

SiC MOSFET(1200V): Inventchip Gen3 IV3Q12013T4Z Overview, Structure, Process and Electrical characteristics Analysis Reports



Package



Inventchip Gen3 SiC MOSFET die

Overview

Inventchip, a major Chinese SiC manufacturer, announced Gen1 SiC MOSFETs in 2019(*), Gen2 SiC MOSFETs in 2023, and Gen3 SiC MOSFETs in June 2024.

This Gen3 SiC MOSFET is a product that shows the progress of China's SiC technology, as it is the same RonxA as the major SiC manufacturers (Infineon, Wolfspeed, Rohm, STMicroelectronics).

In order to clarify the features of this product, we released the following three reports (1) Overview (2) Structure analysis (3) Process and electrical characteristic analysis.

Product features

(*)The Gen1 analysis report 21G-0033-3 is now on sale.

- Product type: IV3Q12013T4Z $V_{DS}=1200V$ $I_D=147A$ $R_{DS(on)}=13.5\text{ m}\Omega$
- Released: June 2024
- Automotive qualified (AEC-Q101)、Applications: EV Motor drivers、Solar MPPT and inverters

Report Contents/Overview of Results

(1) Overview Analysis Report (13 pages)

- Package observation, die observation, size measurement
- Cross-section: Die edge, cell array (Checking epi structure and film thickness)

(2) Structure Analysis Report (84 pages)

- Includes the contents of (1) the overview analysis report, TEM structure analysis of the cell array, and analysis of annealing marks on the backside of the die.
- We have revealed that there are concerns about the reliability of this product.

(3) Process and Electrical characteristics Analysis report (36 pages)

- The manufacturing process and photo/mask are estimated, and the manufacturing sequence details are shown.
- Comparison of RonxAA with the Gen1 and major manufacturers (It is comparable to STMicro' Gen3.)

Report price

Delivered one week after order placement

Please contact us for report pricing.

(1) Overview Analysis Report table of contents

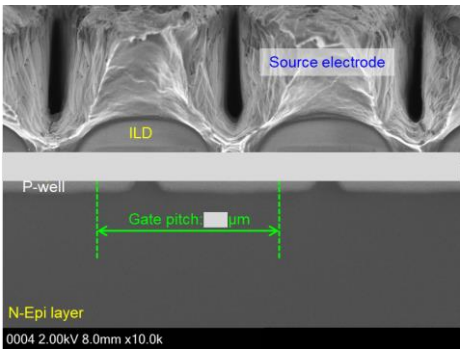
【Table of contents】		Page
1	Device summary	
	Table1-1: Device summary	... 3
1-1.	Summary of analysis results	... 4
	Table1-2: Device structure: SiC MOSFET	... 5
	Table1-3: Device structure: Layer materials and thicknesses	...
2	Package analysis	
2-1.	Appearance observation	... 7
3	SiC MOSFET die structure analysis	
3-1.	Plane structure analysis by Optical Microscope	... 9
3-2.	Cell array cross-sectional structure analysis	... 10
3-3.	Cross-sectional structure analysis of MOSFET die outer periphery	... 11
4	Comparison with Inventchip's 1200V Gen1 product and other manufacturer product	... 12

Excerpt from (1) Overview Analysis Report

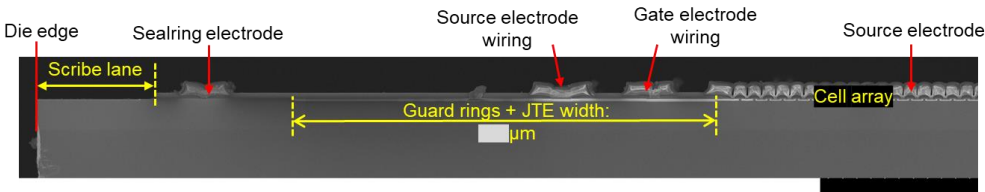
Table1-1: Device summary

Device	SiC MOSFET (VDSS=1200V, $R_{DS(on)}$ (Typ.) = 13.5m Ω (V_{GS} = 18V), I_D = 147A)
Manufacturer	Inventchip Technology Co., Ltd. (China)
Product name	IV3Q12013T4Z
Package type	TO-247-4
Package marking	3Q12013T4Z 2425S HA3H
Die configuration	Transistor: SiC MOSFET x1
Die size	5.0 mm x 5.0 mm = 25.0 mm ²
SiC MOSFET Die manufacturing process	SiC wafer, planer gate, top metal source
Feature	• •
Application	• EV Motor drivers • Solar MPPT and inverters • High Voltage DC/DC Converters • Switch mode power supplies

