Hestia-Power 650V Silicon Carbide Schottky Barrier Diode Qualification Report

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Introduction

The qualification test report is about Hestia-Power 650V silicon carbide (SiC) Schottky barrier diode (TO-252 family) including part number H2S060S010 H2S060S008, H2S060S006, H2S060S004, H2S060S002 (TO-252-2L), and part number H2S060K010, H2S060K008, H2S060K006, H2S060K004, H2S060K002 (TO-252-2L-1NC). Due to the same assembly material and process of TO-252-2L and TO-252-2L-1NC, TO-252-2L is selected for the qualification test. For part number H2S060S010 and H2S060K010, both are fabricated by the same rating chip of part number H2S060H010 which are qualified in Hestia-Power 650V H-Series (TO-220 family) qualification report [1]. Therefore, they can be regarded as qualified bare-die products. The purpose of this qualification is to extend the product portfolio to surface-mount TO-252 packages. All qualification test methods and criteria are performed based on JEDEC Standards [3-7] or AEC-Q101 [2]. Before and after each qualification test, parameter verification is implemented as a minimum.

Failure Criteria

A device failure is defined as the device does not satisfy the specifications of its data sheet or exhibit external damage attributed to the environment test.

Definition of a Qualification Family

A qualification family is defined as meeting the following criteria based on AEC-Q101:

1. The same process technology.
2. The same fab site and fab process such as epi process and thickness, design rules, process flow, lithographic process, cell density, doping process, passivation process, front/back metal materials and thickness, and so on.
3. The same package assembly site and the same package type.
4. The same assembly process such as leadframe base material, die attach material and method, wirebond material , mold compound material, and so on.

Qualification Test Item

The qualification test item of Hestia-Power 650V SiC Schottky barrier diode with TO-252-2L package is outlined in Table 1

Table 1：Hestia-Power 650V SiC Schottky Barrier Diode Qualification Test Item

Test Item	Test Condition	Reference
Parameter Verification	Evaluate Data Sheet Specifications	AEC-Q101-C
External Visual Inspection	Observe External Surfaces	AEC-Q101-C
Pre-condition MSL 3	TC 5cycles, Bake 125℃/24hr, Soak 30℃/60%RH/192hr, IR Reflow Temperature=260℃, 3cycles	JESD22-A113
Autoclave	T_a=121℃, 100%RH, 2atm, 96hr	JESD22-A102
Temperature Cycle	-65℃ to 150℃, 1000cycles	JESD22-A104
H3TRB	V_R=100V, T_a=85℃, 85%RH, 1000hr	JESD22-A101
Temperature Humidity Test	T_a=85℃, 85%RH, 1000hr	JESD22-A101
HTRB	V_R=600V, T_a=175℃, 500hr	JESD22-A108
Intermittent Operating Life	ΔT_j>100℃, 15000cycles	MIL-STD-750 Method 1037
ESD-HBM	8000V	AEC-Q101-001
ESD-MM	400V	AEC-Q101-002
ESD-CDM	1000V	AEC-Q101-005

(V_R = reverse bias, T_a = ambient temperature, T_j = junction temperature)

Note : HTRB is stressed at 600V which is higher than 80% of 650V rating voltage.
The qualification condition meets the industrial grade criteria.

Qualification Test Description and Result

Parameter Verification (PV)

Parameter Verification is implemented to evaluate whether the devices is failure after each qualification test. According to AEC-Q101-REV-C, for diodes, there are minimum parameters which must be verified such as forward voltage (Vf), breakdown voltage (Vbd), and leakage current (Ir).

The parameter verification result of Hestia-Power 650V SiC Schottky barrier diode is outlined in Table 2.

