Industry Session 15: PwrSoC for Next-Gen Power

Si-IPD: Review of continuous improvements with regard to the new challenges in PwrSoC

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Outline

1- Introduction

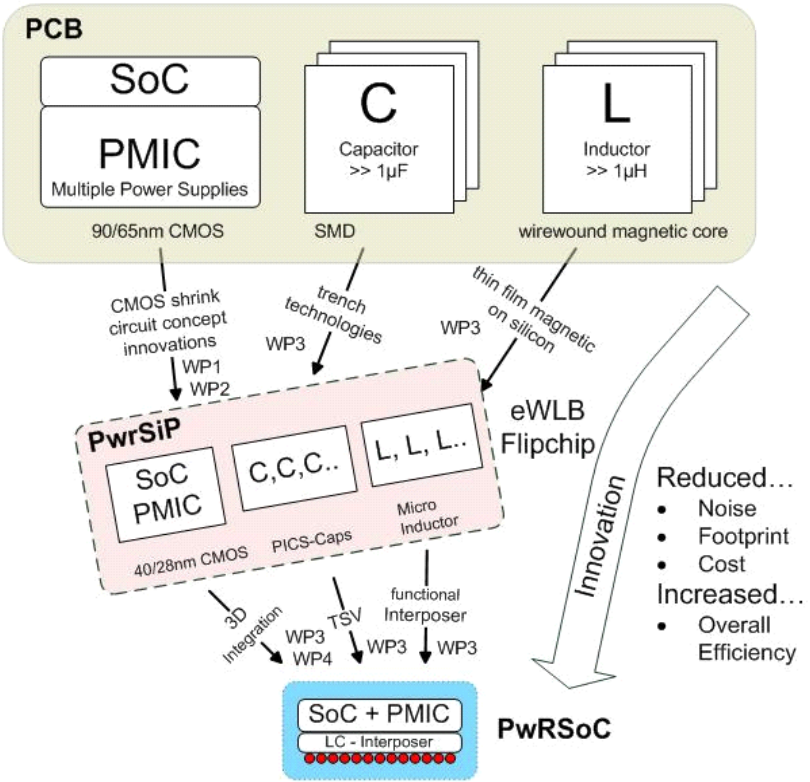
2- Silicon Capacitors technology

3- 3D Silicon capacitors for power applications

- PDN application (Mobile & HPC)
- LiDAR application (Automotive)

4- Summary

1- Introduction



- Major Drivers in power electronics
  - High efficiency
  - Cost-effective
  - High level of integration
- Innovations in:
  - Integrated power passives
    - Capacitors
    - Inductors
  - Nano CMOS Technologies
  - Advanced packaging

CIPS 2014, Cian Ó Mathúna et al.

1- Capacitors technologies

Long Lifetime, Down Sizing

High Capacitance GRM Series
(2.5V~100V, ~220uF)

Polymer Electrolysis ECAS Series
(2.5V~25V, ~470uF)

EDLC DMF Series
(~1000mF, 4.2V)

Low ESL LLL/LLD Series
(~4.3uF, 9.2uF)

Automotive Grade GCM Series
(ISO9001, AEC-Q200, TS16949)

Safety Recognized DE Series
(13 countries Safety Approved, X2/Y1/Y2)

SNUBBER (SHIZUKI) MIC-UV Series
(~1,600V, ~4uF)

High Power EVC Series
(~1,600V, ~4uF)

DC-LINK (SHIZUKI) MEC-DL/HV Series
(~1,200V, ~1,600uF)

High Power Conversion

High Reliability

Metal Terminal KRM Series
(25V~1kV, ~100uF)

Implant Class D GCR/GCH Series
(ISO13485)

Embedded GRU/LLU Series
(110um~, Cu VIA Connection)

Ultra Small Size GRM01/02 Series
(008004, 01005)

Non Magnetic MA Series
(MRI application)

Multilayer RDE Series
(~220uF, ~2kV)

PA High Q GQM Series
(250V~500V, 1GHz~10GHz)

Ultra High Voltage DHS/DHK Series
(DC10~50kV,AC10~25kV)

Optical Transceiver GMA/GMD Series
(Wire Bonding, Au Electrode)

High Voltage DHR Series
(6kV~10kV)

