Generation of Interface States by Ionizing Radiation at 80K Measured by Charge Pumping and Subthreshold Slope Techniques,” *IEEE Transactions on Nuclear Science*, Vol NS-34, No. 6, 1987, pp. 1348–1354.

⁵ For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard’s Document Summary page on the ASTM website.