SiC MOSFET Comparison 2019

POWER report by Amine ALLOUCHE
May 2019 – SAMPLE
# Table of Contents

## Overview / Introduction
- Executive Summary
- Reverse Costing Methodology
- Glossary

## Technology & Market

### Company profile & Supply Chain
- Rohm
- STMicroelectronics
- Wolfspeed
- Littelfuse
- Infineon

## Physical Analysis
- 650V MOSFETs
  - Rohm
  - STMicroelectronics
- 900V MOSFETs
  - Wolfspeed
- 1000V MOSFETs
  - Wolfspeed
- 1200V MOSFETs
  - Wolfspeed
  - Rohm
  - STMicroelectronics
  - Littelfuse
  - Infineon
- 1700V MOSFETs
  - Wolfspeed
  - Littelfuse
  - Infineon

## Technology and Physical Comparison

### MOSFETs Manufacturing Process Flow
- Supply Chains
- Wolfspeed
- Rohm
- STMicroelectronics
- Littelfuse
- Infineon

## Cost and Price Analysis
- Yields Explanation & Hypotheses
- 650V MOSFETs
  - Rohm
  - STMicroelectronics
- 900V MOSFETs
  - Wolfspeed
- 1000V MOSFETs
  - Wolfspeed
- 1200V MOSFETs
  - Wolfspeed
  - Rohm
  - STMicroelectronics
  - Littelfuse
  - Infineon
- 1700V MOSFETs
  - Wolfspeed
  - Littelfuse
  - Infineon

## Cost Comparison

## Feedbacks

## System Plus Consulting Services

©2019 by System Plus Consulting | SiC MOSFET Comparison 2019
Executive Summary

SiC devices are gaining the confidence of many customers and are penetrating various applications. This is confirmed by the promising market outlook for SiC devices, which will reach a compound annual growth rate (CAGR) of 31% for the period 2017-2023. The forecast for the value of the SiC power semiconductor market is about $1.5B by 2023. This relates to market forces pushing for loss reduction and for the sake of improved efficiency.

Nevertheless, the technical panorama of SiC devices is still varying, and every manufacturer has its own solutions to die design and packaging integration. This leads to strong competition, which will accelerate technical innovation and lower prices. Moreover, SiC business models are still very different. In the future, we will see a restructuring of the supply chain driven by the main cost factors.

Manufacturers propose different approaches for gate structure and device design, focused on SiC’s intrinsic properties, or seeking to overcome issues linked to them.

SiC-based MOSFET devices still have some technical and commercial challenges to face, despite the value they add. For example both SiC wafer processing and supply constraints impact wafer price and make it the major cost-driver of a SiC device. Other challenges include wafer size transition from 4-inch to 6-inch and the complexity of some process steps, mainly epitaxy, which hinder SiC adoption on a large commercial scale.

In this report, System Plus Consulting presents an overview of the state of the art of SiC MOSFETs to highlight differences in design and manufacturing processes, and their impact on device size and production cost.

22 SiC MOSFETs of voltages varying from 650V to 1700V from Cree/Wolfspeed, Rohm, STMicroelectronics, Littelfuse, and Infineon have been analyzed. The report provides detailed optical and SEM pictures from the device’s packaging and structure at the microscopic level of transistor design, with a focus on the latter.

This report includes an estimated manufacturing cost of the MOSFET devices and analyzes their selling prices. It provides physical, technological and manufacturing cost comparisons between the analyzed MOSFETs. Moreover it shows a complete analysis of the actual SiC components’ market.
SiC Discrete Transistors: Market Projection By 2023

- The major market part is predicted to be in the 600V - 1200V range.

<table>
<thead>
<tr>
<th></th>
<th>600V-900V</th>
<th>1000V-1200V</th>
<th>1700V</th>
<th>3000V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market</td>
<td></td>
<td>$x, Market in 2023</td>
<td>$y, Market in 2023</td>
<td>$z, Market in 2023</td>
</tr>
<tr>
<td></td>
<td>R&amp;D</td>
<td>R&amp;D</td>
<td>R&amp;D</td>
<td>R&amp;D</td>
</tr>
</tbody>
</table>

