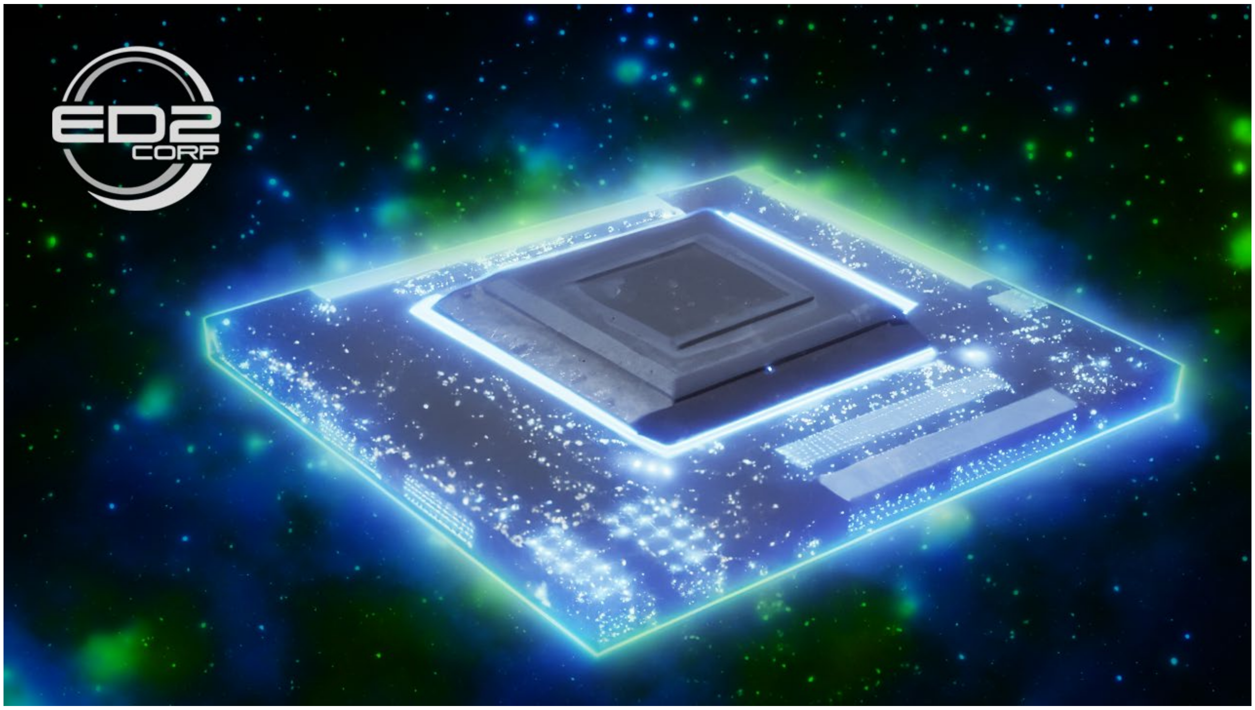

RAD HARD FOR SPACE

Space is characterized by high levels of radiation from sources such as solar, cosmic rays, and trapped radiation belts. Radiation hardness, often abbreviated as RAD HARD, refers to the ability of electronic components and systems to withstand the effects of ionizing radiation in space environments. Ionizing radiation can be harmful to electronics due to its ability to produce charged particles, or ions, as it passes through materials. The interaction between ionizing radiation and electronic components can lead to various adverse effects, potentially causing malfunctions, disruptions, or permanent damage.

RAD HARD Considerations

Electronics designed for space applications typically need to be designed to consider radiation effects. There are a few key considerations when examining both requirements and compliance to RAD HARD electronics needs:

Total Ionizing Dose (TID). RAD HARD electronics should be capable of withstanding cumulative ionizing radiation exposure over the mission's lifetime. TID is measured in Grays or rads and represents the total amount of ionizing radiation absorbed by a material.

Single-Event Effects (SEE). SEE includes phenomena like single-event upset (SEU), single-event latch-up (SEL), and single-event burnout (SEB). These are caused by high-energy particles striking a sensitive point in a semiconductor device, resulting in temporary or permanent malfunctions.