Ultra High Voltage, Communication

Consumer
LED lighting, TV, Air conditioner
Smartphone, Tablet, Wearable

Healthcare
Imaging Therapy, Hearing Aid,
Clinic System

Industry
Factory Automation, PLC,
Inverter

Energy
Wind / PV Power
Generation, Oil/Gas System

High Density

Miniaturization

Low profile

Low ESL

Low ESR

High Reliability

Mechanical strength

High Stability

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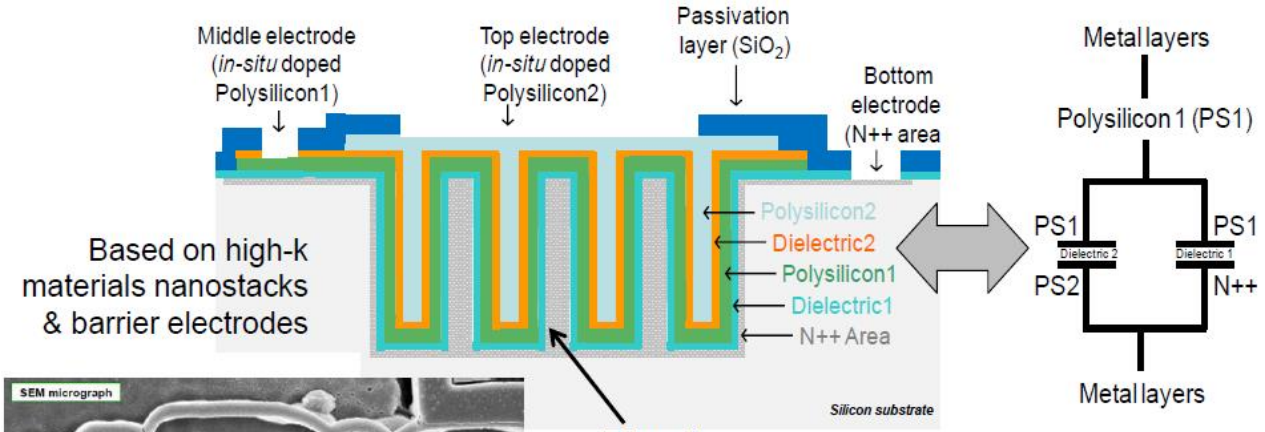
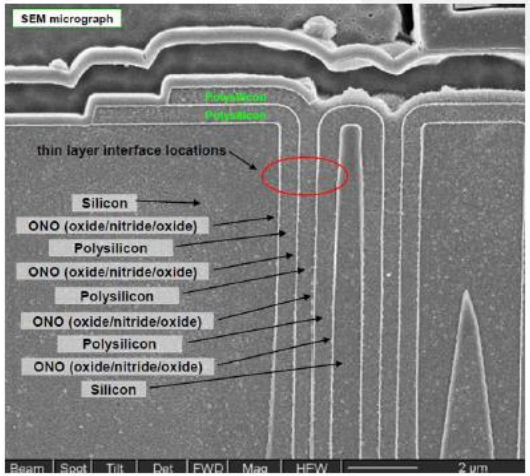
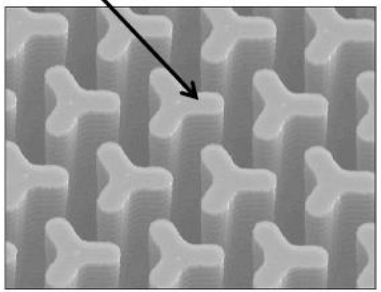
2- Silicon Capacitors Technology

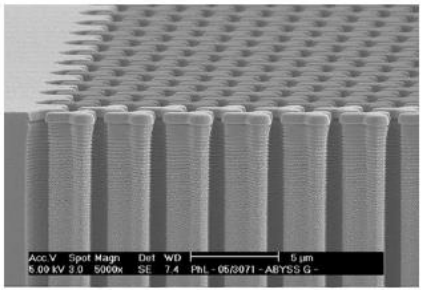
2 parallelized capacitors in a MIMIM architecture to increase the capacitance value





Tripod





Tilted SEM view

Miniaturization

New market opportunities enabled by reduction in product size

Electrical characteristics

Wide frequency range, temp. stability, low leakage, low ESR, low ESL

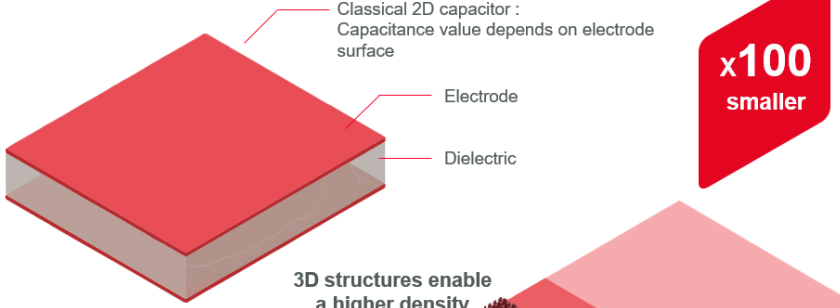
Reliability

Low failure rates even at high temperatures with predictable failure modes

Other key advantages

Non-magnetic, customized products

2- Key features



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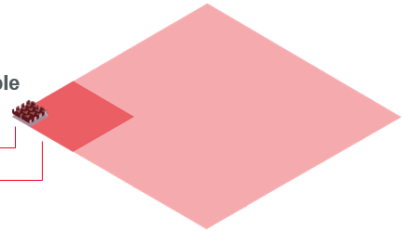
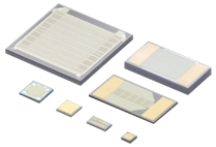