*Non-exhaustive list*
SiC Transistor Main Players Roadmap

First commercial product

2011

2012

2013

2014

2015

2016

2017

2018

Gen 2

ROHM Semiconductor

CREE/Wolfspeed

Mitsubishi

©2019 by System Plus Consulting | SiC MOSFET Comparison 2019

Overview / Introduction

Technology & Market

Company Profile & Supply Chain

Physical Analysis

Technology and Physical Comparison

Manufacturing Process Flow

Cost & Price Analysis

Cost Comparison

Related Reports

About System Plus
Identified SiC Discrete Transistors in the Market

Values based on Datasheet
# Analyzed SiC MOSFETs

## 600V SiC MOSFET

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Year</th>
<th>Device Code</th>
<th>Technology</th>
<th>Packaging</th>
<th>Vds (V)</th>
<th>Id (A) at 25°C</th>
<th>Rdson (Ohm)</th>
<th>Cg (nF)</th>
<th>Die Size (mm²)</th>
<th>Epilast (µm)</th>
<th>Guard Ring (µm)</th>
<th>Pitch (µm)</th>
<th>Wafer Thick (µm)</th>
<th>Current Density (A/mm²)</th>
<th>FOM (Qg* Rdson)</th>
<th>FOM (Resistance)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rohm</td>
<td>2016</td>
<td>STTS316LA1</td>
<td>TO220</td>
<td>650</td>
<td>31</td>
<td>0.130</td>
<td>31</td>
<td>39</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rohm</td>
<td>2013</td>
<td>STTS216LA1</td>
<td>TO220</td>
<td>550</td>
<td>29</td>
<td>0.120</td>
<td>29</td>
<td>41</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STMicroelectronics</td>
<td>2015</td>
<td>STW90G0820Y</td>
<td>TO220</td>
<td>550</td>
<td>11</td>
<td>0.022</td>
<td>11</td>
<td>13</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STMicroelectronics</td>
<td>2017</td>
<td>STW100N6520AG</td>
<td>TO220</td>
<td>650</td>
<td>100</td>
<td>0.020</td>
<td>100</td>
<td>133</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## 900V SiC MOSFET

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Year</th>
<th>Device Code</th>
<th>Technology</th>
<th>Packaging</th>
<th>Vds (V)</th>
<th>Id (A) at 25°C</th>
<th>Rdson (Ohm)</th>
<th>Cg (nF)</th>
<th>Die Size (mm²)</th>
<th>Epilast (µm)</th>
<th>Guard Ring (µm)</th>
<th>Pitch (µm)</th>
<th>Wafer Thick (µm)</th>
<th>Current Density (A/mm²)</th>
<th>FOM (Qg* Rdson)</th>
<th>FOM (Resistance)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wolfspeed</td>
<td>2016</td>
<td>C3M00300900</td>
<td>TO247</td>
<td>900</td>
<td>11.3</td>
<td>0.18</td>
<td>11.3</td>
<td>9.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wolfspeed</td>
<td>2016</td>
<td>C3M00300900</td>
<td>TO247</td>
<td>900</td>
<td>12</td>
<td>0.12</td>
<td>12</td>
<td>17.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wolfspeed</td>
<td>2015</td>
<td>C3M00500900</td>
<td>TO247</td>
<td>900</td>
<td>56</td>
<td>0.065</td>
<td>56</td>
<td>20.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## 1000V SiC MOSFET

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Year</th>
<th>Device Code</th>
<th>Technology</th>
<th>Packaging</th>
<th>Vds (V)</th>
<th>Id (A) at 25°C</th>
<th>Rdson (Ohm)</th>
<th>Cg (nF)</th>
<th>Die Size (mm²)</th>
<th>Epilast (µm)</th>
<th>Guard Ring (µm)</th>
<th>Pitch (µm)</th>
<th>Wafer Thick (µm)</th>
<th>Current Density (A/mm²)</th>
<th>FOM (Qg* Rdson)</th>
<th>FOM (Resistance)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wolfspeed</td>
<td>2016</td>
<td>C3M01200100K</td>
<td>TO247</td>
<td>1000</td>
<td>22</td>
<td>0.12</td>
<td>22</td>
<td>21.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## 1200V SiC MOSFET

