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Glossary of Radiation Terms

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ASIC: Application-Specific Integrated Circuit

Attribute Testing: Quantitative test indicates the total number of devices subjected to various screening steps in a test sequence, as well as the total number of devices passing or failing these steps. Also known as lot testing.

Absorbed Dose: Radiation energy absorbed per unit of material mass.

Alpha Particle: A positive charged nuclear particle (same as a helium nuclei) that is composed of two neutrons and two protons.

ANOVA (Analysis of Variance): A mathematical procedure for testing hypothesis. ANOVA techniques are used to examine a collection of subgroups to then determine whether they all belong to one homogeneous population (single parent population).

ASTM: American Society for Testing and Materials

Best Commercial Practices: This term is used to address all of the design and manufacturing techniques that are used during wafer fabrication and assembly processes, the quality assurance provisions used throughout the processing flow, and the end item testing methodologies employed by component manufacturers regardless of the product category or grade. In other words, "commercial practices" refers to the best manufacturing and quality assurance provisions that are employed by a manufacturer, regardless of the category of products (e.g., consumer, commercial/industrial, or military) that is produced.

Beta Particle: A negatively charged particle that is identical with an electron, including mass.

Bremstrahlung (a.k.a., Braking Radiation): Radiation that is created by the interaction of a Beta particle or an electron with matter. This results in the emission of electromagnetic radiation, such as photon or x-rays.

Chromosphere: The lower level of the solar atmosphere between the photosphere and the corona.

CID: Commercial Item Description

Commercial Products: Products that are not exclusively developed for large volume commercial customers or military applications and are being produced and sold to the open market and/or general public. These products are typically designed and verified for operations over the specific electrical envelope in room-temperature applications. These products typically have a short life cycle and are almost exclusively offered in plastic packaging technology.

Complementary Bipolar IC Process: A bipolar process that uses only vertically designed PNP and NPN transistors fabricated with matched characteristics, such as gain, breakdown voltage, current drive, and frequency responses.

Corona: The uppermost level of the solar atmosphere, characterized by low densities and high temperatures (>1.0E+06°K).

Cosmic Rays: Energetic heavy ions that include all ions in the Periodic Table. Interaction of this environment with material results in the generation of secondary radiation, including ionization and neutron.

COTS: Commercial-Off-the-Shelf

Curie: A unit of radioactivity defined as that undergoing 3.7E10 disintegrations per second.

Displacement Damage: The damage to the bulk structure of a semiconductor device caused by the impact of energetic neutrons and/or protons. This effect can be engendered by either a nuclear weapon detonation (neutrons) or solar activity (neutrons and protons). The result of this irradiation is usually either device performance degradation or failure.

Di-Vacancy: This point defect occurs when two vacancies are located side by side in the crystal lattice.

Dose: A measure of energy deposited per unit. The unit of dose can be rad or Gray.

Dose Rate (Transient Testing): The amount of ionizing radiation which an object would receive per unit of time.

- **High Dose Rates:** For example, greater than 10 rad(Si)/s
- **Low Dose Rates:** For example, less than 0.1 rad(Si)/s

Dose Rate Survivability: The highest level of dose rate that a device can incur without permanent damage such as device latchup or by burnout of the device junction or metallization.

Dose Rate Upset: A momentary disruption of a device caused by a high intensity pulse of ionizing radiation. This temporary disruption can result in a change of stored data, a change of operating state, or a transient output signal that is large enough to have an effect on other circuits.

DRAM: Dynamic Random Access Memory

DSSC (Defense Supply Center, Columbus): The government agency which controls the specifications surrounding military electronics.

EIA: Electronic Industries Alliance

Electron: An atomic particle with a negative electric charge of -1.6E-19 Coulomb and a mass of 9.1E-31 kg.

EMI (Electromagnetic Interference): Any electrical phenomenon where electric and magnetic field energies combine to create noise or interference on electrical signals, i.e., electrostatic discharge.

Endo-atmospheric: Within the atmosphere. An important factor for the nuclear weapon environment. The total dose from a nuclear weapon is delivered in about 10 seconds; the majority of the dose is accumulated in microseconds. Some annealing may occur.

ESA: European Space Agency

ESD: Electrostatic discharge

Exo-atmospheric: Outside the atmosphere. An important factor for the nuclear weapon environment. The total dose from a nuclear weapon is delivered in microseconds. Minimal time is provided for annealing.

Faculae: Bright regions in the photosphere associated with sunspots.

Fission: The splitting of a heavy nucleus into two fragments, or fission products. Fission is accompanied by the emission of neutrons and the release of energy.