Table 2：Hestia-Power 650V SiC Schottky Barrier Diode Parameter Verification Result

Device	Test Condition	Lot Size	Total Sample Size	Failed Size	Result
H2S060S008	Evaluate Data Sheet Specifications	1	240	0	PASS
H2S060S006	Evaluate Data Sheet Specifications	1	240	0	PASS
H2S060S004	Evaluate Data Sheet Specifications	1	240	0	PASS
H2S060S002	Evaluate Data Sheet Specifications	1	423	0	PASS

External Visual (EV)

External Visual is used to evaluate whether the device package has external physical damage during the qualification tests. No visual defects were found after each qualification test.

The external visual result of Hestia-Power 650V SiC Schottky barrier diode is outlined in Table 3.

Table 3：Hestia-Power 650V SiC Schottky Barrier Diode External Visual Result

Device	Test Condition	Lot Size	Total Sample Size	Failed Size	Result
H2S060S008	Observe External Surfaces	1	240	0	PASS
H2S060S006	Observe External Surfaces	1	240	0	PASS
H2S060S004	Observe External Surfaces	1	240	0	PASS
H2S060S002	Observe External Surfaces	1	423	0	PASS

Pre-condition MSL 3

Moisture Sensitive Level (MSL) testing is performed to categorized non-hermetic packaged devices based on sensitivity to damage during IR reflow operations. During IR reflowing process, thermal stress moisture inside the package will increase and lead to failure. MSL testing applies to Surface Mount Devices (SMD) such as TO-252 and TO-263.

The precondition MSL 3 result of Hestia-Power 650V SiC Schottky barrier diode is outlined in Table 4

Table 4：Hestia-Power 650V SiC Schottky Barrier Diode Precondition MSL 3 Result

Device	Test Condition	Lot Size	Total Sample Size	Failed Size	Result
H2S060S008	TC 5cycles, Bake 125℃/24hr, Soak 30℃/60%RH/192hr, IR Reflow Temperature=260℃, 3cycles	1	150	0	PASS
H2S060S006	TC 5cycles, Bake 125℃/24hr, Soak 30℃/60%RH/192hr, IR Reflow Temperature=260℃, 3cycles	1	150	0	PASS
H2S060S004	TC 5cycles, Bake 125℃/24hr, Soak 30℃/60%RH/192hr, IR Reflow Temperature=260℃, 3cycles	1	150	0	PASS
H2S060S002	TC 5cycles, Bake 125℃/24hr, Soak 30℃/60%RH/192hr, IR Reflow Temperature=260℃, 3cycles	1	333	0	PASS

Autoclave (AC)

Autoclave testing is used to determine the moisture resistance of non-hermetic packaged device. The device is subjected to highly humid atmosphere under pressure to force moisture into package. If there are weaknesses such as delamination and metallization corrosion, moisture can penetrate through the protective layer and leads to qualification failure.

The autoclave result of Hestia-Power 650V SiC Schottky barrier diode is outlined in Table 5.

Table 5：Hestia-Power 650V SiC Schottky Barrier Diode Autoclave Result

Device	Test Condition	Lot Size	Total Sample Size	Failed Size	Result
H2S060S008	T_a=121℃, 100%RH, 2atm, 96hr	1	25	0	PASS
H2S060S006	T_a=121℃, 100%RH, 2atm, 96hr	1	25	0	PASS
H2S060S004	T_a=121℃, 100%RH, 2atm, 96hr	1	25	0	PASS
H2S060S002	T_a=121℃, 100%RH, 2atm, 96hr	1	77	0	PASS

Temperature Cycle (TC)

Temperature Cycle testing is used to evaluate the ability of devices and solder interconnects when mechanical stresses are induces by alternating low- and high-temperature cycles. The coefficient of thermal expansion (CTE) mismatch between materials results in mechanical stresses and permanent changes in electrical and/or physical characteristics.

The temperature cycle result of Hestia-Power 650V SiC Schottky barrier diode is outlined in Table 6.