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Year</th>
<th>Device Code</th>
<th>Technology</th>
<th>Packaging</th>
<th>Vds (V)</th>
<th>Id (A) at 25°C</th>
<th>Rdson (Ohm)</th>
<th>Cg (nF)</th>
<th>Die Size (mm²)</th>
<th>Epilast (µm)</th>
<th>Guard Ring (µm)</th>
<th>Pitch (µm)</th>
<th>Wafer Thick (µm)</th>
<th>Current Density (A/mm²)</th>
<th>FOM (Qg* Rdson)</th>
<th>FOM (Resistance)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wolfspeed</td>
<td>2016</td>
<td>C2M00801200</td>
<td>TO247</td>
<td>1200</td>
<td>56</td>
<td>0.084</td>
<td>56</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wolfspeed</td>
<td>2016</td>
<td>C2M00801200</td>
<td>TO247</td>
<td>1200</td>
<td>60</td>
<td>0.061</td>
<td>60</td>
<td>96.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wolfspeed</td>
<td>2014</td>
<td>C2M00401200</td>
<td>TO247</td>
<td>1200</td>
<td>60</td>
<td>0.061</td>
<td>60</td>
<td>96.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wolfspeed</td>
<td>2014</td>
<td>C2M00401200</td>
<td>TO247</td>
<td>1200</td>
<td>90</td>
<td>0.025</td>
<td>90</td>
<td>191</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rohm</td>
<td>2012</td>
<td>SCH2080KE</td>
<td>TO247</td>
<td>1200</td>
<td>40</td>
<td>0.068</td>
<td>40</td>
<td>106</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rohm</td>
<td>2012</td>
<td>SCD100KL</td>
<td>TO247</td>
<td>1200</td>
<td>72</td>
<td>0.068</td>
<td>72</td>
<td>151</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STMicroelectronics</td>
<td>2012</td>
<td>SCT550120</td>
<td>T0247</td>
<td>1200</td>
<td>45</td>
<td>0.088</td>
<td>45</td>
<td>195</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Littelfuse</td>
<td>2017</td>
<td>LS1G1M12000800</td>
<td>TO247</td>
<td>1200</td>
<td>30</td>
<td>0.08</td>
<td>30</td>
<td>98</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infineon</td>
<td>2016</td>
<td>DF11M12W1W1_611</td>
<td>module*</td>
<td>1200</td>
<td>35</td>
<td>0.025</td>
<td>35</td>
<td>123</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## 1500V SiC MOSFET

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Year</th>
<th>Device Code</th>
<th>Technology</th>
<th>Packaging</th>
<th>Vds (V)</th>
<th>Id (A) at 25°C</th>
<th>Rdson (Ohm)</th>
<th>Cg (nF)</th>
<th>Die Size (mm²)</th>
<th>Epilast (µm)</th>
<th>Guard Ring (µm)</th>
<th>Pitch (µm)</th>
<th>Wafer Thick (µm)</th>
<th>Current Density (A/mm²)</th>
<th>FOM (Qg* Rdson)</th>
<th>FOM (Resistance)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wolfspeed</td>
<td>2016</td>
<td>C2M0085170</td>
<td>TO247</td>
<td>1700</td>
<td>72</td>
<td>0.045</td>
<td>72</td>
<td>188</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wolfspeed</td>
<td>2016</td>
<td>C2M0085170</td>
<td>TO247</td>
<td>1700</td>
<td>5</td>
<td>0.75</td>
<td>5</td>
<td>156</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rohm</td>
<td>2015</td>
<td>SCT218KL</td>
<td>TO247</td>
<td>1700</td>
<td>5.7</td>
<td>1.15</td>
<td>5.7</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rohm</td>
<td>2016</td>
<td>SCT21801Y</td>
<td>TO247</td>
<td>1700</td>
<td>5.2</td>
<td>0.75</td>
<td>5.2</td>
<td>17</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Identified Design Technologies (Planar/Trench) by Manufacturer

**Planar**

**Trench**
• xxx device has the best performances regarding the Rdson*Area.
### Rohm Analyzed Devices

<table>
<thead>
<tr>
<th>MOSFET</th>
<th>Voltage</th>
<th>Current at 25°C</th>
<th>Die area</th>
<th>Current density</th>
<th>Rdson</th>
<th>Qg</th>
<th>FOM</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCT3120AL</td>
<td>650 V</td>
<td>21 A</td>
<td>xx mm²</td>
<td>xx A/mm²</td>
<td>0.120 ohm</td>
<td>38 nC</td>
<td>xx ohm*nC</td>
</tr>
<tr>
<td>SCT2120AF</td>
<td>650 V</td>
<td>29 A</td>
<td>xx mm²</td>
<td>xx A/mm²</td>
<td>0.018 ohm</td>
<td>61 nC</td>
<td>xx ohm*nC</td>
</tr>
<tr>
<td>SCT3022AL</td>
<td>650 V</td>
<td>93 A</td>
<td>xx mm²</td>
<td>xx A/mm²</td>
<td>0.022 ohm</td>
<td>133 nC</td>
<td>xx ohm*nC</td>
</tr>
<tr>
<td>SCH2080KE</td>
<td>1200 V</td>
<td>40 A</td>
<td>xx mm²</td>
<td>xx A/mm²</td>
<td>0.080 ohm</td>
<td>106 nC</td>
<td>xx ohm*nC</td>
</tr>
<tr>
<td>SCT3030KL</td>
<td>1200 V</td>
<td>72 A</td>
<td>xx mm²</td>
<td>xx A/mm²</td>
<td>0.030 ohm</td>
<td>131 nC</td>
<td>xx ohm*nC</td>
</tr>
<tr>
<td>SCT2H12NZ</td>
<td>1700 V</td>
<td>3.7 A</td>
<td>xx mm²</td>
<td>xx A/mm²</td>
<td>1.150 ohm</td>
<td>14 nC</td>
<td>xx ohm*nC</td>
</tr>
<tr>
<td>SCT2750NY</td>
<td>1700 V</td>
<td>5.9 A</td>
<td>xx mm²</td>
<td>xx A/mm²</td>
<td>0.750 ohm</td>
<td>17 nC</td>
<td>xx ohm*nC</td>
</tr>
</tbody>
</table>
SCT2120AF