Fluence: The number of particles crossing per unit area from either side. Another definition is that fluence is the flux integrated over time.

Flux: The transfer of energy or particles per unit of time across a unit area from either side.

Functional Failure: The point at which the device can no longer operate.

Fusion: The process by which nuclei of light elements, especially the hydrogen isotopes deuterium and tritium, combine to form the nucleus of a heavier element with a substantial exothermic release of energy.

GaAs: Gallium Arsenide

Galactic Cosmic Rays: Primarily cosmic rays that originate outside of the Solar System. These cosmic rays provide a continuous, low flux component of the space radiation environment and consist of 85% protons, 14% alpha particles, and 1% heavier nuclei with energies extending up to about 1GeV.

Gamma Rays: Pure electromagnetic energy traveling through space at the speed of light. Also referred to as photons. A Gamma Ray has no electrical charge or mass. These rays are electromagnetic and have very short wave lengths with discrete and definite energies. The gamma rays are lightly ionizing and highly penetrating, leaving no radioactivity in the irradiated material.

Geostationary Orbit: A circular equatorial orbit that has a period of 24 hours and co-rotates with the Earth. An object positioned in this orbit appears to be stationary to an Earth observer since it matches the Earth's rotational velocity.

Geosynchronous Orbit: A low inclination orbit in which the satellite's orbital velocity is matched to rotational velocity of the planet. The orbit is generally slightly elliptical, but maintains a period of 24 hours. A satellite in this orbit would appear to move slightly to the Earth observer since the orbit is not circular.

Gray (Gy): The SI unit for absorbed dose (total dose, total ionizing dose) in the field of radiation dosimetry.

1 Gy (x) = 1 J/kg

1 Gy (x) = 100 rad (x)

(x) = specific material of interest, i.e., Gy (Si) or Gy (GaAs)

IC: Integrated Circuit

IMF (Interplanetary Magnetic Field): The magnetic field carried with the solar wind.

INR (Initial Nuclear Radiation): Radiation that arrives at the system within one minute.

Interstitial: This point defect occurs when an atom leaves its regular site in a crystal and takes a position between established atom sites that is a normal vacant void within the crystal lattice.

Ionizing Radiation: Electromagnetic radiation (gamma rays or x-rays) or particle radiation (proton, electron, neutron, etc.) that is capable of producing ions in its passage through matter.

Ionosphere: A region of charged particles in a planet's upper atmosphere; the part of the Earth's atmosphere beginning at an altitude of about 25 miles and extending outward 250 miles or more.

JAN (Joint Army Navy): Military standard

JEDEC: Joint Electronic Devices Engineering Council

Latchup: A catastrophic failure that causes an electronic device to generate a low impedance path between two or more voltage sources or a high current state that results in a loss of device functionality. The latchup is generated by a parasitic Silicon-Controlled-Rectifier (SCR) structure in an integrated circuit (IC) that becomes energized by voltage overstressing, is radiation induced, or is attributable to other causes.

LET (Linear Energy Transfer): Restricted collision stopping power. LET is the mean energy that is lost by a charged particle in electronic collisions per unit length of its trajectory.

LRU: Line Replaceable Unit

Magnetosphere: The region of space in which a planet's magnetic field dominates that of the solar wind.

Magnetotail: The portion of a planetary magnetosphere which is pushed away from the Sun by the solar wind.

MDS: National Semiconductor's military datasheet.

Military Products: These products are typically available from the open market and are sold primarily to military customers. Electrical performance characteristics are specified and verified for operations in harsh environmental applications (i.e., -55˚C to +125˚C). These products are verified for long-term operations and have been offered primarily in hermetic packages.

Muon: A charged particle (exists in either positive or negative form and carries one electric charge of $\pm$ 1.6 x 10^{-19} C). Also known as "heavy electron". It has a mass about 207 times the mass of an electron.

NASA: National Aeronautics and Space Administration

Neutrino: A fundamental particle supposedly produced in massive numbers by the nuclear reactions in stars. They are difficult to detect since the vast majority of them pass completely through the Earth without interacting.

Neutron: One of the basic particles of the atomic nucleus. It has no charge and has a rest mass of 1.67E-27 kg. The neutron is difficult to stop. The capture of a neutron may result in the emission of a gamma ray.

NSEE: Neutron Single Event Effects

NSEL: Neutron Single Event Latchup

NSEU: Neutron Single Event Upset

NWE: Nuclear Weapons Effects

Parametric Failure: The point at which the device under test goes out of defined specification limits.

Parametric Testing: The measurement of individual variables or parameters. Values are recorded and are traceable to individual devices. Parametric testing contrasted with attribute or lot testing.