Displacement Damage Dose (DDD): DDD is a measure of the damage caused by displacement of atoms in a material due to ionizing radiation. RAD HARD electronics should have sufficient tolerance to displacement damage, ensuring long-term reliability.

Temperature and Thermal Cycling: RAD HARD components must operate within specified temperature ranges and handle thermal cycling without degradation. Thermal management is crucial for preventing overheating and ensuring consistent performance in the space environment.

Spacecraft Charging Mitigation: Spacecraft can accumulate charge in certain regions, leading to discharges that may affect onboard electronics. RAD HARD designs incorporate measures to mitigate spacecraft charging effects.

Materials Selection: Radiation-resistant materials should be selected for RAD HARD environments. For instance, semiconductors, ceramics, and insulating materials are chosen to minimize the impact of radiation.

Shielding and Redundancy: Shielding is sometimes employed to protect critical components from radiation. Redundancy in electronic systems helps ensure continued operation in the event of component failures due to radiation effects.

Testing and Qualification: RAD HARD electronics undergo rigorous testing and qualification processes, including exposure to simulated space radiation environments. This ensures that the components meet or exceed specified radiation hardness requirements.

Mitigation Strategies: Designers implement mitigation strategies such as error correction codes (ECC), triple modular redundancy (TMR), and other fault-tolerant techniques to enhance the reliability of RAD HARD electronics.

These requirements collectively aim to ensure the resilience and longevity of electronic systems in the challenging radiation environment of space.

Fused Silica (“Glass”) and RAD HARD Requirements

Fused silica, also known as quartz glass, or abbreviated simply to “glass,” is often used in the construction of electronic components for applications where radiation hardness (RAD HARD) is a critical requirement. Fused silica exhibits several properties that make it suitable for use in environments with ionizing radiation, such as space.

Radiation Resistance: Glass is inherently resistant to ionizing radiation. Its amorphous and highly ordered structure helps it withstand the effects of radiation, making it a suitable material for components exposed to harsh radiation environments in space.

TID Resistance: Fused silica demonstrates resistance to TID effects. This resistance is crucial for ensuring the long-term stability and functionality of electronic components in space missions.

Low Atomic Number: Fused silica has a low atomic number (example: Si: 14, O: 8), which can be advantageous in minimizing the production of secondary radiation when exposed to high-energy particles. Secondary radiation refers to additional radiation generated as a result of interactions between high-energy particles and materials. When charged particles, such as protons or heavy ions, penetrate or interact with electronic components or shielding materials in a spacecraft or satellite, they can produce secondary radiation.

Structural Stability: Known for its excellent thermal and structural stability, fused silica maintains its physical and chemical properties under a wide range of temperatures and environmental conditions, including those encountered in space.

Fused silica is renowned for its excellent structural stability under a variety of environmental conditions. This stability is attributed to its unique chemical and physical properties.

- Amorphous Structure: Fused silica is primarily composed of silicon dioxide (SiO_2) with a highly amorphous structure. Unlike crystalline materials, the lack of a regular crystalline lattice in fused silica contributes to its isotropic and homogeneous properties.

- High Melting Point: Fused silica has a high melting point, typically around 1,700 degrees Celsius (3,092 degrees Fahrenheit). This high melting point allows it to retain its structural integrity at elevated temperatures, making it suitable for applications involving exposure to heat.

- Low Thermal Expansion: Fused silica exhibits a low coefficient of thermal expansion (CTE), meaning it undergoes minimal dimensional changes with temperature variations. This property helps prevent thermal stress and cracking in response to temperature fluctuations, contributing to the material's stability.

- Thermal Shock Resistance: Fused silica possesses good thermal shock resistance, allowing it to withstand rapid temperature changes without experiencing damage.

- Chemical Inertness: Fused silica does not readily react with most chemicals or substances. This inertness contributes to its stability in various chemical environments, making it suitable for applications where resistance to chemical corrosion is essential.

