Voltage Multipliers, Inc.

Glass vs Epoxy Passivation for High Reliability High Voltage Silicon Diodes

Abstract:

This paper compares the material characteristics of glass and epoxy passivation methods for high voltage silicon diodes, with a focus on reliability-critical applications in harsh or demanding environments.

When designing for high voltage, high reliability applications, understanding the materials used in components construction is essential. In this document, we will be reviewing the pros and cons of different passivation methods for high voltage silicon diodes. Specifically, we will be reviewing the passivation method of epoxy and glass on high voltage silicon diodes.

Methods of Comparison:

Voltage Multipliers Inc. is a qualified vendor under MIL-PRF-19500, with capabilities including long-term reliability tests such as High Temperature Reverse Bias (HTRB, MIL-STD-750 Method 1038) and Thermal Shock (MIL-STD-750 Method 1051). See Appendix A for additional high reliability testing methods and information.

High reliability for high voltage diodes is a multifaceted problem, depending on the exact usage of the part. Generally speaking, a device requiring high reliability necessitates one or more of the extreme environmental conditions:

- High temperature (Method 1038, 1031)
- Temperature shock (Method 1051, 1056)
- Humidity (Method 1021, 1071, 1072)
- Corrosive environments (Method 1011)
- Vibration (Method 2016, 2056)

- Long term performance (Method 1038)

The process of passivating silicon with glass requires a high temperature process after the glass is added to the cleaned silicon of the diode. At temperatures above 700°C, the glass fuses to the silicon of the diode, creating a robust, hermetic seal. In addition, the glass has a Coefficient of Thermal Expansion (CTE) similar to silicon, making the entire structure more predictable at extreme low temperatures (<-25°C) and extreme high temperatures (>+150°C).

Conversely, using a high voltage epoxy is a straightforward lower temperature process. Epoxy tends to have a CTE much higher than that of the silicon or metals used in the construction of the diode. This process, however, can be done at much lower temperatures and be done in a more automated manner, allowing for different (lower cost) construction methods and materials. Normal methods of epoxy molding of the devices will compress onto silicon, providing good passivation and predictable package dimensions.

Glass passivated diodes offer superior material characteristics compared to epoxy passivated devices but require a more involved manufacturing process.

Passivation Comparison - Epoxy vs Glass:

Now let's compare the two methods of passivation under the lens of reliability. Put simply, glass passivated diodes will have superior performance in most categories.

Temperature Comparison:

For extreme high and extreme low temperatures, the fused glass-silicon bond of the glass passivation is going to expand and contract at similar rates. Pure silicon has a CTE of approximately 3.0ppm/°C, and glass has a CTE of approximately 3.3ppm/°C. Though the CTE of epoxy can vary widely, some of the specially designed lower CTE materials that are designed for high voltage design could be in the range of approximately 20ppm/°C – close to 7 times that of the silicon – however common epoxies often have a CTE in the 30-100ppm/°C range. Though this is not a problem in more normal temperature ranges, at higher temperatures the epoxy can pull away from the silicon, compromising the dielectric characteristics of the part and creating an environment to allow partial discharge and corona effects. Lower temperatures can compress the epoxy around silicon, creating mechanical stress.

Humidity Comparison:

In high humidity environments or corrosive environments, the hermetic seal created by the glass fused to silicon will keep contaminants away from the high voltage gradients that exist along the internal structures of the diodes. Epoxies have different degrees of moisture

permeability, but are not hermetic, meaning they can have degradation over time exposed to high moisture, corrosive environments, or low atmospheric conditions (outgassing).

Physical stresses, vibration, mechanical shock, sheer forces, are a mixed bag for glass and epoxy comparisons. Epoxy tends to be less brittle compared to glass, allowing some flexibility from sheer forces. This does mean that the epoxies can be deformed or damaged under extreme conditions, especially at higher temperatures, but depending on the application, deformation may be advantageous.

Long Term Usage Comparison:

For long term applications, there are more extreme considerations for epoxy passivated diodes. Ion migration doesn't exist for glass but can lead to long term degradation of an epoxy material under electric field stresses. Partial discharge (PD) is a localized dielectric breakdown that occurs in voids, inclusions, or along delaminated surfaces when exposed to high voltage stress, progressively degrading insulation systems. While PD can occur in any trapped void, glass passivation's hermetic and mechanically stable nature greatly reduces the risk of delamination, making PD events more likely in epoxy passivated devices over time.

Comparison Summary:

To summarize the performance of the two methods:

Characteristic	Glass Passivated	Epoxy Passivated
Breakdown voltage	Higher, more stable	Good initially, may degrade
Leakage current	Lower and more stable	Can increase with aging, moisture, degradation (ion migration, corona, partial discharge)
Temperature range	Wider (up to ~250°C)	Limited (~-25°C to +150°C)
Mechanical durability	Hard, but brittle	Softer, more tolerant of deflection and some vibration
Moisture resistance	Excellent (hermetic)	Moderate to good(non-hermetic)
Cost	Higher	Lower
Production	Longer lead time, more involved manufacturing	Shorter lead time, mass production capable

Risk Summary:

To summarize risks:

Risk/Property	Glass Passivated	Epoxy Passivated
CTE mismatch with silicon	Very low (~3 ppm/°C)	High (~20-100 ppm/°C)
Thermal cycle durability	Excellent	Requires careful design
High voltage field control	Excellent (stable, hermetic)	Moderate (stress-dependent)
Ion migration risk	Negligible (contaminants)	Moderate to high (moisture + bias driven)
Mechanical stresses	High hardness, brittle under sheer forces	Moderate hardness, potential deflection under sheer forces

Summary:

For applications requiring the highest reliability under extreme environmental and operational stresses, glass passivated diodes should be the preferred solution. While epoxy passivation offers cost and mechanical benefits for less demanding environments, the long-term stability and hermetic performance of glass passivation make it the superior choice for high reliability systems.

Appendix A: Relevant Reliability Test Standards

Test Type	MIL-STD-750 Method	Purpose
High Temperature Operating Life (HTRB)	1038	Verifies long-term operation under elevated junction temperature and reverse bias
High Temperature Storage Life (HTSL)	1031	Evaluates device stability in high-temp storage conditions
Temperature Cycling (Thermal Shock)	1051/1056	Checks mechanical integrity and CTE mismatch effects
Moisture Resistance/Humidity	1021	Assesses device resistance to high humidity
Salt Atmosphere (Corrosion)	1011	Evaluates corrosion resistance in salt fog
Hermetic Seal (Fine and Gross Leak)	1071 & 1072	Verifies hermeticity of sealed packages
Mechanical Shock	2016	Assesses resistance to mechanical impact
Vibration (Variable Frequency)	2056	Checks device resistance to vibration
Power Burn-in (Dynamic Burn-in)	1038	Detects latent defects via elevated stress

Note: All tests conducted per MIL-PRF-19500 for applicable diode qualifications and screen requirements. Contact VMI for additional details on test capability and parameters.