1200-V Zero Recovery® Rectifiers

Qualification Report

Summary

This report documents the qualification and reliability test results for the Cree 1200-V Schottky diode product families. This report also describes the test methods and criteria used the testing process.

This report certifies that Schottky diode die manufactured at Cree, Inc., Durham, North Carolina, USA, which are voltage breakdown rated at 1200 V, current rated at or below 20 A and are fabricated using nominally 100-mm (or smaller) SiC substrates manufactured by Cree, Inc., Furthermore, this report certifies that product families using 1200-V SiC Schottky diode die assembled in TO-220 and TO-247 package styles are styles are qualified products.

In total, 2,358 devices were evaluated in a variety of qualification stress tests across the various current ratings and package styles available for the 1200-V Schottky Diode product line. Of the devices tested, there were zero failures during qualification testing. Analysis of field data collected to date shows an estimated FIT value of 3.2 to 6.1 failures per billion device hours, representing a total of over 600 million device hours (power-on hours) for Cree Schottky diode products in the field.

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Qualification Test Plan

The product qualification test plan is outlined in Table 1. This plan is based on the guidelines of JESD47B, *Stress-Test-Driven Qualification of Integrated Circuits, Published by the Jedec Solid State Technology Association,* and AEC-Q101-REV-C, *Stress Test Qualification for Automotive Grade Discrete Semiconductors,* Published by the Automotive Electronics Council.

Table 1: 1200-V Schottky Diode Product Qualification Test Plan

(T_c = case temperature, T_j = junction temperature, V_{br}= breakdown voltage)

Test	Stress	Duration	Sample Size	Reference
Parametric Verification	Evaluate Data Sheet Specifications at 25ºC and 175ºC	N/A	3 lots x 25 devices (75 total)	AEC-Q101-REV-C
External Visual Inspection	Observe External Surfaces and Markings	N/A	All devices used for qualification	AEC-Q101-REV-C
Autoclave	Moisture, Thermal, Pressure 100%RH, 121ºC, 205kPa	96h	3 lots x 25 devices (75 total)	JESD22-A102-B Condition C
H3TRB	Bias, Moisture 100V 85C/85%RH	1000h	3 lots x 77 devices (231 total)	JESD22-A101-B
HTRB	Bias, Thermal 80% V_{br} T_c=175ºC	500h	3 lots x 77 devices (231 total)	AEC-Q101-REV-C
Temperature Cycle	Thermal, Mechanical -55ºC to 150ºC 1000 cycles	1 minute soak, 15ºC/min ramp rate 2 cycles per hour	3 lots x 77 devices (231 total)	JESD22-A104-B Condition H Soak mode 1
Intermittent Operating Life	Bias, Thermal ΔT_j(min) 100ºC	Product dependent*	3 lots x 77 devices (231 total)	JESD22-A105-C and AEC-Q101-C
ESD-HBM	Electric Field	5 cycles/terminal	1 lot, 30 devices (30 total)	AEC-Q101-001
ESD-CDM	Electric Field	5 cycles/terminal	1 lot, 30 devices (30 total)	AEC-Q101-005
ESD-MM	Electric Field	5 cycles/terminal	1 lot, 30 devices (30 total)	AEC-Q101-002

*Duration and number of cycles is product dependent, as described in AEC-Q101-REV-C and Table 4 of this document.

Sampling Plan

Random sampling procedures are used to select devices to be evaluated in the various product qualification tests on Table 1. Sample size meets or exceeds the recommendations of standards JESD47B and AEC-Q101-REV-C for qualification of a product family where generic data may be used. For component-specific qualifications, the three-lot sample size (where specified in Table 1) is reduced to one lot.

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Failure Criteria

A device failure is defined as a condition in which a stressed device can no longer meet its data sheet specifications or has consequential external physical damage attributable to an environmental test.