Device summary



Cross-sectional SEM image of cell array



Cross-sectional SEM image of die outer periphery

Table4-1: Comparison

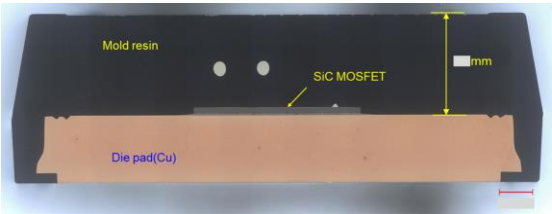
		IV1Q12080T3 (Gen1)	IV3Q12013T4Z (Gen3)	Wolf speed E4M0013120K (Gen4)
ON resistance: RON	(m Ω) / V_{GS} (V)	80 / 20	13.5 / 18	13 / 15
ON resistance per unit area RONxAA	m Ω ·mm ²			
Die size	mm x mm = mm ²			
Transistor active area AA	mm ²			

Comparison with Gen1 product and the major manufacturers products

(2) Structure Analysis Report table of contents

【Table of contents】		Page
1	Device summary	
	Table1-1: Device summary	... 3
1-1.	Summary of analysis results	... 4
	Table1-2: Device structure: SiC MOSFET	... 5
	Table1-3: Device structure: Layer materials and thicknesses	... 6
	Table1-4: Device structure: Package structure summary	... 7
2	Package analysis	
2-1.	Appearance observation	... 9
2-2.	Internal layout observation	... 11
2-3.	Package cross-sectional structure analysis	... 12
3	SiC MOSFET die structure analysis	
3-1.	Plane structure analysis by Optical Microscope	... 26
3-2.	Plane structure analysis by SEM	... 42
3-3.	Cell array cross-sectional structure analysis	... 50
3-4.	Cross-sectional structure analysis of MOSFET die outer periphery	... 57
3-5.	Cross-sectional structure analysis of Gate electrode pad	... 66
4	TEM structure analysis	... 70
5	SiC MOSFET die backside structure analysis (Analysis of annealing marks)	... 76
6	Comparison with Inventchip's 1200V Gen1 and Gen2 SiC MOSFET	... 80
7	Comparison with other manufacturers' SiC MOSFET	... 83

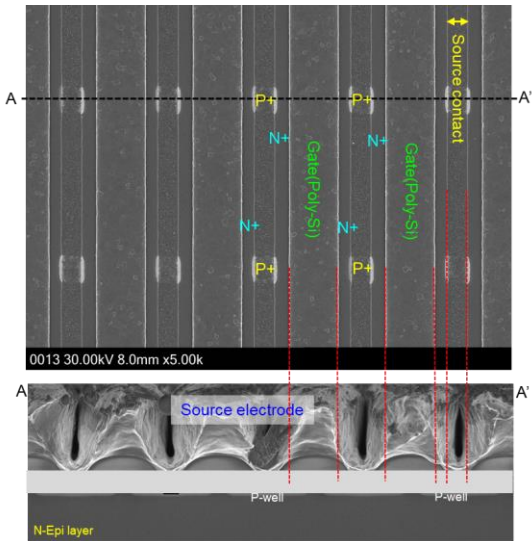
Excerpt from (2) Structure Analysis Report



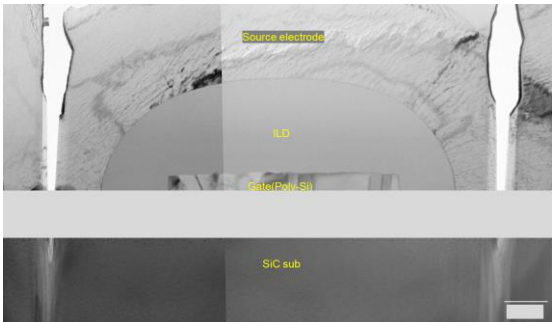
Package cross-sectional structure

番号	測定箇所	測長	材料
1	Mold resin		
2	Al wire		
2-1	Wire diameter : Gate		
2-2	Wire diameter : Source		
2-3	Wire average length		
3	SiC-MOSFET		
3-1	Surface protection film		
3-2	Top metal		
3-3	Substrate		
3-4	Backside metal-1		
3-5	Backside metal-2		
3-6	Backside metal-3		
4	Die attach		
5	Die pad		
5-1	Die pad		
5-2	Plating layer		

Package cross-sectional structure summary



Alignment of cell plane structure and cross-sectional structure



Cross-sectional TEM image of cell array

	IV1Q12080T3 (Gen1)	IV2Q12040T4Z (Gen2)	IV3Q12013T4Z (Gen3)
Epi layer thickness (μm)			
Cell pitch (μm)			
ILD shape			
P-well implantation depth (μm)			

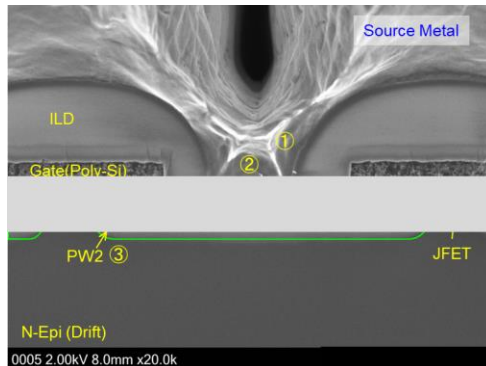
Comparison with previous generation products (Cell cross-sectional structure)

