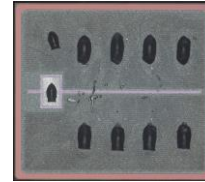


SiC MOSFET(1200V) : WOLFSPEED 4th Gen E4M0013120K Overview, Structure, and Process Analysis Reports



Package



SiC MOSFET

Overview

In June 2024, WOLFSPEED, the world's largest manufacturer of SiC wafers, released their 4th - generation 1200V SiC MOSFET. LTEC released three reports. (1) Die overview analysis, (2) Structural analysis of the die (including a comparison with 3rd-generation products), (3) Manufacturing process and electrical characteristics analysis report.

Product features * Contact LTEC for the structural analysis report (23G-0478-1) of the 3rd Generation product.

- Product number : E4M0013120K 1200V, 153A, 13m Ω Released: June 2024.
- Automotive qualified (AEC-Q101) and PPAP compliant
- Applications: Motor Control, EV Battery Chargers, High Voltage DC/DC Converters

Reports Contents/Overview of Results

1. Overview Analysis Report (11 pages)

- Observation of the package and die, and cross-section of the transistor cell and chip end.

2. Structure analysis Report (78 pages)

- The 4th Gen die size is 17% smaller than the 3rd Gen product having same Ron=13m Ω .
- As new feature, the transistor cell array (planar) of this product has a honeycomb structure.
- The contents of the 1. Overview analysis report are also included.

3. Process analysis Report (47 pages)

- The specific on-resistance (RonxAA) is compared with MOSFETs from major manufacturers (ROHM, INFINEON).
- The Ron components are quantitatively analyzed, and the effect of the new structure and layout (honeycomb) in reducing RonxAA and channel resistance component Rch is revealed.
- The manufacturing process and photo/mask are estimated, and comprehensive details of the manufacturing sequence are shown.
- The evolution of WOLFSPEED's technology and improvements from the 2nd to 4th generations are surveyed, and the company's development strategy can be inferred.

Please contact LTEC for delivery time and prices for optional SCM analysis.

Report price

Delivered one week after order placement

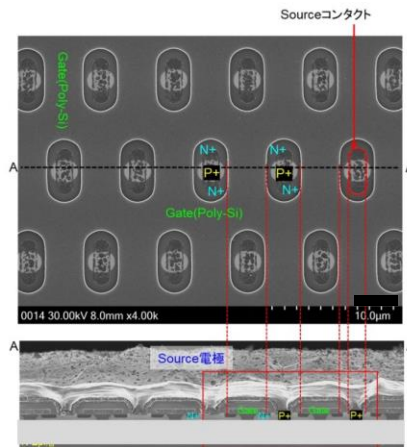
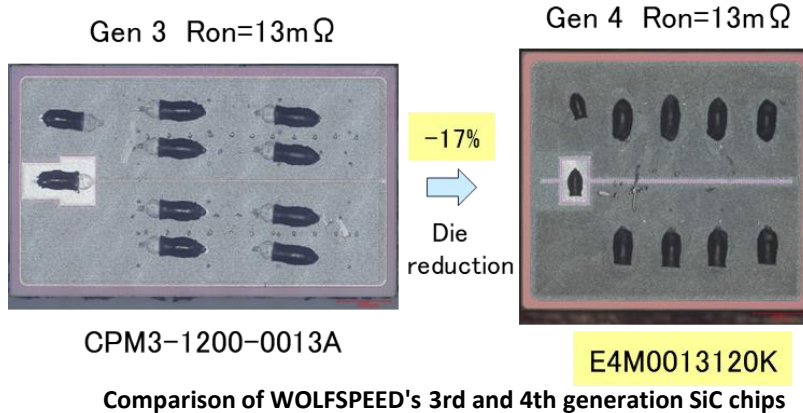
Please contact us for report pricing.

