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Cree *Z-Rec*™ 1200V Qualification Report

Summary

This report documents the technology and product qualification and reliability test results for the 1200 V breakdown rated Z Rec™ Schottky diode products. The die are fabricated on silicon carbide (SiC) substrates, nominally 100 mm or smaller, at Cree, Inc., Durham, North Carolina, USA. This qualification covers packaged products rated up to 10 Amps with TO-252-2, 20 Amps with TO-220-2, and 40 Amps with TO-247-3 assembly, as well as die products rated up to 20 A. Zero device failures were observed out of a total of 781 devices evaluated in a variety of qualification and reliability stress tests. Zero failures were observed up to the maximum recommended levels for ESD-HBM, ESD-MM, and ESD-CDM, which results in the highest ESD rating classifications for all three test methodologies. The results qualify the products for volume manufacturing for applications with junction temperature up to 175 °C and case temperature up to 135 °C.

Product	Description
C4D02120E	2A 1200V ZREC SiC Schottky diode in TO-252-2
C4D05120E	5A 1200V ZREC SiC Schottky diode in TO-252-2
C4D08120E	7.5A 1200V ZREC SiC Schottky diode in TO-252-2
C4D10120E	10A 1200V ZREC SiC Schottky diode in TO-252-2
C4D02120A	2A 1200V ZREC SiC Schottky diode in TO-220-2
C4D05120A	5A 1200V ZREC SiC Schottky diode in TO-220-2
C4D08120A	7.5A 1200V ZREC SiC Schottky diode in TO-220-2
C4D10120A	10A 1200V ZREC SiC Schottky diode in TO-220-2
C4D10120D	2x5A 1200V ZREC SiC Schottky diode in TO-247-3
C4D15120A	15A 1200V ZREC SiC Schottky diode in TO-220-2
C4D20120A	20A 1200V ZREC SiC Schottky diode in TO-220-2
C4D20120D	2x10A 1200V ZREC SiC Schottky diode in TO-247-3
C4D30120D	2x15A 1200V ZREC SiC Schottky diode in TO-247-3
C4D40120D	2x20A 1200V ZREC SiC Schottky diode in TO-247-3
CPW4-1200-S002B	2A, 1200V ZREC Schottky die (Al/Ag)
CPW4-1200-S005B	5A, 1200V ZREC Schottky die (Al/Ag)
CPW4-1200-S008B	7.5A, 1200V ZREC Schottky die (Al/Ag)
CPW4-1200-S010B	10A, 1200V ZREC Schottky die (Al/Ag)
CPW4-1200-S015B	15A, 1200V ZREC Schottky die (Al/Ag)
CPW4-1200-S020B	20A, 1200V ZREC Schottky die (Al/Ag)

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Qualification Plan

Test Descriptions

Parametric Verification (PV)
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 is a statistical measure of the capability of the process to produce devices within the specification limits.

External Visual (EV)
EV will utilize and automated, high-power visual inspection tool to identify external defects associated with the chip.

High Humidity, High Temperature Reverse Bias (H3TRB)
H3TRB testing is used to evaluate resistance to Galvanic, electrochemical and direct corrosion, as well as ionic migration, in a high moisture and temperature environment as well as high electric field.

High Temperature Reverse Bias (HTRB)
HTRB testing is used to evaluate reliability under high electric field and temperature.

Temperature Cycle (TC)
TC will accelerate damage caused by thermal-mechanical stress as a result of thermal mismatch and dimensional differences.

Intermittent Operating Life (IOL)
IOL testing is designed to evaluate resistance to damage caused by thermal-mechanical stress as a result of thermal mismatch associated with local thermal gradients within the chip caused by internal power dissipation.

Electrostatic Discharge (ESD)
ESD ratings are established for human body model (HBM), machine model (MM) and charged device model (CDM).

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Test Plan

The product qualification test plan outlined Table 1 is based on the guidelines of AEC-Q101, Stress Test Qualification for Automotive Grade Semiconductors, and references therein. For the die technology qualification and TO-220-2 product family qualification, die are to be randomly sampled from two wafer lots and assembled in TO-220-2 packages. For the TO-247-3 and TO-252-2 product family qualifications, devices are to be randomly sampled from three assembly lots.