Table 6：Hestia-Power 650V SiC Schottky Barrier Diode Temperature Cycle Result

Device	Test Condition	Lot Size	Total Sample Size	Failed Size	Result
H2S060S008	-65℃ to 150℃, 1000cycles	1	25	0	PASS
H2S060S006	-65℃ to 150℃, 1000cycles	1	25	0	PASS
H2S060S004	-65℃ to 150℃, 1000cycles	1	25	0	PASS
H2S060S002	-65℃ to 150℃, 1000cycles	1	77	0	PASS

H3TRB/ Temperature Humidity Test (THT)

Temperature Humidity Test testing is performed to determine the reliability of non-hermetic packaged device in humid environments. Temperature and humidity are applied to accelerate the penetration of moisture through the external protective material and lead to moisture-related failure.

The H3TRB/THT result of Hestia-Power 650V SiC Schottky barrier diode is outlined in Table 7.

Table 7：Hestia-Power 650V SiC Schottky Barrier Diode H3TRB/THT Result

Device	Test Condition	Lot Size	Total Sample Size	Failed Size	Result
H2S060S008	T_a=85℃, 85%RH, 1000hr	1	25	0	PASS
	V_R=100V, T_a=85℃, 85%RH, 1000hr	1	25	0	PASS
H2S060S006	T_a=85℃, 85%RH, 1000hr	1	25	0	PASS
	V_R=100V, T_a=85℃, 85%RH, 1000hr	1	25	0	PASS
H2S060S004	T_a=85℃, 85%RH, 1000hr	1	25	0	PASS
	V_R=100V, T_a=85℃, 85%RH, 1000hr	1	25	0	PASS
H2S060S002	V_R=100V, T_a=85℃, 85%RH, 1000hr	1	77	0	PASS

HTRB

High temperature reverse bias (HTRB) testing is designed to evaluate the breakdown robustness of devices under high temperature and high electric field. The test is biased at high voltage and high temperature so that it can result in early-life failure and field-accelerated failure.

The HTRB result of Hestia-Power 650V SiC Schottky barrier diode is outlined in Table 8.

Table 8：Hestia-Power 650V SiC Schottky Barrier Diode HTRB Result

Device	Test Condition	Lot Size	Total Sample Size	Failed Size	Result
H2S060S008	V_R=600V, T_a=175℃, 500hr	1	25	0	PASS
H2S060S006	V_R=600V, T_a=175℃, 500hr	1	25	0	PASS
H2S060S004	V_R=600V, T_a=175℃, 500hr	1	25	0	PASS
H2S060S002	V_R=600V, T_a=175℃, 500hr	1	77	0	PASS

Note : HTRB is stressed at 600V which is higher than 80% of 650V rating voltage.
The qualification condition meets the industrial grade criteria.

Intermittent Operating Life (IOL)

Intermittent Operating Life testing is used to accelerate the failure cause due to thermal mechanism. When the device is switched from zero bias to forward bias to achieve a variation in junction temperature (T_j) greater than 100℃, the coefficient of thermal expansion (CTE) mismatch between materials results in mechanical stresses and permanent changes in electrical and/or physical characteristics.

The intermittent operating life result of Hestia-Power 650V SiC Schottky barrier diode is outlined in Table 9.

Table 9：Hestia-Power 650V SiC Schottky Barrier Diode IOL Result

Device	Test Condition	Lot Size	Total Sample Size	Failed Size	Result
H2S060S008	ΔT_j>100℃, 15000cycles	1	25	0	PASS
H2S060S006	ΔT_j>100℃, 15000cycles	1	25	0	PASS
H2S060S004	ΔT_j>100℃, 15000cycles	1	25	0	PASS
H2S060S002	ΔT_j>100℃, 15000cycles	1	25	0	PASS

Electrostatic Discharge (ESD)

Electrostatic Discharge testing is implemented to evaluate the robustness of electrostatic charge accumulation. The source of electrostatic discharge is including of human body, robot arm, product packaging and so on.