(1) Overview Analysis Report:

Table of Contents

Content	Page
1 Device Summary	
Table1-1: Device summary	... 3
Table1-2: Device structure : SiC MOSFET	... 4
Table1-3: Device structure : Layers' material, thicknesses	... 5
Table1-4: Device structure : Package structure overview	
2 Package Analysis	
2-1. External appearance	... 7
3 SiC MOSFET die structure analysis	
3-1. Planar structural analysis (by Optical Microscope observation)	... 9
3-2. Cell area: Cross-sectional structure analysis	... 10
3-3. Die outer periphery: Cross-sectional structure analysis	... 11

Excerpt from (1) Overview Analysis Report



Planar and cross-sectional SEM images of cell array

Table1-3: Device structure:SiC MOSFET

Die size	mm x mm		
Die area, A	mm ²		
Transistor Active Area, AA	mm ²		
Transistor array configuration	Ho		
Basic structure of a transistor cell (Gate)			
Cell Source-Source Pitch, P	μm		

Table1-4: Device structure: Layers' materials and thicknesses

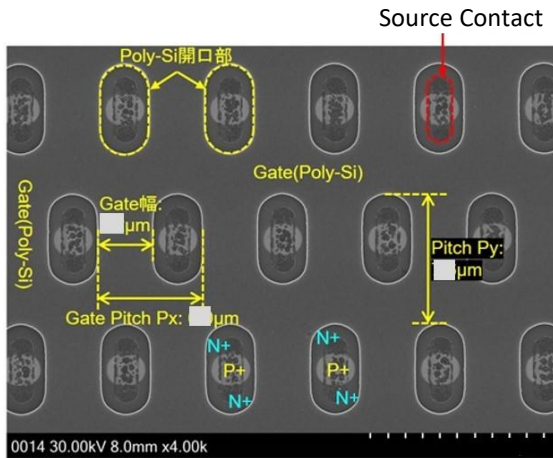
Description	Thickness	Material	Remarks
Wafer type (Bulk, Epi)			
N-epi			
Gate electrode structure and materials			
Gate dielectric			
Silicide			
Source barrier metal	1		
ILD (Gate-Metal)			
Passivation layer			

(2) Structural Analysis Report

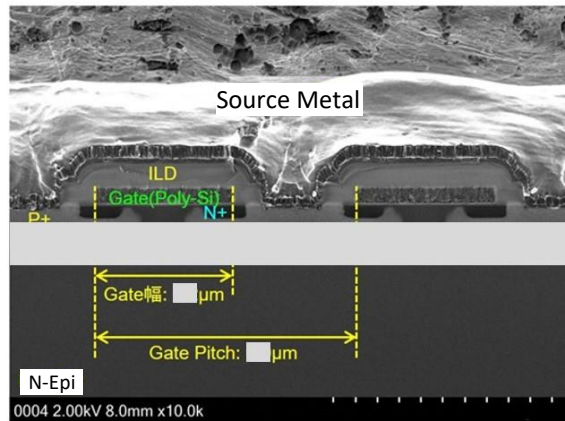
Table of Contents

Content	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 : Layers material and thickness	... 6
Table1-4: Device structure : Package structure overview	... 7
2 Package analysis	
2-1. External appearance	... 8
2-2. Mounted die	... 11
2-3. Package cross-sectional structure analysis	... 12
3 SiC MOSFET Structure analysis	
3-1. Planar structural analysis (OM)	... 25
3-2. Planar structural analysis (SEM)	... 42
3-3. Cell array cross-sectional structure analysis (SEM)	... 48
3-4. Die outer periphery cross-sectional structure analysis(SEM)	... 56
3-5. Gate electrode pad section cross-sectional structure (SEM)	... 63
4 TEM Structure analysis	... 66
5 SiC MOSFET die backside structure analysis	... 73
6 Comparison with WOLFSPEED's 3 rd -generation SiC MOSFET	... 76

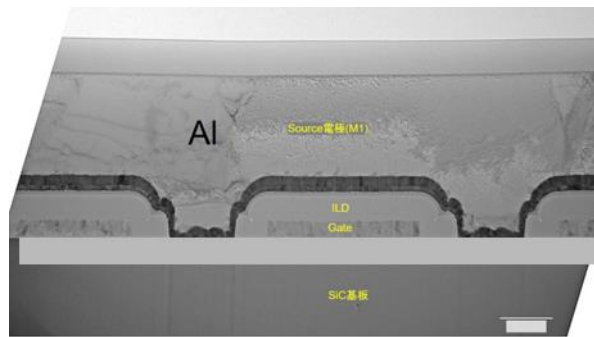
Excerpt from (2) Structure Analysis Report