(3) Process and Electrical characteristics Analysis Report

table of contents

Contents	Page
1 INVENTCHIP's 3rd generation SiC-MOSFET IV3Q12013T4Z: Executive Summary	3
1-1. Comparison of characteristics between INVENTCHIP 1200V products and other companies' SiC-MOSFETs	4
1-2. SiC-MOSFET die	5
1-3. Die peripheral edge	6
1-4. Device structure: SiC-MOSFET	7
Transistor schematic cross-sectional view	7
2 SiC-MOSFET Observation	8
2-1. Structure analysis (SEM)	8
Transistor structure and process features (1) – (5)	8-12
2-2. Details of the self-aligned formation process to determine the MOSFET channel length Lch (estimated)	13
3 Summary of analysis results for INVENTCHIP's 3rd generation SiC-MOSFET IV3Q12013T4Z	14
Table 1 Device structure: SiC-MOSFET	14
Table 2 Device structure: Layer materials and film thicknesses	15
4 Manufacturing Process Flow Analysis	16
4-1. SiC-MOSFET front-end wafer process flow (estimated)	17
4-2. Cross-sectional view of the manufacturing process sequence	18-22
5 Electrical Characteristics Evaluation	23
5-1. INVENTCHIP IV3Q12013T4Z Id-Vds characteristics	24
5-2. OFF-state drain current vs drain voltage (Vds) as a function of temperature, and activation energy (Ea)	25
5-3. OFF-state breakdown voltage BVdss characteristics	26
5-4. Comparison of OFF-state drain leakage current characteristics	27
5-5. Gate leakage current Igss characteristics	28
5-6. Body diode characteristics	29
5-7. Ciss, Coss, Crss-Vds Capacitances	30
5-8. Device structure and electrical property analysis: ON resistance component analysis	31-33
5-9. N-epi (Drift) layer impurity concentration analysis	34
5-10. Device structure and electrical characterization: Breakdown voltage	35
6 References	36

Excerpt from (3) Process and Electrical characteristics Analysis Report

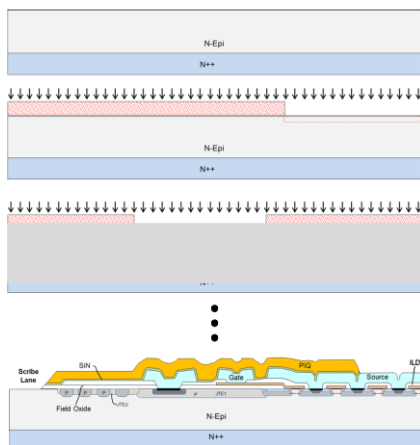


Transistor cell

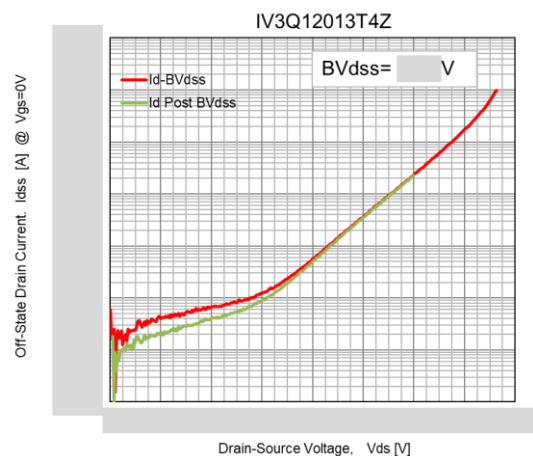
Possible Alignment Tree:



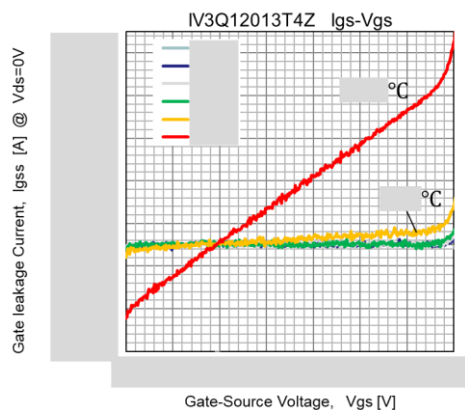
Alignment Tree



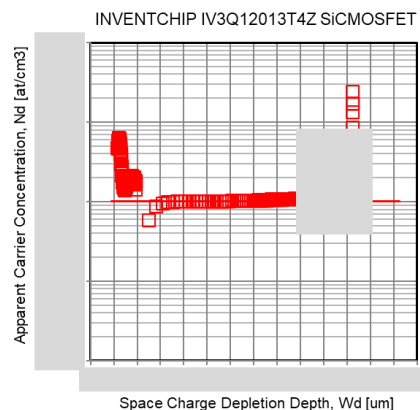
SiC MOSFET process sequence (estimated)



Off-state breakdown voltage BVdss



Gate leakage current vs. Gate-Source voltage



Carrier concentration profile in the depth direction