Silicon Capacitors

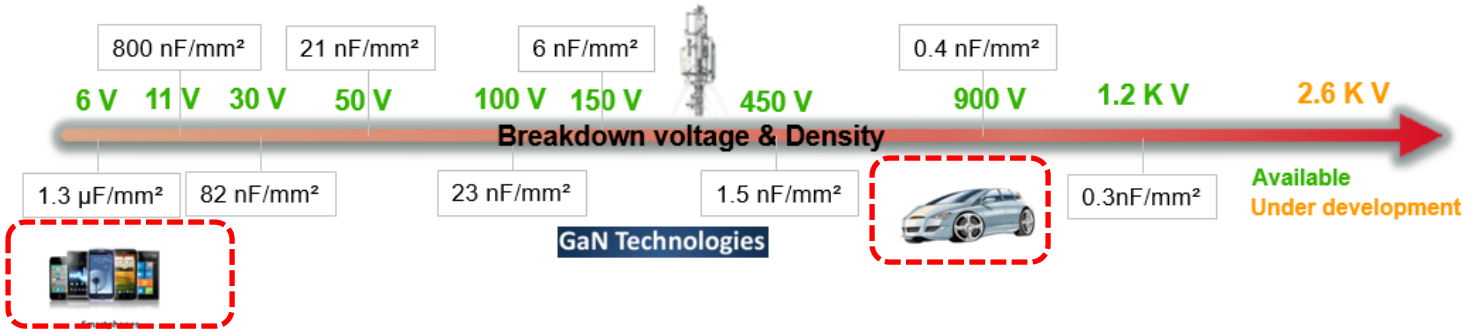
High stability in temperature
Up to **250°C** environments

Signal stability over frequency
Up to **110 GHz** applications

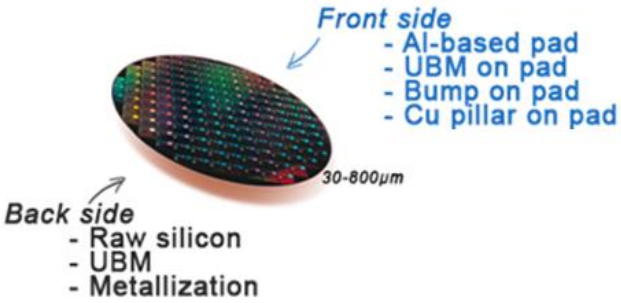
Stability regarding voltage
For **450 V** applications

Stability over ageing
Minimum lifetime of **10 years**

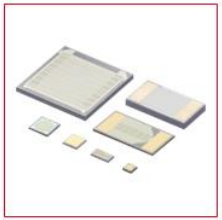
Extreme low thickness
Down to less than **50 µm**

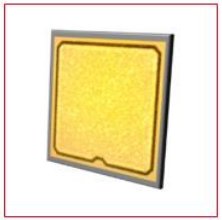


2- Different configurations



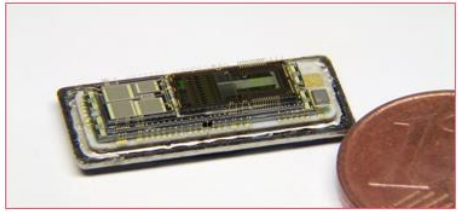
Stand alone and standard components :
horizontal and vertical capacitors





Component arrays:
combination of several passive components into a single silicon die

Interposers:
use of semiconductor assembly technologies to build high performance 3D structures



2- Market Drivers and challenges

Market description	- Automotive / Under-the-hood electronics
Typical use cases	- Temperature sensor - Rotation speed - Bearings control
Key challenges faced	- Space and weight constraint - Reliability, lifetime
Market drivers and trends	- Shrink more and more electronics under-the-hood - Need of stable and reliable electronics at temp. above 175°C

High Volt./Current

Market description	- Telecom infrastructure - Base stations - Radars
Typical use cases	- Integration in power RF transistors - Wireless modules - Transmitters
Key challenges faced	- Miniaturization - Performance reliability - ESL
Market drivers and trends	- Insatiable demand for higher data bandwidth - Higher volumes, and faster and wider coverage

High Reliability/Temp.