- 650V 29A
- SiC MOSFET

- Die area: xx mm²
- Pitch: xx µm
- Termination: xx mm

Source details after delayering – SEM view

Die Dimensions – Optical View
SCTW90N65G2V

- Package type: HiP247
- Package size: 34mm x 15mm x 5mm
- Pin pitch: 5.45 mm

The package include the following markings:

- Reference of component
  - Package Front view
  - Package Back view
  - Drain
  - Heat sink
  - Gate (G)
  - Source (S)

Package Opening

©2019 by System Plus Consulting
SCTW90N65G2V

- Die thickness: xx µm
- Al thickness: xx µm
- Epitaxy: xx µm
- Polyimide: xx µm
- Passivation: xxx
- Backside: xxx

Die Cross-Section – SEM View
Overview / Introduction

Technology & Market

Company Profile & Supply Chain

Physical Analysis
- 650V
  - Rohm
  - STMicroelectronics
- 900V
- 1000V
- 1200V
- 1700V

Technology and Physical Comparison

Manufacturing Process Flow

Cost & Price Analysis

Cost Comparison

Related Reports

About System Plus
650V SiC MOSFET Comparison – STMicroelectronics vs Rohm

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Year</th>
<th>Device Code</th>
<th>Technology</th>
<th>Vds (V)</th>
<th>Id (A) @ 25°C</th>
<th>Die Size (mm²)</th>
<th>Epitaxy (µm)</th>
<th>Pitch (µm)</th>
<th>Wfr Thick (µm)</th>
<th>Current Density (A/mm²)</th>
<th>FOM (Qg*Rdson)</th>
<th>FOM (Rdson*Area)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rohm</td>
<td>2016</td>
<td>SCT3120AL</td>
<td>xxx</td>
<td>650</td>
<td>21</td>
<td>xxx</td>
<td>xxx</td>
<td>xxx</td>
<td>xxx</td>
<td>xxx</td>
<td>xxx</td>
<td>xxx</td>
</tr>
<tr>
<td>Rohm</td>
<td>2013</td>
<td>SCT2120AF</td>
<td>xxx</td>
<td>650</td>
<td>29</td>
<td>xxx</td>
<td>xxx</td>
<td>xxx</td>
<td>xxx</td>
<td>xxx</td>
<td>xxx</td>
<td>xxx</td>
</tr>
<tr>
<td>Rohm</td>
<td>2016</td>
<td>SCT3022AL</td>
<td>xxx</td>
<td>650</td>
<td>93</td>
<td>xxx</td>
<td>xxx</td>
<td>xxx</td>
<td>xxx</td>
<td>xxx</td>
<td>xxx</td>
<td>xxx</td>
</tr>
<tr>
<td>STMicroelectronics</td>
<td>2016</td>
<td>SCTW90N65G2V</td>
<td>xxx</td>
<td>650</td>
<td>110</td>
<td>xxx</td>
<td>xxx</td>
<td>xxx</td>
<td>xxx</td>
<td>xxx</td>
<td>xxx</td>
<td>xxx</td>
</tr>
<tr>
<td>STMicroelectronics</td>
<td>2017</td>
<td>SCTW100N65G2AG</td>
<td>xxx</td>
<td>650</td>
<td>100</td>
<td>xxx</td>
<td>xxx</td>
<td>xxx</td>
<td>xxx</td>
<td>xxx</td>
<td>xxx</td>
<td>xxx</td>
</tr>
</tbody>
</table>

- STMicroelectronics’ xxx devices shows xxx epitaxy layers < xxµm (half than xxx’s devices).
  It also employs xxx substrates (< xxµm).
- Devices with comparable current values, have close values of xxx.
- xxx’s gen xxx structure shows the xxx FoM : for both (Qg*Rdson) and (Area*Rdson).
- xxx shows the best FoM (Area*Rdson).
- xxx structures (xxx) employs the thickest epitaxy layers.
### 1200V SiC MOSFET Comparison