A determination of root cause will be made immediately for any failure found. If the root cause of failure is mishandling, test-equipment failure, or a data-acquisition failure, the failing devices will be removed from the test and not counted as a qualification failure. If time constraints regarding test suspension are not violated, the qualification test will resume with the remaining devices so long as the total number of remaining devices is at least 90% of the starting sample size (per lot).

A single failure that cannot be identified within the time constraint for a suspended test, or is identified as an inherent device failure, will constitute a qualification failure for the test at hand and noted in the final qualification report. Other qualification tests may proceed so long as their results are not likely to be significantly impacted by the corrective action required by the identified failure mode. This determination will be made by the reliability manager responsible for the product qualification.

Definition of a Qualification Family

A qualification family is defined as meeting all of the following criteria:

1. A single process technology (Schottky diode, MOSFET, p-n junction diode, BJT, JFET, etc.)
2. A single fab process (same design rules, process flow, number of masks and lithographic process, cell density, doping process and dopant type, epi process and thickness, substrate process and thickness, passivation material and thickness, oxidation process and thickness, front/back metal materials, thicknesses, and number of levels)
3. A single fab site
4. A single package assembly site
5. A single package type (TO-220, TO-247, TO-252, TO-263, etc.)
6. A single assembly process (leadframe base material, leadframe plating, die attach material and method, wirebond material and method, mold compound or other encapsulation material)

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Summary of Qualification Test Results

A summary of qualification test results is provided for easy reference. Additional details of the tests are given in the subsequent section.

Table 2a: Parametric Verification Results C2D10120A at 25ºC

TEST NAME	UNIT	SPEC LSL	SPEC USL	MIN	MAX	MEAN	STD.DEV.	CPK
VF (Rated Current)	V		1.8	1.4	1.7	1.5	0.04	2.47
IR at 1200 V	µA		200	2.5	55.0	28.3	15.4	3.66
VBR at 200 µA	V	1200		1475	1960	1754	55	3.31

Table 2b: Parametric Verification Results C2D10120A at 175ºC

TEST NAME	UNIT	SPEC LSL	SPEC USL	MIN	MAX	MEAN	STD.DEV.	CPK
VF (Rated Current)	V		3.0	2.4	2.8	2.6	0.06	2.19
IR at 1200 V	µA		1000	9.5	142.0	96.3	33.8	8.80
VBR at 200 µA	V	1200		1392	1805	1598	78	1.68

Table 3: Environmental and Operational Test Results

Test #	TEST DESCRIPTION	TEST CONDITIONS	LOTS	TESTED	FAILED
1	External Visual	Per spec	6	2358	0
2	HTRB	Ta = @175ºC, 960 V	6	462	0
3	Thermal Cycling	T_low = -55ºC, T_high = 150ºC	6	462	0
4	Autoclave	Ta = 121ºC, P = 205 kPa, RH = 100%	6	150	0
5	H3TRB	Ta = 85ºC, 85% RH, 100 V	6	462	0
6	IOL	T on/off = see Table 4	6	462	0
7	DPA	Per spec	6	12	0

Table 4: ESD Test Results at 25ºC, 60% RH

ESD CLASSIFICATION			
Product	**HBM**	**MM**	**CDM (FIC*)**
C2D10120A	3B (>8 kV)	C (>400 V)	IV (>1000 V)
C2D05120A	3B (>8 kV)	C (>400 V)	IV (>1000 V)
C2D10120D	3B (>8 kV)	C (>400 V)	IV (>1000 V)
C2D20120D	3B (>8 kV)	C (>400 V)	IV (>1000 V)

*** Field-induced charge method**

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Detailed Qualification Test Descriptions and Results

The following tests are implemented according to the Cree Schottky Diode Product Qualification Plan. Please refer to Table 1 for specific test conditions.

Parametric Verification
Parametric verification (PV) is used to evaluate whether the devices tested meet performance specifications as listed on the product data sheet. The process capability index (C_{pk}) is calculated to determine whether the total variation in the process meets customer quality requirements.