Si Capacitor

High Capacitance

Market description	- Medical Electronics
Typical use cases	- Pacemaker - Monitoring - Hearing aid - Eye implant
Key challenges faced	- Space and weight constraint - Reliability, lifetime
Market drivers and trends	- Get smaller and longer lasting devices to simplify surgical operations and reduce their cost.

Smaller Thinner

Market description	- Electronics for Power and Signal integrity
Typical use cases	- High speed IC - Power distribution network - Application processors in smartphone
Key challenges faced	- Space constraint - ESL - BGA pitch size
Market drivers and trends	- Need ultra low ESL capacitor in ultra low profile - Need to decrease the Power Delivery Network impedance

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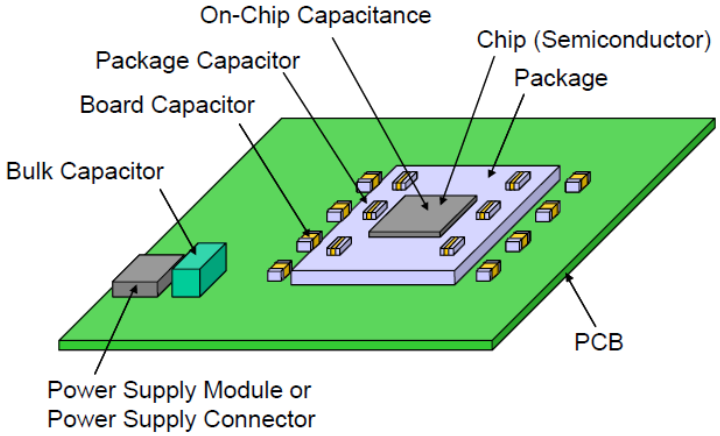
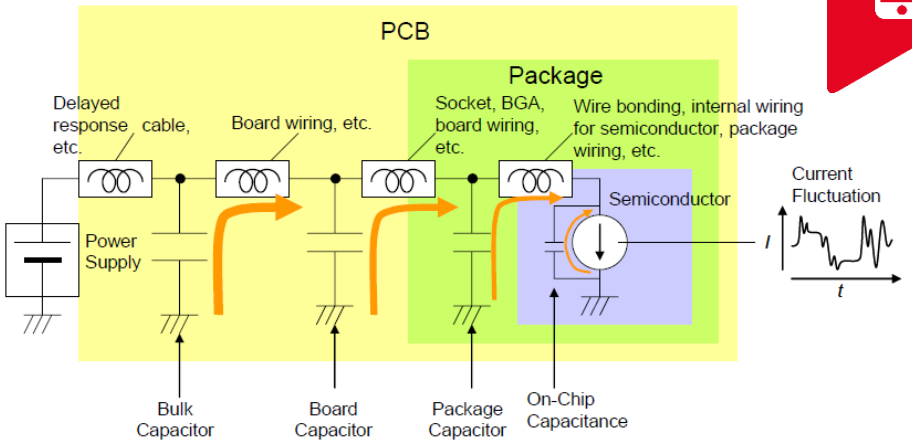
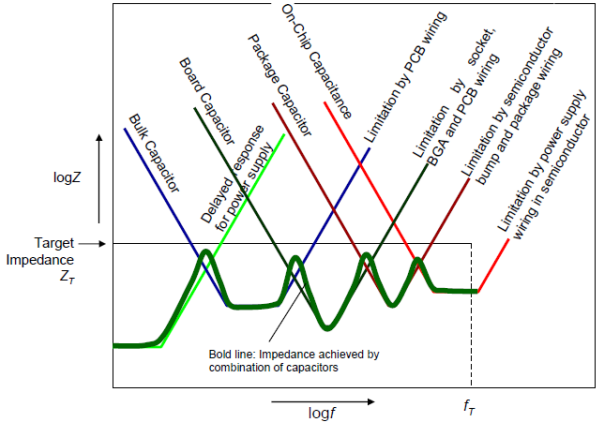
3- PDN Applications