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Year</th>
<th>Device Code</th>
<th>Technology</th>
<th>Vds (V)</th>
<th>Id (A) @ 25°C</th>
<th>Die Size (mm²)</th>
<th>Epitaxy (µm)</th>
<th>Pitch (µm)</th>
<th>Wfr Thick (µm)</th>
<th>Current Density (A/mm²)</th>
<th>FOM (Qg*Rsdon)</th>
<th>FOM (Rsdon*Area)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wolfspeed</td>
<td>2015</td>
<td>C2M0080120D</td>
<td>xxx</td>
<td>1200</td>
<td>36</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
</tr>
<tr>
<td>Wolfspeed</td>
<td>2011</td>
<td>CMF20120</td>
<td>xxx</td>
<td>1200</td>
<td>42</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
</tr>
<tr>
<td>Wolfspeed</td>
<td>2014</td>
<td>C2M0040120D</td>
<td>xxx</td>
<td>1200</td>
<td>60</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
</tr>
<tr>
<td>Wolfspeed</td>
<td>2014</td>
<td>C2M0025120D</td>
<td>xxx</td>
<td>1200</td>
<td>90</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
</tr>
<tr>
<td>Rohm</td>
<td>2012</td>
<td>SCH2080KE</td>
<td>xxx</td>
<td>1200</td>
<td>40</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
</tr>
<tr>
<td>Rohm</td>
<td>2016</td>
<td>SCT3030KL</td>
<td>xxx</td>
<td>1200</td>
<td>72</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
</tr>
<tr>
<td>STMicroelectronics</td>
<td>2012</td>
<td>SCT30N120</td>
<td>xxx</td>
<td>1200</td>
<td>45</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
</tr>
<tr>
<td>Littelfuse</td>
<td>2017</td>
<td>LSIC1MO120E0080</td>
<td>xxx</td>
<td>1200</td>
<td>39</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
</tr>
<tr>
<td>Infineon</td>
<td>2016</td>
<td>DF11MR12W1M1_B11</td>
<td>xxx</td>
<td>1200</td>
<td>55</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
</tr>
</tbody>
</table>

**1200V xxx Structures (comparable current values) – SEM Views**

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Year</th>
<th>Device Code</th>
<th>Technology</th>
<th>Vds (V)</th>
<th>Id (A) @ 25°C</th>
<th>Die Size (mm²)</th>
<th>Epitaxy (µm)</th>
<th>Pitch (µm)</th>
<th>Wfr Thick (µm)</th>
<th>Current Density (A/mm²)</th>
<th>FOM (Qg*Rsdon)</th>
<th>FOM (Rsdon*Area)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wolfspeed</td>
<td>2015</td>
<td>C2M0080120D</td>
<td>xxx</td>
<td>1200</td>
<td>36</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
</tr>
<tr>
<td>Wolfspeed</td>
<td>2011</td>
<td>CMF20120</td>
<td>xxx</td>
<td>1200</td>
<td>42</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
</tr>
<tr>
<td>Wolfspeed</td>
<td>2014</td>
<td>C2M0040120D</td>
<td>xxx</td>
<td>1200</td>
<td>60</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
</tr>
<tr>
<td>Wolfspeed</td>
<td>2014</td>
<td>C2M0025120D</td>
<td>xxx</td>
<td>1200</td>
<td>90</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
</tr>
<tr>
<td>Rohm</td>
<td>2012</td>
<td>SCH2080KE</td>
<td>xxx</td>
<td>1200</td>
<td>40</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
</tr>
<tr>
<td>Rohm</td>
<td>2016</td>
<td>SCT3030KL</td>
<td>xxx</td>
<td>1200</td>
<td>72</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
</tr>
<tr>
<td>STMicroelectronics</td>
<td>2012</td>
<td>SCT30N120</td>
<td>xxx</td>
<td>1200</td>
<td>45</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
</tr>
<tr>
<td>Littelfuse</td>
<td>2017</td>
<td>LSIC1MO120E0080</td>
<td>xxx</td>
<td>1200</td>
<td>39</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
</tr>
<tr>
<td>Infineon</td>
<td>2016</td>
<td>DF11MR12W1M1_B11</td>
<td>xxx</td>
<td>1200</td>
<td>55</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
</tr>
</tbody>
</table>
Analyzed Devices – Die Size Mapping
Analyzed Devices Technology – Epitaxy Trend

- **General trend by manufacturer:**
  
  The xxx to be held by a MOSFET, the xxx is the epitaxial layer to be patterned.

- xxx devices show the thinnest epitaxy layers (all voltage included) compared to its competitors → xxx cost impact.

- xxx is using the thickest epitaxy layers in its designs (all voltage included) compared to other manufacturers.

- Two xxV xxx’s devices (gen x design) with different currents show exactly the same epitaxy layer thickness. The epitaxy layer is dependant on the xxx and xxx.

- Rohm xxx its epitaxy layer thickness for its xxx structures when xxx.