Phonons: A quanta of energy of the normal modes of a crystal lattice or an elastic continuum. The concept of phonons refers to the quantization of energy content of each oscillator, not to the nature of the oscillator itself. The concept of the phonon is closely analogous to that of the photon in electrodynamics.

Photon: A quantum of electromagnetic energy such as light, radio waves, etc. Photons can also be gamma rays (energies >250keV) or x-rays (energies of 1keV to <250kev). At 250keV, the interaction between the photon and the target material changes from a photoelectric effect to the Compton Scattering Effect in Si.

Photosphere: The visible surface of the Sun; sunspots and faculae are observed in the photosphere.

Pion: A fundamental particle that can be positive, negative, or neutral that has a mass 270 times that of an electron.

PIPL: Post-Irradiation Parametric Limit

Prompt Dose: The radiation dose received from the initial radiation pulse from a nuclear explosion.

Proton: One of the basic particles of the atomic nucleus (the other is the neutron). The proton has a charge of +1.6E-19 Coulomb and has a rest mass of 1836 times greater than an electron.

QML: Qualified Manufacturers' List

Qualification: A process in advance of, and independent of, an acquisition by which a manufacturer's or distributor's products are examined, tested, and approved to determine conformance with requirements of a specification.

Rad: A basic unit of absorbed dose for ionized radiation. The rad represents the absorption of 100 ergs of energy per gram of targeted material specified. In the case of integrated circuits, the specified material is generally silicon (Si) or SiO_2.

Radiation: For this Manual, either ionizing or displacement. Ionizing radiation creates charge carriers in insulators and reversed biased junction where there were previously almost no carriers. Displacement radiation, particularly neutron radiation, produces defects in atomic (i.e., lattice) structures. These defects act as traps and recombination centers to reduce the free-carrier lifetime and (thermally generated) carrier density.

Radiation Hardness Assurance (RHA): The procedures used to ensure that the radiation hardness capability of a semiconductor device is in compliance with the product specifications.

Radiation Hardness Assurance (RHA) Categories: Designates guaranteed limits up to:

- **M** = 3 krad(Si)
- **D** = 10 krad(Si)
- **P** = 30 krad(Si)
- **L** = 50 krad(Si)
- **R** = 100 krad(Si)
- **F** = 300 krad(Si)
- **G** = 500 krad(Si)
- **H** = 1 Mrad(Si)

Radiation Hardness Assured Capability Limit (RHACL): This is the minimum radiation level that the manufacturer guarantees that a semiconductor device can be exposed to and still meet parametric specifications. It is typically based on data obtained from exposing devices or test structures to radiation in accordance with MIL-STD-883 or MIL-I-38535.

Radioactivity: Disintegration of the nuclei of the atoms of certain elements during which gamma rays and elementary particles are emitted.

Rebound Effect (a.k.a., Super-Recovery): After irradiation, recovery of a MOSFET's V_{TH} past its initial value.

REM [Roentgen Equivalent (in) Man]: Total ionizing dose unit

Roentgen: The quantity of x-ray or gamma ray ionizing radiation that will produce one electrostatic unit (ESU) of ions in one cm^3 of dry air (at standard temperature and pressure) which has a total charge of 3.33E-10 Coulomb. One roentgen equals 0.865 rad.

SCD (Source Control Drawing): SCDs can be used to specify radiation testing to either a Level S or a Level B process flow. SCDs are also used to define tighter radiation-assurance specifications than are available via the RHA's broader categories.

SEC: Standard Evaluation Circuit

SEE (Single Event Effects): The radiation response of a semiconductor caused by the impact of galactic cosmic rays, solar-enhanced particles, and/or energetic neutrons and protons. Responses can include upset (non-destructive, and latchup or gate-rupture (destructive).

SEL (Single Event Latchup): A loss of device functionality due to a single event. It may be manifested by a high current density state that may cause permanent damage to the device. If permanent damage is not sustained, power cycling of the device (off and back on) is necessary to restore normal operations. SEL is the result of a parasitic SCR structure in an IC becoming energized by an ion strike.

SEP (Single Event Phenomena): The effects caused by the passage of an alpha particle, proton, or cosmic ray (heavy ion). These effects include upset, latchup, funnel effect, ion shunting, etc.

SEU (Single Event Upset): A "soft error", change of logic state, or a bit flip caused by alpha particles or cosmic rays as they pass through a device.