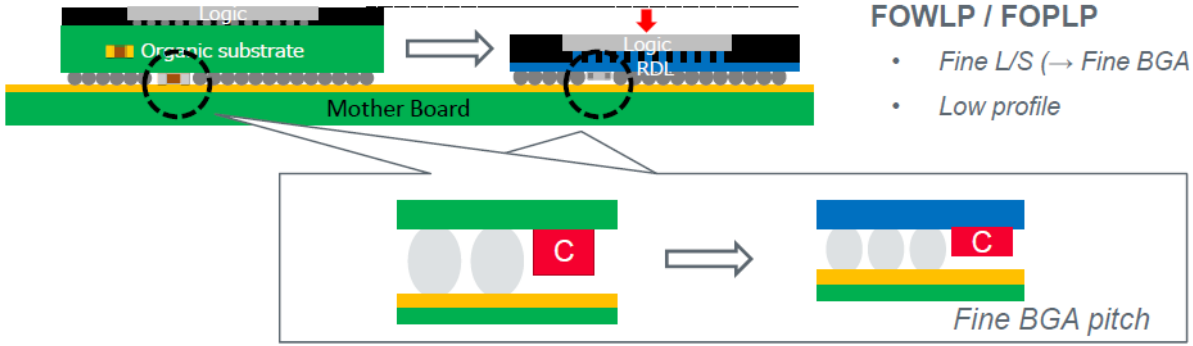


- Power supply impedance must be made small over a wide frequency range
- One capacitor cannot achieve the necessary impedance, multiple capacitors are positioned hierarchically to achieve the target power supply impedance
- Due to space constraints, on-chip capacitance is not enough to reduce impedance at high frequencies.



3- PDN Applications_Requirements

Thickness



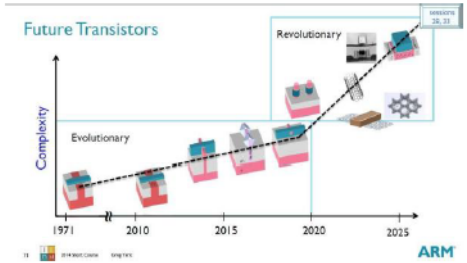
FOWLP / FOPLP

- *Fine L/S (→ Fine BGA pitch)*
- *Low profile*

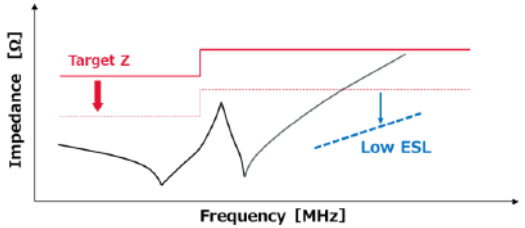
Low profile capacitor is needed

ESL

Microfabrication of process ⇒ Lower target impedance



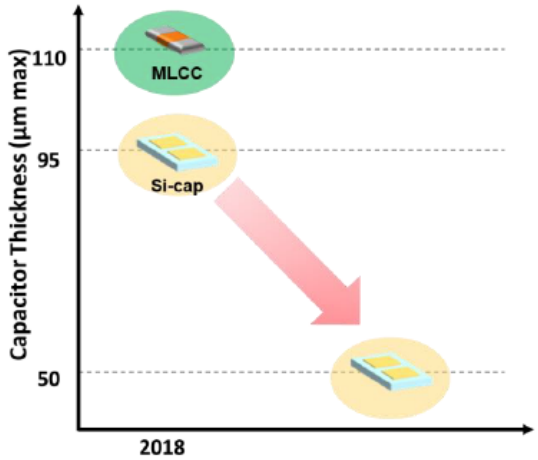
10 nm → 7 nm → 5 nm…



Low ESL capacitor is needed

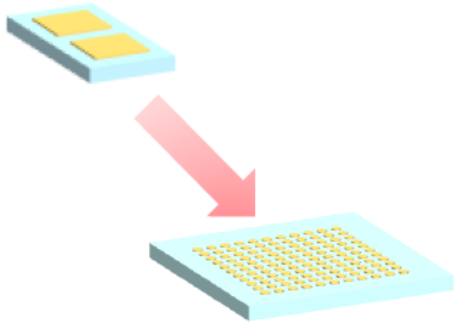
3- PDN Applications_Improvements

- Low profile



- *Achieve low thickness (~ 50 µm)*
- *Higher robustness*

- Multi-terminal

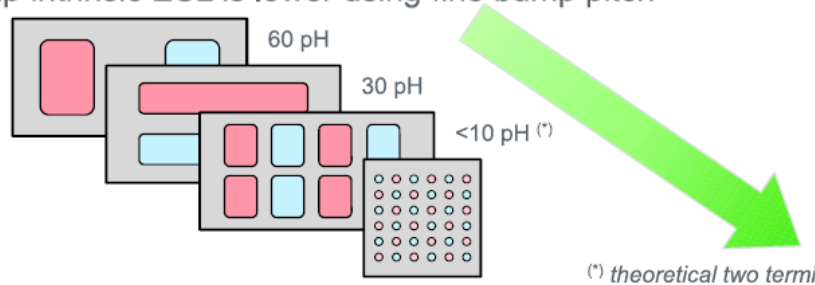


- *Design many terminals on capacitor*

Extremely low ESL < 10pH

3- PDN Applications_Benefits

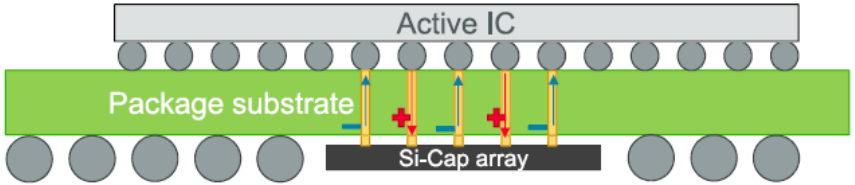
- Si-Cap intrinsic ESL is lower using fine bump pitch