Table 2a: Parametric Verification Results C2D10120A at 25ºC

TEST NAME	UNIT	SPEC LSL	SPEC USL	MIN	MAX	MEAN	STD.DEV.	CPK
VF (Rated Current)	V		1.8	1.4	1.7	1.5	0.04	2.47
IR at 1200 V	µA		200	2.5	55.0	28.3	15.4	3.66
VBR at 200 µA	V	1200		1475	1960	1754	55	3.31

Table 2b: Parametric Verification Results C2D10120A at 175ºC

TEST NAME	UNIT	SPEC LSL	SPEC USL	MIN	MAX	MEAN	STD.DEV.	CPK
VF (Rated Current)	V		3.0	2.4	2.8	2.6	0.06	2.19
IR at 1200 V	µA		1000	9.5	142.0	96.3	33.8	8.80
VBR at 200 µA	V	1200		1392	1805	1598	78	1.68

A C_{pk} of 1.33 (or above) is considered indicative of a process that is statistically well in control. C_{pk} values shown are for the largest current-rated single-die device in the product family. Values for specific products are available upon request.

External Visual
External visual (EV) inspection is used to identify external defects associated with the device package. Markings, construction and workmanship are evaluated with the unaided eye or with up to a 30X magnification, as appropriate for the device feature under inspection.

No visual anomalies were observed during external visual inspection on any of the die used for qualification.

Autoclave
Autoclave testing is used to evaluate the moisture resistance of non-hermetic packaged devices. The device under test (DUT) is unbiased. Autoclave testing is used to identify failure mechanisms internal to the package, such as delamination and corrosion.

External inspection detected no defects after autoclave stressing. No internal defects were observed during destructive physical analysis (DPA). No electrical failures were observed.

H3TRB
High-humidity, high-temperature reverse bias (H3TRB) testing is used to evaluate the reliability of the DUT in humid environments. The DUT is biased at 100 V. H3TRB is designed to accelerate moisture-related failure modes, including internal corrosion, internal oxidation and dendritic growth.

External inspection detected no defects after H3TRB stressing. No internal defects were observed during DPA. No electrical failures were observed.

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HTRB
High-temperature reverse bias (HTRB) testing is used to determine the breakdown robustness of devices under high field and temperature conditions. For 1200 V products, the DUT is biased at 80% of its maximum operating static DC field conditions at a flange temperature equal to its maximum static DC forward-operating junction temperature. HTRB is designed to hasten field-accelerated failure modes and early-life failures due to fabrication errors.

External inspection detected no defects after HTRB stressing. No internal defects were observed during DPA. No electrical failures were observed.

Temperature Cycle
Temperature cycling is used to determine the robustness of devices and interconnects when exposed to alternating high- and low-temperature extremes. The DUT is unbiased. Temperature cycling is used to identify failure modes that result from coefficient of thermal expansion (CTE) mismatch between materials and similar thermo-mechanical phenomena.

External inspection detected no defects after temperature-cycle stressing. No internal defects were observed during DPA. No electrical failures were observed.

Intermittent Operating Life
Intermittent operating life (IOL) testing is designed to hasten thermally accelerated failure modes (under bias) and early-life failures due to CTE mismatch and assembly defects. The DUT is switched from forward bias to zero bias in specific time intervals to achieve a change in junction temperature (T_J) of 100°C or greater. Table 5 details the time intervals to be used.