- xxx designs seems to require more epitaxy thickness than a xxx structure holding the same breakdown voltage and drain current.
Rohm Gen3 Double Trench SiC MOSFET – Process Flow (3/4)

- Dielectric deposition and pattern
- xxx deposition and patterning
- xxx and xxx deposition and patterning

Drawing not to Scale
Littelfuse Planar SiC MOSFET – Process Flow (4/4)

- **Passivation**
  - Silicon oxide and xxx deposition and pattern

- **Backside**
  - XXX
  - Xxx Backside contact

- **Polyimide**
  - Polyimide deposition and pattern

Drawing not to Scale
## Wolfspeed Analyzed Devices : 900V

### Technology and Physical Comparison

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Year</th>
<th>Device Code</th>
<th>Technology</th>
<th>Packaging</th>
<th>Vds (V)</th>
<th>Id (A) @ 25°C</th>
<th>Rdson (Ohm)</th>
<th>Qgs (nC)</th>
<th>Die Size (mm²)</th>
<th>Epltaxy (µm)</th>
<th>Guard Ring (µm)</th>
<th>Pitch (µm)</th>
<th>Wafer Thickness (µm)</th>
<th>Current Density (A/mm²)</th>
<th>FOM (Qgs/Rdson)</th>
<th>FOM (Qgs²/Area)</th>
</tr>
</thead>
</table>
In our simulation, we assume a development and a production ramp up without important technical problem.
## Wolfspeed Wafer & Die cost & Price

### Overview / Introduction

- Technology & Market
- Company Profile & Supply Chain
- Physical Analysis
- Technology and Physical Comparison
- Manufacturing Process Flow

### Cost & Price Analysis

- **650V**
  - Wolfspeed
    - C3M0280090D
    - C3M0120090D
    - C3M0065090D
- **900V**
  - Wolfspeed
    - C3M0280090D
    - C3M0120090D
    - C3M0065090D
  - 1000V
  - 1200V
  - 1700V

## Cost Comparison

### Wolfspeed Wafer & Die cost & Price

<table>
<thead>
<tr>
<th>Front-End</th>
<th>C3M0280090D</th>
<th>Cost</th>
<th>Breakdown</th>
<th>C3M0120090D</th>
<th>Cost</th>
<th>Breakdown</th>
<th>C3M0065090D</th>
<th>Cost</th>
<th>Breakdown</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw wafer Cost (SiC)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Epitaxy cost</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Front-side+Back-side</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yield losses Cost</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>MOSFET Front-End Cost</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Die Cost</th>
<th>C3M0280090D</th>
<th>Cost</th>
<th>Breakdown</th>
<th>C3M0120090D</th>
<th>Cost</th>
<th>Breakdown</th>
<th>C3M0065090D</th>
<th>Cost</th>
<th>Breakdown</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front-End Cost</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BE : Probe Test Cost</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BE : Dicing Cost</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total Wafer Cost</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Nb of potential dies per wafer
- Nb of good dies per wafer

<table>
<thead>
<tr>
<th>Die Cost</th>
<th>C3M0280090D</th>
<th>Cost</th>
<th>Breakdown</th>
<th>C3M0120090D</th>
<th>Cost</th>
<th>Breakdown</th>
<th>C3M0065090D</th>
<th>Cost</th>
<th>Breakdown</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front-End Cost</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BE : Probe Test</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BE : Dicing Cost</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BE : Yield losses</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Wolfspeed Wafer & Die cost & Price

### Packaging Cost

<table>
<thead>
<tr>
<th>Substrate Cost</th>
<th>Clean Room Cost</th>
<th>Equipment Cost</th>
<th>Consumable Cost</th>
<th>Labor Cost</th>
<th>Yield losses Cost</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>Breakdown</td>
<td>Cost</td>
<td>Breakdown</td>
<td>Cost</td>
<td>Breakdown</td>
<td>Total Cost</td>
</tr>
</tbody>
</table>

### Component Cost

<table>
<thead>
<tr>
<th>MOSFET Die cost</th>
<th>Packaging cost</th>
<th>Final test &amp; Calibration cost</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>Breakdown</td>
<td></td>
<td>Total Cost</td>
</tr>
</tbody>
</table>

### Component Price

<table>
<thead>
<tr>
<th>Component Cost</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>Breakdown</td>
</tr>
</tbody>
</table>

---

**Cost Comparison**

- **650V**
- **900V**

**Wolfspeed**

- C3M0280090D
- C3M0120090D
- C3M0065090D

---

**Cost Analysis**

- Wafer & Die cost
- Packaging cost
- Final test & Calibration cost
- Yield losses cost