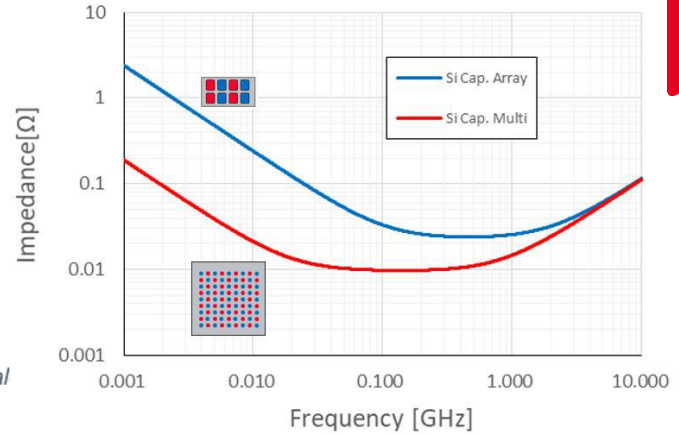
(*) *theoretical two terminal equival*

- Assembly ESL is reduced

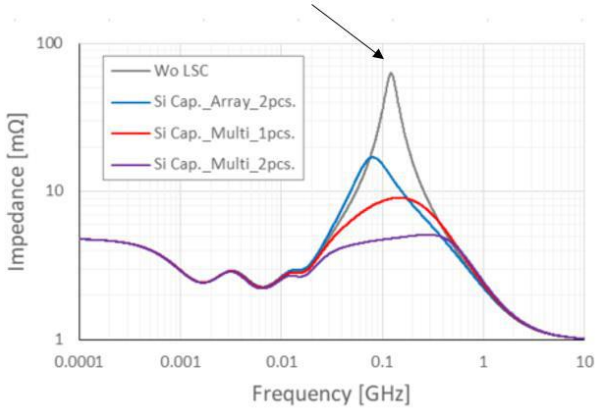
Multi-term generate smaller current loop ➔ lower ESL
Particularly with multi-terminals (shorter distance between pads)



Typical Assembly Schema_Cross section view



Z_{peak} : anti-resonance between Chip and Board



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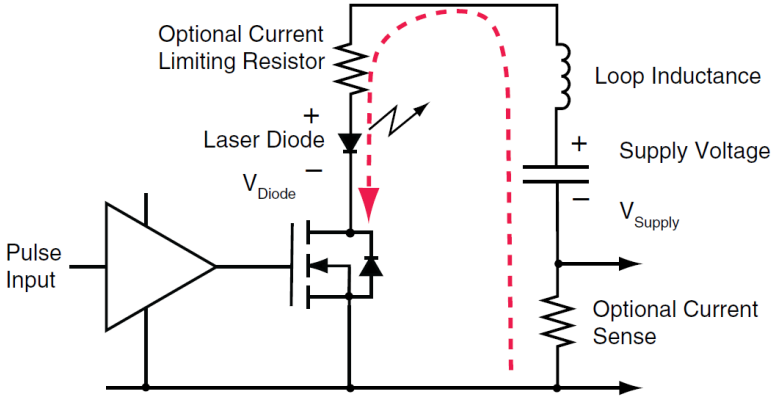
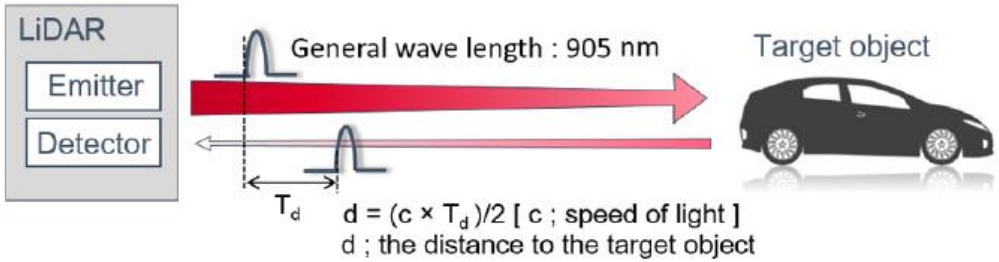
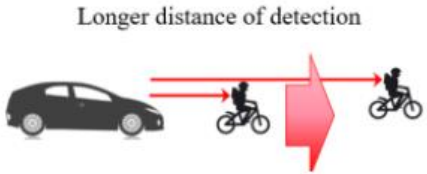
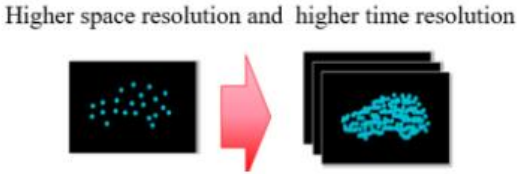
3- LiDAR Applications