Human Body Model (HBM)

Electrostatic Discharge - Human Body Model testing is used to simulate the electrostatic charge transfers from human body to devices through pin during manual device handling.

The ESD-HBM result of Hestia-Power 650V SiC Schottky barrier diode is outlined in Table. 10.

Table. 10：Hestia-Power 650V SiC Schottky Barrier Diode ESD-HBM Result

Device	Test Condition	Lot Size	Total Sample Size	Failed Size	Result
H2S060S008	8000V	1	30	0	PASS
H2S060S006	8000V	1	30	0	PASS
H2S060S004	8000V	1	30	0	PASS
H2S060S002	8000V	1	30	0	PASS

Machine Model (MM)

Electrostatic Discharge – Machine Model testing is used to simulate the electrostatic charge transfers from machine such as robot arm to devices. Due to machine usually made of metal, the electrostatic charge will through an extremely low resistance pass to devices.

The ESD-MM result of Hestia-Power 650V SiC Schottky barrier diode is outlined in Table. 11.

Table. 11：Hestia-Power 650V SiC Schottky Barrier Diode ESD-MM Result

Device	Test Condition	Lot Size	Total Sample Size	Failed Size	Result
H2S060S008	400V	1	30	0	PASS
H2S060S006	400V	1	30	0	PASS
H2S060S004	400V	1	30	0	PASS
H2S060S002	400V	1	30	0	PASS

Charged Device Model (CDM)

Electrostatic Discharge – Charged Device Model is used to simulate the electrostatic charge that accumulating in devices and discharge during manual device handling or pin grounding.

The ESD-CDM result of Hestia-Power 650V SiC Schottky barrier diode is outlined in Table. 12.

Table. 12：Hestia-Power 650V SiC Schottky Barrier Diode ESD-CDM Result

Device	Test Condition	Lot Size	Total Sample Size	Failed Size	Result
H2S060S008	1000V	1	30	0	PASS
H2S060S006	1000V	1	30	0	PASS
H2S060S004	1000V	1	30	0	PASS
H2S060S002	1000V	1	30	0	PASS

Conclusion

Hestia-Power 650V SiC Schottky barrier diode with TO-252-2L package and TO-252-2L-1NC package passed the qualification test based on JEDEC Standards or AEC-Q101. In total, 1143 devices were from 4 batches evaluated in reliability stress test. As a result, no failure sample was found. The qualification result of Hestia-Power 650V SiC Schottky barrier diode is done and summarized in Table 13.

Table 13：Hestia-Power 650V SiC Schottky Barrier Diode Qualification Result

Test Item	Lot Size	Total Sample Size	Failed Size	Result
Parameter Verification (PV)	4	1143	0	PASS
External Visual Inspection (EV)	4	1143	0	PASS
Precondition MSL 3	4	783	0	PASS
Autoclave (AC)	4	152	0	PASS
Temperature Cycle (TC)	4	152	0	PASS
H3TRB	4	152	0	PASS
Temperature Humidity Test (THT)	3	75	0	PASS
HTRB	4	152	0	PASS
Intermittent Operating Life (IOL)	4	100	0	PASS
ESD-HBM	4	120	0	PASS
ESD-MM	4	120	0	PASS
ESD-CDM	4	120	0	PASS

Reference

[1] Hestia-Power 650V Silicon Carbide Schottky Barrier Diode Qualification Report

[2] AEC-Q101-C Automotive Electronics Council Q101 REV C

[3] JESD22-A113 Preconditioning for Plastic Surface Mount Devices Prior to Reliability Testing

[4] JESD22-A101 Steady State Temperature Humidity Bias Life Test

[5] JESD22-A102 Accelerated Moisture Resistance – Unbiased Autoclave

[6] JESD22-A104 Temperature Cycling

[7] JESD22-A108 Temperature, Bias, and Operating Life

[8] MIL-STD-750 Military Standard 750