---

**Related Reports**

- Wolfspeed Wafer & Die cost & Price

---

**About System Plus**

- System Plus Consulting

---

**©2019 by System Plus Consulting | SiC MOSFET Comparison 2019**
Cost of SiC Substrate

- The main cost in SiC MOSFET manufacturing process is xxx.
- SiC MOSFET manufacturers are currently doing xxx SiC wafers or have already started SiC MOSFET development on xxx.
- However, only a few players are able to supply xxx wafers and even those players might have some issues if they have to provide large volume of reproducible high quality wafers.
### 1200V SiC MOSFET Comparison

<table>
<thead>
<tr>
<th>MOSFET</th>
<th>Manufacturer</th>
<th>Year</th>
<th>Technology</th>
<th>Voltage (V)</th>
<th>Current (25°C)</th>
<th>Wafer Size</th>
<th>Die Area (mm²)</th>
<th>Epitaxy (µm)</th>
<th>Current Density (A/mm²)</th>
<th>Wafer Cost ($)</th>
<th>Die Cost ($)</th>
<th>Ampere Cost ($/A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LSIC1M0120E0080</td>
<td>Littelfuse</td>
<td>2017</td>
<td>xx</td>
<td>1200</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
</tr>
<tr>
<td>SCT30N120</td>
<td>STMicroelectronics</td>
<td>2012</td>
<td>xx</td>
<td>1200</td>
<td>45</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
</tr>
<tr>
<td>C2M0080120D</td>
<td>Wolfspeed</td>
<td>2015</td>
<td>xx</td>
<td>1200</td>
<td>36</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
</tr>
<tr>
<td>DF11MR12W1M1_B11</td>
<td>Infineon</td>
<td>2016</td>
<td>xx</td>
<td>1200</td>
<td>55</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
</tr>
<tr>
<td>SCH2080KE</td>
<td>Rohm</td>
<td>2012</td>
<td>xx</td>
<td>1200</td>
<td>40</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
</tr>
<tr>
<td>SCT3030KL</td>
<td>Rohm</td>
<td>2016</td>
<td>xx</td>
<td>1200</td>
<td>72</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
</tr>
</tbody>
</table>

xxx’s xxx structure shows an improved Ampere cost compared to xxx.
Related Reports

REVERSE COSTING ANALYSES - SYSTEM PLUS CONSULTING

POWER SEMICONDUCTORS & COMPOUND
- Wolfspeed CAS325M12HM2 1200V SiC Module
- Rohm SiC MOSFET Gen3 family
- Tesla Model 3 Inverter with SiC Power Module from STMicroelectronics

MARKET AND TECHNOLOGY REPORTS - YOLE DÉVELOPPEMENT

POWER ELECTRONICS & COMPOUND SEMI
- Power SiC 2018: Materials, Devices and Applications
- Status of the Power Electronics Industry 2018
- Power GaN 2018: Epitaxy, Devices, Applications and Technology Trends
- Power Electronics for EV/HEV 2018

PATENT ANALYSIS - KNOWMADE

POWER SEMICONDUCTORS & COMPOUND
- Power SiC: MOSFETs, SBDs and Modules 2019 – Patent Landscape Analysis

©2019 by System Plus Consulting | SiC MOSFET Comparison 2019
Business Models Fields of Expertise

- Custom Analyses
  (>130 analyses per year)
- Reports
  (>60 reports per year)
- Costing Tools
- Trainings

Overview / Introduction
Technology & Market
Company Profile & Supply Chain
Physical Analysis
Technology and Physical Comparison
Manufacturing Process Flow
Cost & Price Analysis
Cost Comparison
Related Reports

About System Plus
- Company services
- Contact
ORDER FORM

Please process my order for “SiC MOSFET Comparison 2019” Reverse Costing® – Structure, Process & Cost Report
Ref: SP19449

☐ Full Structure, Process & Cost Report : EUR 6,490*
☐ Annual Subscription offers possible from 3 reports, including this report as the first of the year. Contact us for more information.

SHIP TO

Name (Mr/Ms/Dr/Pr): .............................................................
Job Title: .............................................................................
Company: .............................................................................
Address: .............................................................................
City: .......................................................... State: ................................
Postcode/Zip: ..........................................................................
Country: .............................................................................
VAT ID Number for EU members: ..........................................
Tel: ..........................................................................................
Email: ..................................................................................
Date: ....................................................................................
Signature: ............................................................................

BILLING CONTACT

First Name : ...........................................................................
Last Name: ...........................................................................
Email: ..................................................................................
Phone: ..................................................................................

