



# 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 Characteristics<sup>1</sup>

This standard is issued under the fixed designation F 996; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 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.<sup>2, 3, 4</sup> The subthreshold technique is used to separate the ionizing radiation-induced inversion voltage shift,  $\Delta V_{INV}$  into voltage shifts due to oxide trapped charge,  $\Delta V_{ot}$  and interface traps,  $\Delta V_{it}$ . 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 given in SI units are to be regarded as standard. No other units of measurement are included in this test method.

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 appro-*

*priate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Terminology

2.1 *Definitions of Terms Specific to This Standard:*

2.1.1 *anneal conditions*—the bias and temperature of the MOSFET in the time period between irradiation and measurement.

2.1.2 *doping concentration,  $N$* — $N$ - or  $P$ -type doping, is the concentration of the MOSFET channel region adjacent to the oxide/silicon interface.

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

2.1.4 *inversion voltage,  $V_{INV}$* —the gate-source voltage corresponding to a surface potential of  $2\phi_B$ .

2.1.5 *irradiation biases*—the biases on the gate, drain, source, and substrate of the MOSFET during irradiation.

2.1.6 *midgap current,  $I_{MG}$* —the MOSFET channel current at a gate-source voltage equal to the midgap voltage.

2.1.7 *midgap voltage,  $V_{MG}$* —the gate-source voltage corresponding to a surface potential of  $\phi_B$ .

2.1.8 *oxide thickness,  $t_{ox}$* —the thickness of the oxide of the MOSFET under test.

2.1.9 *potential,  $\phi_B$* —the potential difference between the Fermi level and the intrinsic Fermi level.

2.1.10 *subthreshold swing*—the change in the gate-source voltage per change in the log source or drain current of the MOSFET channel current below the inversion current. The value of the subthreshold swing is expressed in V/decade (of current).

2.1.11 *surface potential,  $\phi_s$* —the potential at the MOSFET semiconductor surface measured with respect to the intrinsic Fermi level.

## 3. Summary of Test Method

3.1 The subthreshold charge separation technique is based on standard MOSFET subthreshold current-voltage characteristics. The subthreshold drain or source current at a fixed drain to source voltage,  $V_{DS}$ , is measured as a function of gate voltage from the leakage current (or limiting resolution of the

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee F01 on Electronics and is the direct responsibility of Subcommittee F01.11 on Quality and Hardness Assurance.

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<sup>2</sup> For formulation of subthreshold charge separation technique see 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.

<sup>3</sup> 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.

<sup>4</sup> 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.