- In a LIDAR system to increase resolution current needs to be switched as quickly as possible through the laser diode.
- Gan FET's have very low input capacitance and can switch on very fast





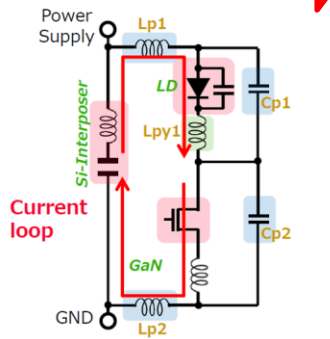
3- LiDAR Applications_Requirements

General requirements for LiDAR

- Longer range detection
- Higher space and time resolution
- Compliance with eye safety standards

General requirements for laser pulse

- Higher peak power
- Shorter pulse width
- Stability of pulse
- High reliability



Equivalent Circuit with Parasitic Contribution

Needs for Capacitor

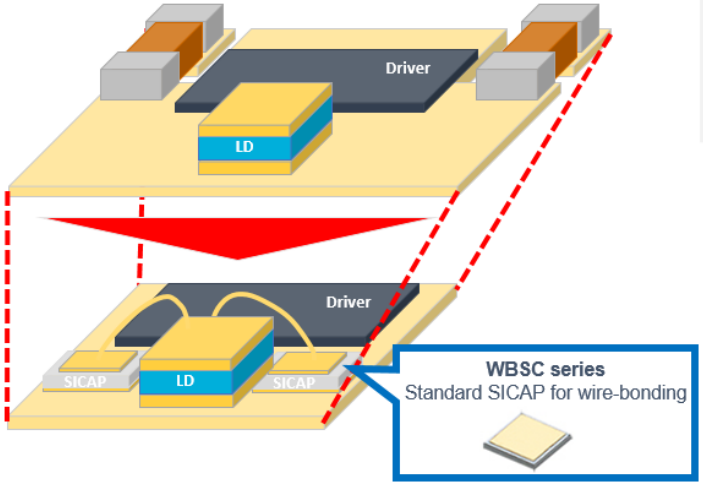
- Withstand higher voltage : 120V as applied voltage
- Higher capacitance value : ~ 10nF
- Low ESL: 100pH for whole circuit
- Stable capacitance value vs temperature (up to 105℃)
- Availability of Wire-bonding

Needs for Interposer

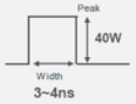
- Withstand higher voltage : 80V as applied voltage
- Low ESL: 100pH for whole circuit

3- LiDAR Applications_Improvements

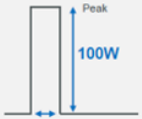
Design optimization by using SICAP for **lower loop ESL & miniaturization**.