PAYMENT

By credit card:
Number: |__|__|__|__| |__|__|__|__| |__|__|__|__|
|__|__|__|__|
Expiration date: |__|__|/|__|__|
Card Verification Value: |__|__|__|

By bank transfer:
HSBC - CAE- Le Terminal -2 rue du Charron - 44800 St Herblain France
BIC code: CCFRFRPP
■ In EUR
Bank code : 30056 - Branch code : 00955 - Account : 09550003234
IBAN: FR76 3005 6009 5509 5500 0323 439
■ In USD
Bank code : 30056 - Branch code : 00955 - Account : 09550003247
IBAN: FR76 3005 6009 5509 5500 0324 797

Return order by:
FAX: +33 2 53 55 10 59
MAIL: SYSTEM PLUS CONSULTING
22, bd Benoni Goullin
Nantes Biotech
44200 Nantes – France
EMAIL: sales@systemplus.fr

*For price in dollars please use the day’s exchange rate
*All reports are delivered electronically in pdf format
*For French customer, add 20 % for VAT
*Our prices are subject to change. Please check our new releases and price changes on www.systemplus.fr. The present document is valid 6 months after its publishing date: May 2019

ANNUAL SUBSCRIPTIONS

Each year System Plus Consulting releases a comprehensive collection of new reverse engineering and costing analyses in various domains. You can choose to buy over 12 months a set of 3, 4, 5, 7, 10 or 15 Reverse Costing® reports.

Up to 47% discount!

More than 60 reports released each year on the following topics (considered for 2018):
• Power: GaN - IGBT - MOSFET - Si Diode - SiC
• Imaging: Camera - Spectrometer
• LED and Laser: UV LED – VCSEL - White/blue LED
• Packaging: 3D Packaging - Embedded - SIP - WLP
• Integrated Circuits: IPD – Memories – PMIC – SoC
• RF: FEM - Duplexer
• Systems: Automotive - Consumer - Energy - Telecom
1. INTRODUCTION
The present terms and conditions apply to the offers, sales and deliveries of services managed by System Plus Consulting except in the case of a particular written agreement. Buyer must note that placing an order means an agreement without any restriction with these terms and conditions.

2. PRICES
Prices of the purchased services are those which are in force on the date the order is placed. Prices are in Euros and worked out without taxes. Consequently, the taxes and possible added costs agreed when the order is placed will be charged on these initial prices. System Plus Consulting may change its prices whenever the company thinks it necessary. However, the company commits itself in invoicing at the prices in force on the date the order is placed.

3. REBATES and DISCOUNTS
The quoted prices already include the rebates and discounts that System Plus Consulting could have granted according to the number of orders placed by the Buyer, or other specific conditions. No discount is granted in case of early payment.

4. TERMS OF PAYMENT
System Plus Consulting delivered services are to be paid within 30 days end of month by bank transfer except in the case of a particular written agreement. If the payment does not reach System Plus Consulting on the deadline, the Buyer has to pay System Plus Consulting a penalty for late payment the amount of which is three times the legal interest rate. The legal interest rate is the current one on the delivery date. This penalty is worked out on the unpaid invoice amount, starting from the invoice deadline. This penalty is sent without previous notice. When payment terms are over 30 days end of month, the Buyer has to pay a deposit which amount is 10% of the total invoice amount when placing his order.

5. OWNERSHIP
System Plus Consulting remains sole owner of the delivered services until total payment of the invoice.

6. DELIVERIES
The delivery schedule on the purchase order is given for information only and cannot be strictly guaranteed. Consequently any reasonable delay in the delivery of services will not allow the buyer to claim for damages or to cancel the order.

7. ENTRUSTED GOODS SHIPMENT
The transport costs and risks are fully born by the Buyer. Should the customer wish to ensure the goods against lost or damage on the base of their real value, he must imperatively point it out to System Plus Consulting when the shipment takes place. Without any specific requirement, insurance terms for the return of goods will be the carrier current ones (reimbursement based on good weight instead of the real value).

8. FORCE MAJEURE
System Plus Consulting responsibility will not be involved in non-execution or late delivery of one of its duties described in the current terms and conditions if these are the result of a force majeure case. Therefore, the force majeure includes all external event unpredictable and irresistible as defined by the article 1148 of the French Code Civil?

9. CONFIDENTIALITY
As a rule, all information handed by customers to System Plus Consulting are considered as strictly confidential. A non-disclosure agreement can be signed on demand.

10. RESPONSIBILITY LIMITATION
The Buyer is responsible for the use and interpretations he makes of the reports delivered by System Plus Consulting. Consequently, System Plus Consulting responsibility can in no case be called into question for any direct or indirect damage, financial or otherwise, that may result from the use of the results of our analysis or results obtained using one of our costing tools.

11. APPLICABLE LAW
Any dispute that may arise about the interpretation or execution of the current terms and conditions shall be resolved applying the French law. It the dispute cannot be settled out-of-court, the competent Court will be the Tribunal de Commerce de Nantes.