



Designation: E3084 – 17

Standard Practice for Characterizing Particle Irradiations of Materials in Terms of Non-Ionizing Energy Loss (NIEL)¹

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1. Scope

1.1 This practice describes a procedure for characterizing particle irradiations of materials in terms of non-ionizing energy loss (NIEL). NIEL is used in published literature to characterize both charged and neutral particle irradiations.

1.2 Although the methods described in this practice apply to any particles and target materials for which displacement cross sections are known (see Practice E521), this practice is intended for use in irradiations in which observed damage effects may be correlated with atomic displacements. This is true of some, but not all, radiation effects in electronic and photonic materials.

1.3 Procedures analogous to this one are used for calculation of displacements per atom (dpa) in charged particle irradiations (see Practice E521) or neutron irradiations (see Practice E693).

1.4 Guidance on calculation of dpa from NIEL is provided.

1.5 Procedures related to this one are used for calculation of 1-MeV equivalent neutron fluence in electronic materials (see Practice E722), but in that practice the concept of damage efficiency, based on correlation of observed damage effects, is included.

1.6 Guidance on conversion of NIEL in silicon to monoenergetic neutron fluence in silicon (see Practice E722), and vice versa, is provided.

1.7 The application of this standard requires knowledge of the particle fluence and energy distribution of particles whose interaction leads to displacement damage.

1.8 The correlation of radiation effects data is beyond the scope of this standard. A comprehensive review (1)² of displacement damage effects in silicon and their correlation with NIEL provides appropriate guidance that is applicable to semiconductor materials and electronic devices.

¹ This test method is under the jurisdiction of ASTM Committee E10 on Nuclear Technology and Applications and is the direct responsibility of Subcommittee E10.07 on Radiation Dosimetry for Radiation Effects on Materials and Devices.

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² The boldface numbers in parentheses refer to a list of references at the end of this standard.

2. Referenced Documents

2.1 ASTM Standards³

E170 Terminology Relating to Radiation Measurements and Dosimetry

E521 Practice for Investigating the Effects of Neutron Radiation Damage Using Charged-Particle Irradiation

E693 Practice for Characterizing Neutron Exposures in Iron and Low Alloy Steels in Terms of Displacements Per Atom (DPA), E 706(ID)

E722 Practice for Characterizing Neutron Fluence Spectra in Terms of an Equivalent Monoenergetic Neutron Fluence for Radiation-Hardness Testing of Electronics

3. Terminology

3.1 Definitions of some terms used in this practice can be found in Terminology E170.

3.2 Definitions:

3.2.1 *tracked particles*—those particles whose position-dependent fluence spectra are calculated in a particle transport calculation for a specific target geometry.

3.2.1.1 *Discussion*—In calculating displacement damage energy and NIEL, the tracked particles should include neutrons, photons, protons and ions up to $Z=2$, unless their contributions are known to be negligible. Heavier ions may also be tracked in some Monte Carlo codes. Except in the case of neutrons, particles below a specified minimum energy are not tracked, and are treated as *non-tracked particles*.

3.2.2 *tracked-particle fluence spectrum*, $\Phi_p(E)$ —the fluence spectrum of particles, of species p and at particle energy E , that are tracked in a particle transport calculation. For each species of tracked particle other than neutrons there is a specified minimum energy. Particles at lower energy are non-tracked particles.

3.2.3 *secondary particles*—those particles produced in a material by interaction with the tracked particles. Secondary particles may include tracked particles and non-tracked particles.

³ 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.