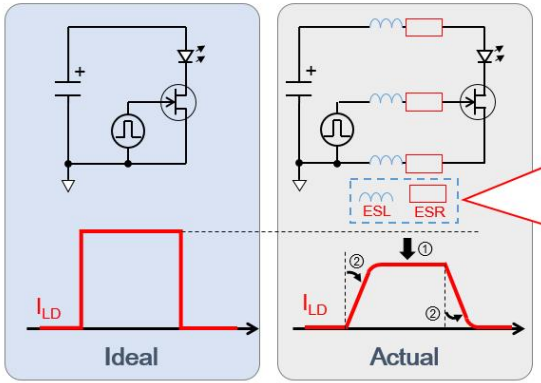


Ceramic Capacitor
Light output 40W×3~4ns



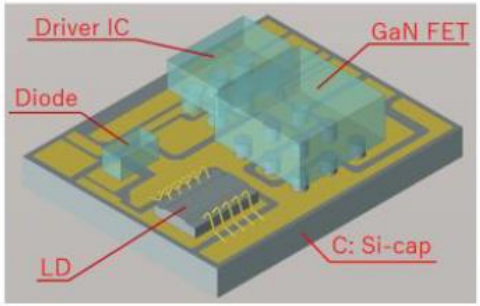
Silicon Capacitor
100W×1.5ns

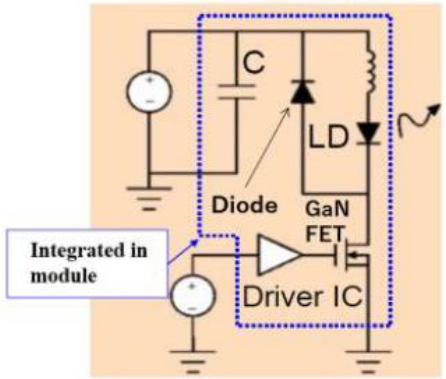


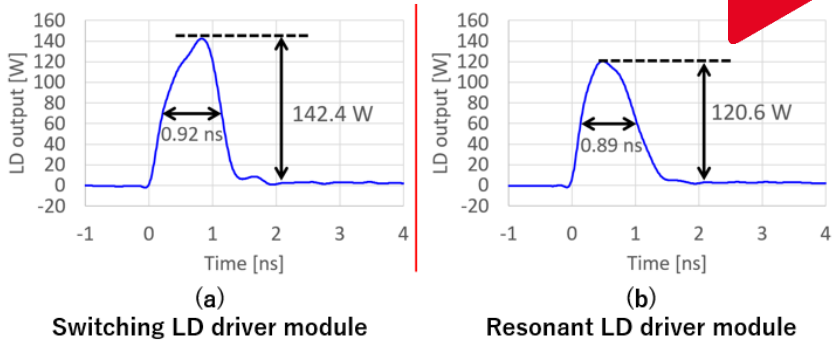


Effect ① : Decrease LD current peak
Effect ② : Decrease LD current change rate
↳ **Lower peak power & longer pulse width**

3- LiDAR Applications_Benefits

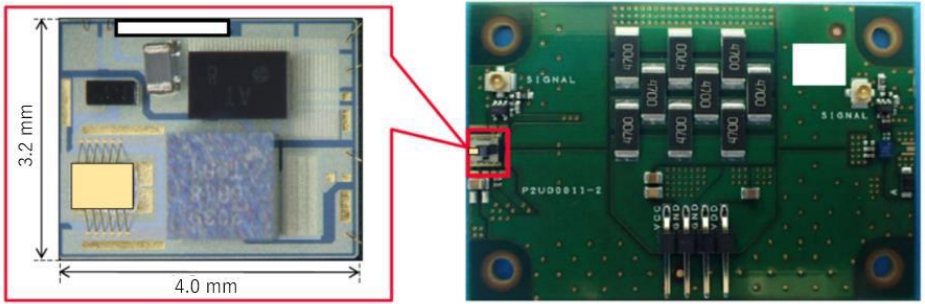






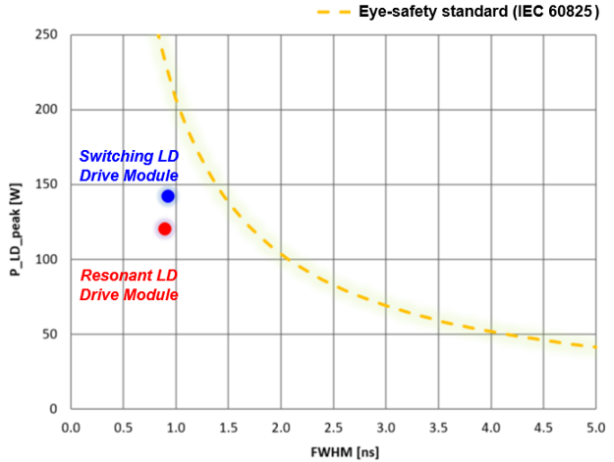
(a) Switching LD driver module

(b) Resonant LD driver module



Si-IPD

PCB



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- PwrSiP and PwrSoC are pushing passive devices to their technological limits
- Many parameters to take into account: specific to the passive component but also in relation with the surrounding environment (packaging, parasitic)
- Silicon technology presents a good alternative to classical solutions
- PDN applications (Mobile & HPC)
  - Requirements in terms of high density, low profile and low ESL
  - Silicon capacitors flexibility: process, materials, design, interconnects and assembly
  - Challenges in integration, testability, measurements (very low parasitic), simulations (electrical and mechanical robustness)
- LiDAR applications (Automotive)
  - High voltage, low ESL loop, Thermal stability
  - Silicon capacitive interposer presents innovative solution from electrical and assembly point of view
  - Challenges: automotive reliability standard (AEC-Q100) and Eye safety (IEC 60825)

Thanks a lot for your time and attention!

Any questions and/or comments?