Table 1: Qualification Test Plan for die technology qualification and TO-220-2 product family qualification

Test	Sample Size per Lot	# of Lots	Stress Conditions	Acceptance Criterion
PV	15	2	n/a	Cpu ≥ 1.33 (4 σ)
EV	All devices used for qualification	2	n/a	Pass inspection criteria
H3TRB	75	2	1000 hours at 85 °C, 85% RH with device reverse biased at 100 V	0 fail
HTRB	75	3	1000 hours at 130 °C with device reverse biased to 960 V (80% of max)	0 fail
TC	25	2	1000 cycles, -55 °C to 130 °C, 5 minute dwell time	0 fail
IOL	25	2	8572 cycles, 3.5 minutes on / 3.5 minutes off*, ΔTj ≥ 100 °C	0 fail
ESD-HBM	3	1	Ramp per AEC-Q101	Characterization
ESD-MM	3	1	Ramp per AEC-Q101	Characterization
ESD-CDM	3	1	Ramp per AEC-Q101	Characterization

Table 2: Qualification Test Plan for TO-247-3 product family qualification

Test	Sample Size per Lot	# of Lots	Stress Conditions	Acceptance Criterion
EV	All devices used for qualification	3	n/a	Pass inspection criteria
HTRB	25	3	1000 hours at 130 °C with device reverse biased to 960 V (80% of max)	0 fail
TC	25	1	1000 cycles, -55 °C to 130 °C, 5 minute dwell time	0 fail; this test was run as a confirmation; die qualified by similarity to Z-Rec in TO-220; package qualified by similarity to C2D10120A
IOL	25	3	8572 cycles, 3.5 minutes on / 3.5 minutes off*, ΔTj ≥ 100 °C	0 fail

PV and ESD: die qualified by similarity to Z-Rec in TO-220. H3TRB: die qualified by similarity to Z-Rec in TO-220; package qualified by similarity to C2D10120A.

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Table 3: Qualification Test Plan for TO-252-2 product family qualification

Test	Sample Size per Lot	# of Lots	Stress Conditions	Acceptance Criterion
EV	All devices used for qualification	3	n/a	Pass inspection criteria
HTRB	25	3	1000 hours at 130 °C with device reverse biased to 960 V (80% of max)	0 fail
TC	25	1	1000 cycles, -55 °C to 130 °C, 5 minute dwell time	0 fail; this test was run as a confirmation; die qualified by similarity to Z-Rec in TO-220; package qualified by similarity to C2D10120A
IOL	25	3	8572 cycles, 3.5 minutes on / 3.5 minutes off*, $\Delta T_j \geq 100$ °C	0 fail

PV and ESD: die qualified by similarity to Z-Rec in TO-220.
H3TRB: die qualified by similarity to Z-Rec in TO-220; package qualified by similarity to C2D05120E.
TC: die qualified by similarity to Z-Rec in TO-220; package qualified by similarity to C2D05120E.

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Device Failure Criteria

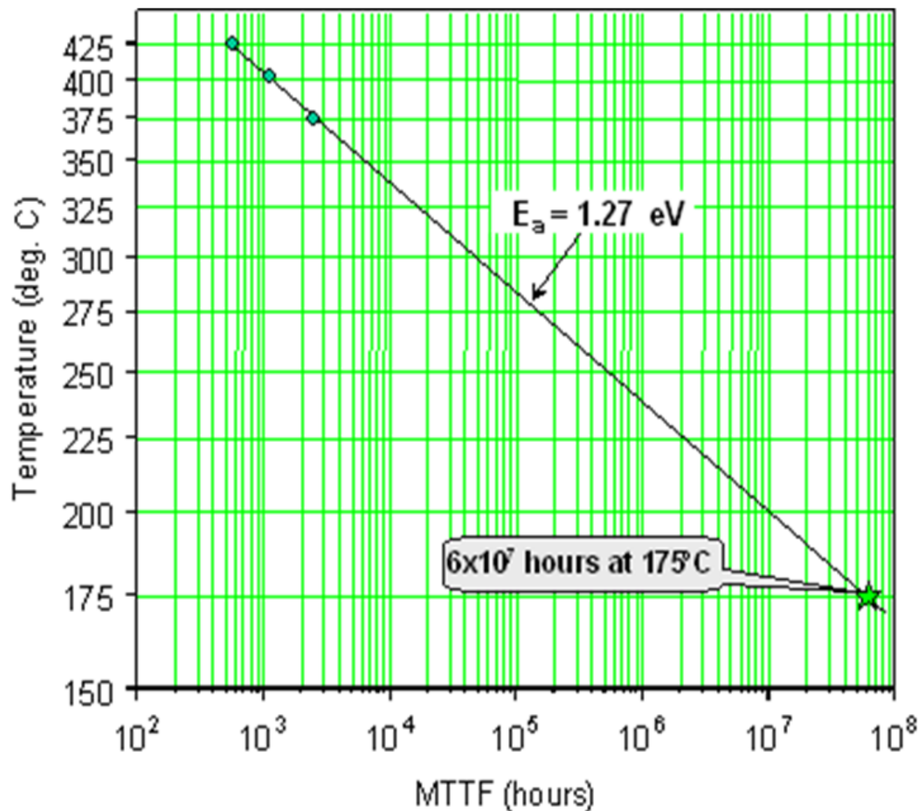
A device failure is defined as a condition in which a stressed device can no longer meet its data sheet specifications, or has consequential external physical damage attributable to an environmental test.