Table 5: IOL Test Conditions

Package Type	Number of cycles (change in T_j greater than or equal to 100oC)	Number of cycles (change in T_j greater than or equal to 125oC)	Time per cycle (seconds)
Small (e.g., SMD SOTS)	15,000	7,500	120 on / 120 off
Medium (e.g., TO-220)	8,572	4,286	210 on / 210 off
Large (e.g., TO-247)	6,000	3,000	300 on / 300 off

External inspection detected no defects after IOL stressing. No internal defects were observed during DPA. No electrical failures were observed**.**

ESD-HBM
Electrostatic discharge (ESD) – human body model (HBM) testing is used to determine the electrostatic discharge threshold above which damage occurs in the device under test. HBM is meant to simulate an ESD event that occurs when a human body acquires charge and transfers that charge to a device during manual device handling or assembly. A standardized circuit is used to apply a specified waveform to the device, and the results dictate an ESD-HBM classification.

All Cree Schottky diode products meet the following HBM classifications: AECQ101-001/ANSI ESD-STM5.1 Classification 3B (>8000 V), JEDEC/EIA JESD22 A114-D Classification 3B (>8000 V).

ESD-CDM
Electrostatic discharge (ESD) – charged device model (CDM) testing is used to determine the electrostatic discharge threshold above which damage occurs in the device under test. CDM is meant to simulate an ESD event that occurs when triboelectric charge transfers to a device during manual device handling, assembly or product packaging. A standardized circuit is used to apply a specified waveform to the device, and the results dictate an ESD-CDM classification.

All Cree Schottky diode products meet the following CDM classifications: ANSI ESD-DS5.3 Classification C5 (>1000 V), JEDEC/EIA JESD22 C101-C Classification IV (>1000 V).

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ESD-MM
Electrostatic discharge (ESD) – machine model (MM) testing is used to determine the electrostatic discharge threshold above which damage occurs in the device under test. MM is meant to simulate an ESD event that occurs when an object transfers a charge to a device through a very low resistance path. A standardized circuit is used to apply a specified waveform to the device, and the results dictate an ESD-MM classification.

All Cree Schottky diode products meet the following MM classifications: AECQ101-002/ANSI ESD-S5.2 Classification M4 (>400 V), JEDEC/EIA JESD22 A115-A Classification C (>400 V).

DHTRB
Dynamic HTRB (DHTRB) stresses the part in the same manner as HTRB, but the bias is switched from 100% of rated reverse bias to zero at 10.4kHz and a 50% duty cycle. The purpose of DHTRB is to accelerate failures driven by the increased leakage current that is present under transient conditions. To further accelerate the test, DHTRB is performed at 200ºC to maximize thermally generated leakage. DHTRB is not included in the qualification test plan since it is not a standardized test. However, the results are mentioned here for completeness. Four hundred and sixty-two samples were used for DHTRB testing.

External inspection detected no defects after 1000-hour DHTRB stressing. No internal defects were observed during DPA. No electrical failures were observed.

Field Reliability and Failure Rate

Historically, Cree's 1200-V Schottky diode technology has demonstrated a high level of field reliability, as shown in Table 6. FIT is a statistical estimate of non-wearout failure rate and is expressed in "failures per billion device hours."

Table 6: Historical Cree SiC Schottky Diode Performance

FIELD FAILURE RATE DATA		
Product	**Cumulative Device Hours 6×10^8**	**FIT**
C2D10120		6.1
C2D05120		3.2
Total		3.8

The assumptions made in calculating the FIT value are as follows: Product is in the field 60 days from the shipment received, the product operates continuously for 12 hours per day, and 50% of field failures are reported to Cree. Table 6 represents the FIT value of single die assembled either in a TO-220-2 (single-die "A" product) or TO-247-3 (dual-die "D" product)-style package.

Conclusion

Cree 1200-V Schottky diode products were selected and tested as described in this report. The devices tested met all electrical performance requirements, and no failures were observed in any qualification test. Based on these results, Cree 1200-V Schottky diode products C2D05120A, C2D10120A, C2D10120D and C2D20120D are certified* as qualified product according to Cree's internal requirements.

* This report and its conclusions do not imply any guarantee, warranty, or suitability for any purpose regarding the products mentioned. Results represent the particular devices tested, which were randomly selected according to the sampling plan described herein.

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