SI: International System of Units

Si: Silicon

SID: Selected Item Drawing

SiO_2: Silicon dioxide

SMD: Standard Microcircuit Drawing

Solar Cosmic Rays: In addition to producing an intense burst of UV (ultra-violet) and x-rays, solar flares accelerate solar material to high velocities. These solar particles are similar to galactic cosmic rays; but owing to their different origin, are not identical in composition.

Solar Flares: Solar eruptions produce energetic protons with a minor contribution of alpha particles, heavy ions, and electrons. Energies range to hundreds of MeV.

Solar Wind: A tenuous flow of gas and energetic charged particles, mostly protons and electrons – plasma – which stream from the Sun. Typical solar wind velocities are near 350 kilometers per second.

SOS: Silicon-on-Saphire

SRAM: Static Random Access Memory

Statistics: A subsection of the science of mathematics concerned with the organization, collection, analysis, interprelation, and presentation of data.

Step-Stress Radiation Approach: A series of discrete cumulative irradiations with measurements made after each irradiation increment.

Sunspot: An area seen as a dark spot on the photosphere of the Sun. Sunspots are concentrations of magnetic flux, typically occurring in bipolar clusters or groups. They appear dark because they are cooler than the surrounding photosphere.

Terrestrial Cosmic Rays: These constitute the primary cosmic radiation which penetrates the Earth's atmosphere. They are rapidly transformed by interactions that produce a cascade of secondary radiation.

TDE: Time Dependent Effect

TID: Total Ionizing Dose

Total Dose: The total accumulated amount of absorbed ionizing radiation specified at a particular dose rate exposure at +25˚C.

Total Ionizing Dose Effect: The response of a semiconductor device to ionizing radiation that can occur due to the neutron x-ray and gamma emanations of a nuclear weapon or due to electrons/protons trapped in the Earth's magneto- sphere, occurring in space, or surrounding other planets. The effects of ionizing radiation include device degradation and/or failure.

Trapped Radiation: This consists of a broad spectrum of energetic charged particles that are trapped in the Earth's magnetic field, thus forming the radiation belts.

TRB: Technology Review Board

TREE: Transient Radiation Effects (on) Electronics

Van Allen Belts: Radiation belts surrounding the Earth. Discovered by American physicist James Van Allen, using an instrument aboard the first successful American satellite, Explorer I.

Vacancy: This is a point defect that results when an atom is removed from its lattice site and moved to the surface of the crystal. Also known as a Schottky Defect.

Variables Testing: See Parametric Testing.

X-Rays: These are short-wavelength photons or electromagnetic radiation. An x-ray originates from electronic shells or charged particle collisions. X-rays have energies that are less than 250keV.

Glossary of Measurement Terms

Ref. No. 5

Symbol	Definition
A	Ampere, SI unit of electric current
b/s	Bits per second
C	Coulomb; quantity of electric charge; SI unit of electric charge
c	SI prefix for 10^{-2}, centi
cm	Centimeter
cm^3	Cubic centimeter
°	Degree
°C	SI unit of Celsius temperature
°K	SI unit of temperature
eV	Electronvolt
erg	Unit of energy or work; equal to 10^{-7} J
f	Farad; SI unit of capacitance
G	SI prefix for 10^{9}; giga
g	gram
GeV	Gigaelectronvolt
GHz	Gigahertz
H	SI unit of inductance; henry
Hz	SI unit of frequency; hertz
h	Hour
in	Inch
J	SI unit of energy, work; quantity of heat; joule
k	SI prefix for 10^{3}; kilo
kb/s	Kilo bit per second
kbps	Kilo bit per second
keV	Kiloelectronvolt
kg	SI unit of mass; kilogram
kHz	Kilohertz
km	Kilometer
krad	Kilorad

Symbol	Definition
M	SI prefix for 10^{6}; mega
m	SI prefix for 10^{-3}; milli
Mb/s	Megabits per second
mA	Milliampere
MeV	Megaelectronvolt
mg	Milligram
mil	0.001 inch
min	minute (time)
mm	Millimeter
mrad	Millirad
mrem	Millirem
ms	Millisecond
mV	Millivolt
mW	Milliwatt
n	SI prefix for 10^{-9}; nano
nA	Nanoampere
nF	Nanofrarad
nm	Nanometer
ns	Nanosecond
Ω	SI unit of resistance; ohm
p	SI prefix for 10^{-12}; pico
pF	Picofarad
SI	International System of Units
s	SI unit of time; second
t	Time
µ	SI prefix for 10^{-6}; micro
µA	Microampere
µm	Micrometer
µrad	Microrad
µrem	Microrem
µu	Microsecond
µV	Microvolt
V	SI unit of voltage; volt
W	SI unit of power; watt