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.

Intrinsic Reliability

The intrinsic reliability performance is qualified by similarity to previously qualified SiC MESFETs. Previous studies on the SiC MESFETs have shown that the wear-out intrinsic reliability failure mechanism is Ohmic contact degradation under high current and temperature conditions. The Cree SiC Schottky diodes all utilize the same Ohmic contact structures as the SiC MESFETs. Accelerated life testing of Ohmic test structures resulted in an activation energy of 1.27 eV and intrinsic lifetime projection of 6x107 hours (60% lower confidence limit = 4.3 x107 hours) for continuous operation under forward bias at the maximum junction temperature of 175oC, as shown in the figure below.



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Results

Parametric Verification

The tables below show the results of parametric verification testing. The resulting capability indices all meet or exceed the target value of 1.33, indicating a capable process.

Table 4: Parametric Verification Results C4D20120A at 25ºC

TEST NAME	UNIT	SPEC LSL	SPEC USL	MIN	MAX	MEAN	STD.DEV.	CPK
VF (Rated Current)	V	NA	1.8	1.52	1.66	1.60	0.03	2.28
IR at 1200 V	µA	NA	200	5	75	13	1	4.69
VBR at 500 µA	V	1350	NA	1560	1710	1640	41	2.36

Table 5: Parametric Verification Results C4D20120A at 175ºC

TEST NAME	UNIT	SPEC LSL	SPEC USL	MIN	MAX	MEAN	STD.DEV.	CPU/CPL
VF (Rated Current)	V	NA	2.8	1.87	2.28	2.17	0.07	2.91
IR at 1200 V	µA	NA	400	43	320	105	63	1.57
VBR at 10 µA	V	1350	NA	1680	1810	1750	38	3.53

External Visual

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

Reliability

Table 5 and Table 6 show the results of the reliability testing. Zero failures were observed for all electrical and environmental stress tests conducted. Zero failures were observed up to the maximum recommended levels for ESD-HBM, ESD-MM, and ESD-CDM, which results in the highest ESD rating classifications for all three test methodologies.

Table 6: Reliability results for die technology qualification and TO-220-2 product family qualification

Stress	Failures/# tested	Result
H3TRB	0/150	Pass
HTRB	0/225	Pass
TC	0/50	Pass
IOL	0/50	Pass
ESD-HBM	0/3	Class 3B (>8000V)
ESD-MM	0/3	Class C (≥400V)
ESD-CDM	0/3	Class IV (≥1000V)

Table 7: Reliability results for TO-247-3 product family qualification

Stress	Failures/# tested	Result
HTRB	0/75	Pass
TC	0/25	Pass
IOL	0/75	Pass

ESD: die qualified by similarity to Z-Rec in TO-220.
H3TRB: die qualified by similarity to Z-Rec in TO-220; package qualified by similarity to C2D10120A.

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Table 8: Reliability results for TO-252-2 product family qualification

Stress	Failures/# tested	Result
HTRB	0/75	Pass
TC	0/25	Pass
IOL	0/75	Pass

Conclusion

The 1200 V breakdown rated Z Rec™ Schottky diode products are qualified for volume manufacturing, as a result of parametric verification, external visual inspection, and zero failures out of the qualification plan for electrical and environmental reliability and ESD stress. The results qualify the following products for volume manufacturing for applications with junction temperature up to 175 °C and case temperature up to 130 °C, with the highest available ESD ratings:

Product	Description
C4D02120E	2A 1200V ZREC SiC Schottky diode in TO-252-2
C4D05120E	5A 1200V ZREC SiC Schottky diode in TO-252-2
C4D08120E	7.5A 1200V ZREC SiC Schottky diode in TO-252-2
C4D10120E	10A 1200V ZREC SiC Schottky diode in TO-252-2
C4D02120A	2A 1200V ZREC SiC Schottky diode in TO-220-2
C4D05120A	5A 1200V ZREC SiC Schottky diode in TO-220-2
C4D08120A	7.5A 1200V ZREC SiC Schottky diode in TO-220-2
C4D10120A	10A 1200V ZREC SiC Schottky diode in TO-220-2
C4D10120D	2x5A 1200V ZREC SiC Schottky diode in TO-247-3
C4D15120A	15A 1200V ZREC SiC Schottky diode in TO-220-2
C4D20120A	20A 1200V ZREC SiC Schottky diode in TO-220-2
C4D20120D	2x10A 1200V ZREC SiC Schottky diode in TO-247-3
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