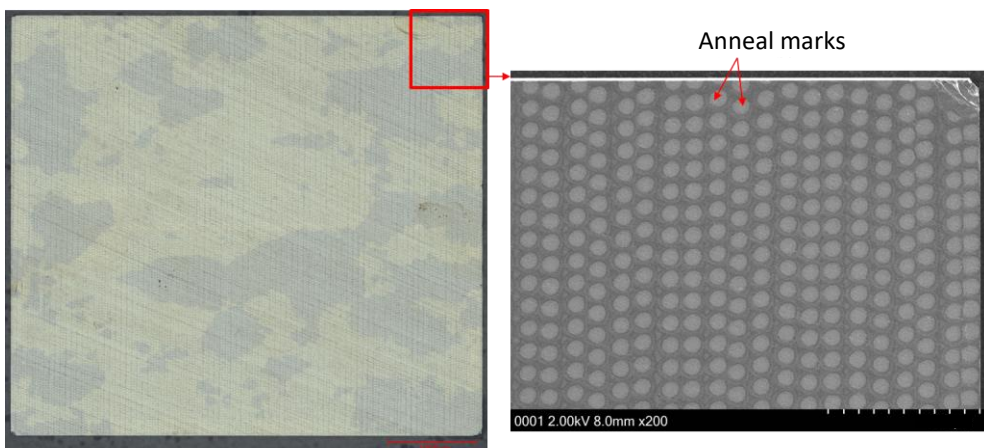
Cell array: Planar SEM image (Poly-Si layer)



Cell array: cross-sectional SEM image



Cell array: cross-sectional TEM image



OM image of the backside of SiC MOSFET die

(3) Process Analysis Report

Table of Contents

Content	Page
1 WOLFSPEED E4M0013120K SiC-MOSFET Summary of analysis results	3
1-1. Characteristics comparison between WOLFSPEED and other companies' 1200V SiC-MOSFETs	4
1-2. SiC-MOSFET whole die	5
1-3. Die edge observation	6
1-4. Device structure: SiC-MOSFET Transistor schematic cross-sectional view	7
1-5 Planar structure analysis (SEM): Transistor structure	8
2 SiC-MOSFET observation	
2-1 Cross-sectional/planar structural analysis (SEM) Features of transistor structure and process (1) - (8)	10
2-2. Details of self-alignment formation process of N+ and P well diffusion to define the channel length Lch (estimate)	18
3 WOLFSPEED E4M0013120K SiC-MOSFET analysis results summary	20
Table 1 Device structure: SiC-MOSFET	20
Table 2. SiC-MOSFET structure : Layers materials/film thicknesses	21
4 Manufacturing process flow	22
4-1. SiC-MOSFET front-end wafer process flow (estimated)	23
4-2. Cross-sectional schematic views of SiC-MOSFET process sequence	24
5 Electrical characteristics evaluation	30
5-1. E4M0013120K SiC-MOSFET Id-Vds characteristics and RON temperature dependence	31
5-2. Off-state drain current vs. drain voltage (Vds) with device temperature as a parameter and activation energy (Ea)	32
5-3. Off-state breakdown voltage BVdss characteristic	33
5-4. Gate leakage current (I _{gss}) characteristics	34
5-5. Comparison of leakage current between manufacturers	35
5-6. Body diode characteristics	36
5-7. Capacitances (C _{iss} , C _{oss} , C _{rss})-Vds characteristics	37
5-8. Device structure and electrical properties analysis: ON resistance	38
5-9. N-epi layer impurity concentration analysis	41
5-10. Device structure and electrical properties analysis: Breakdown voltage	42
6 Evolution of WOLFSPEED technology and improvements from 2nd to 4th generation	43
6-2. Main trends in the specific ON resistance index (RONxA) of 1200V SiC MOSFETs	45
7 Summary of analysis results	46
8 Related references	47
9 Related WOLFSPEED patents	47

Excerpt from (3) Process Analysis Report

Transistor structure and process features (3)

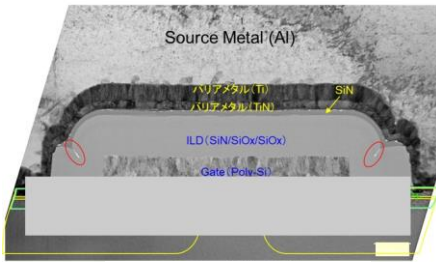


Fig.2-1-5 Transistor array TEM image

Possible Alignment Tree:

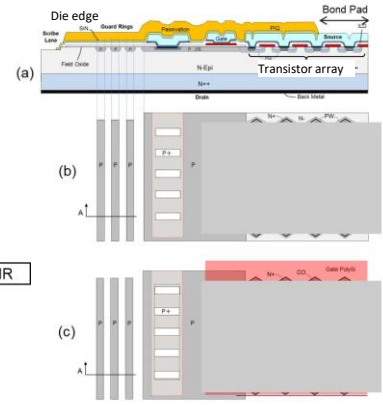


Fig.4-2-1 Transistor cross-section and layout schematics

WOLFSPEED SiC MOSFET E4M0013120K Process flow sequence

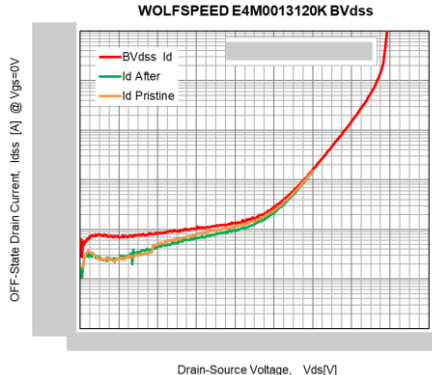
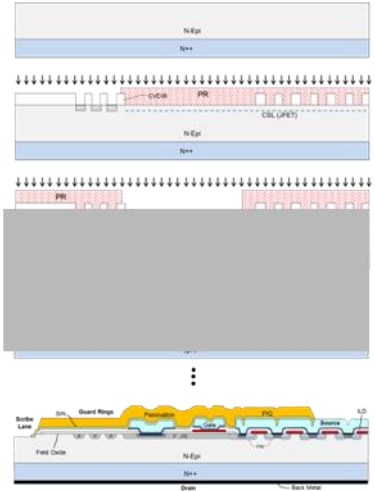


Fig.5-5-1 OFF-state breakdown voltage BVdss

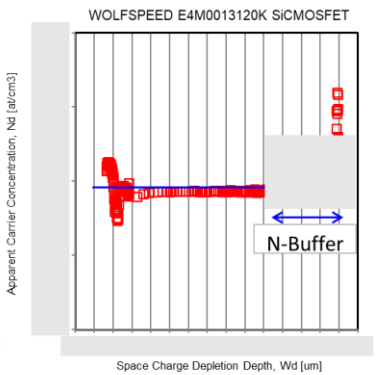


Fig.5-9-1(a) Carrier doping profile in depth direction

Table 6.1 Evolution of WOLFSPEED technology and improvements from 2nd to 4th generation

Product name	C2M0080120D	C3M0075120K	E4B450M12X3 (Module) CPM3-1200-0013A (Chip)	E4M0013120K
SiC MOSFET Technology Gen./生産開始	2 nd / 2013年	3 rd / 2016年	3 rd / 2022-23年	4 th / 2024年
Package	TO-247	TO-247-4L	Module and Bare die	TO-247-4L
Transistor Size	mm x mm			
Transistor Area, A	mm ²			
Transistor Active Area, AA	mm ²			
Total Channel Width, W	mm			
Layout Efficiency, W/AA	mm ²			
Rated Vdss	V			
Measured Breakdown Voltage, BVdss	V			
DC Id @ Tc=25°C	A			
Tjmax	°C			
Operating Gate Source voltage	V			
RON @ Tc=25°C	mΩ			
Specific ON resistance, RONxAA	mΩ·cm ²			
Threshold Voltage, Vth	V			
Transconductance, gm @ Vds=20V	A/V			
Transistor configuration (N+/Pwell)	onal			
Gate dielectric thickness, Tox	nm			
Triode transconductance parameter, β	A ² /V			
Normalized mobility: (β/W)/(L/Cox)	cm ² /Vs			
MOSFET Channel Resistance, Rch/BON	Ω			
Process changes from previous generation				

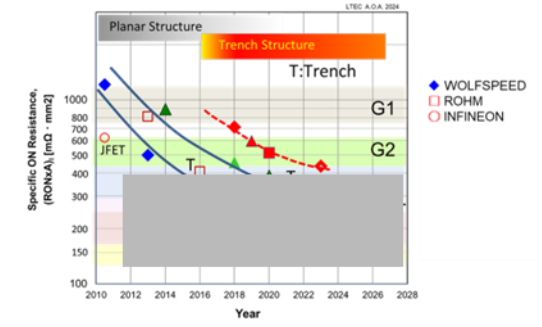


Fig.6-2-1 Trend in the specific ON resistance index (RONxA) of 1200V SiC MOSFETs