- Low Expansion Coefficient at Cryogenic Temperatures: Glass maintains stability even at cryogenic temperatures.

Low Thermal Expansion: As ED2 CORPORATION has highlighted in other papers, fused silica has a low coefficient of thermal expansion, which means it is less likely to experience thermal stresses and cracking under temperature variations.

Insulating Properties: Fused silica is an excellent insulator, preventing unintended electrical paths. This property is important for avoiding radiation-induced conductivity.

While fused silica possesses favorable properties for radiation-hardened applications, it's important to note that the overall design and construction of electronic systems play a crucial role in achieving RAD HARD requirements.

Standards

Several standards organizations and space agencies have developed and published standards for radiation hardness. Here are some of the key standards commonly used in the field.

NASA Standards: NASA (National Aeronautics and Space Administration) has several standards related to radiation hardness. Notable documents include:

- NASA-STD-6016: Space Environment for Vehicles and Hardware
  This NASA standard provides comprehensive information on the space environment and its effects on spacecraft and hardware. It covers various radiation-related topics, including ionizing radiation, solar particle events, and cosmic rays.

- NASA-STD-8739.6: Standard for Electrostatic Discharge Control (ESD) and High-Reliability
  Focused on preventing and controlling electrostatic discharges, this standard is important for ensuring the reliability of electronic components in space systems.

- NASA-HDBK-3112: Handbook for Surface Mount Technology for High Reliability and High Performance
  This handbook offers guidance on surface mount technology for achieving high reliability and performance in electronic components used in space applications.

- NASA-STD-7003: Requirements for Protection of Electronic Parts, Assemblies, and Equipment (NASA EEE Standard)

European Cooperation for Space Standardization (ECSS): ECSS, a collaboration between the European Space Agency (ESA), the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), and the European Union (EU), provides standards for space projects. Relevant documents include:

- ECSS-E-ST-10-01C: Space Engineering - Space Environment
  This standard provides information on the space environment, helping engineers understand and design for the challenges posed by space radiation.

- ECSS-Q-ST-60-13C: EEE Components - Total Ionizing Dose (TID) Test Method
  This standard outlines the test method for determining the total ionizing dose (TID) resistance of electrical, electronic, and electromechanical (EEE) components used in space systems.

- ECSS-Q-ST-60-15C: EEE Components - Single Event Effects (SEE) Testing of Devices

MIL-STD (Military Standards): While primarily developed for military applications, some MIL-STDs are relevant to radiation-hardened electronic components. For example:

- MIL-STD-883: Test Methods and Procedures for Microelectronics
  Although primarily developed for military applications, MIL-STD-883 includes test methods relevant to radiation hardness, such as radiation-induced electrical degradation and TID testing.

- MIL-HDBK-217: Reliability Prediction of Electronic Equipment

- MIL-PRF-38535: Integrated Circuits (Microcircuits) Manufacturing

ISO Standards: ISO (International Organization for Standardization) has standards that may be applicable to radiation-hardened electronic components:

- ISO 26262: Road Vehicles - Functional Safety
  While not specific to space, ISO 26262 is a standard for functional safety of electrical and electronic systems in automobiles. Some principles from this standard may be relevant to ensuring the safety and reliability of electronics in harsh environments, including radiation exposure.

- ISO 22301: Societal Security - Business Continuity Management Systems

Aerospace Corporation Standards: The Aerospace Corporation, a nonprofit organization that provides technical guidance to the space community, has developed standards such as TOR-2007(8575)-0101 (Single Event Effects Testing of Microelectronics).

The importance of a particular standard often depends on the specific needs and regulations of a given project. For space missions, adherence to the relevant standards ensures that electronic components can withstand the effects of ionizing radiation and operate reliably in the challenging space environment. Engineers and project managers typically refer to a combination of these standards to develop and verify radiation-hardened systems.

ED2 CORPORATION has extensive experience in both designing and manufacturing devices with RAD HARD requirements. ED2 fused silica-based 3D heterogeneous modules are excellent design choices for electronics that need to exist in a RAD HARD context.