Numerical evaluations of 3D stacking power SoC

Wataru Yoshida, Kengo Hiura, Satoshi Matsumoto
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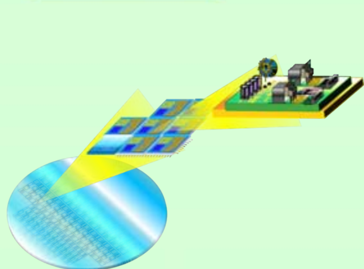
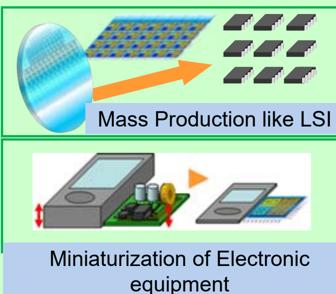
Introduction

Power SOC

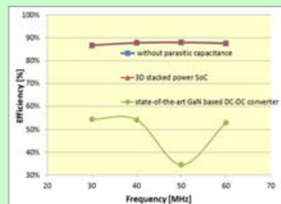


Advantages



Mass Production like LSI

Miniaturization of Electronic equipment

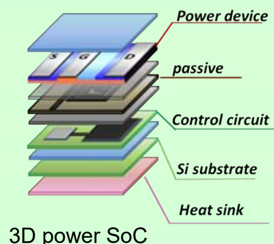


Y. Ikeda et al., to be presented at pwr-SoC2016

High Efficiency

Challenges

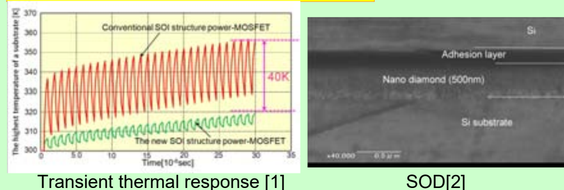
- High frequency switching
  - ⇒ 3D power SoC
  - Self heating
  - Electro magnetic noise
  - 3D stacking process



3D power SoC

Approaches

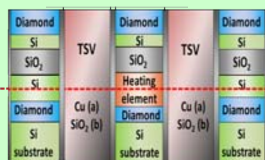
Silicon on Diamond (SOD)



Transient thermal response [1]　　SOD[2]

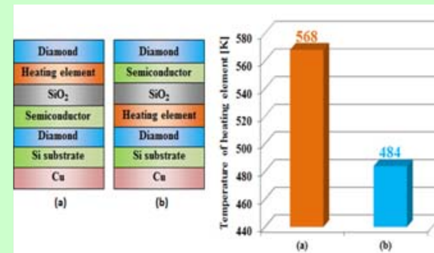
[1] K. Nakagawa, et al., JJAP, vol.53, No.4, 04EP16, 2014.
[2] S. Duangcham, et al., IEEE ECTC, 2015.

TSV

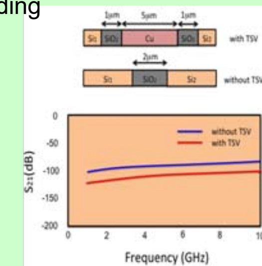


Results

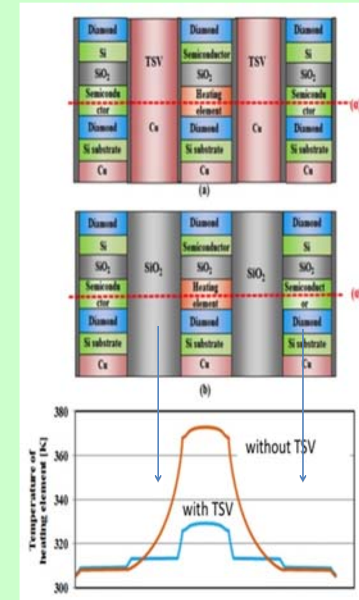
Position of heating element



Impact of TSV for noise shielding



Impact of TSV for self heating



Conclusions

TSV

Good heat exhausting

Good noise shielding

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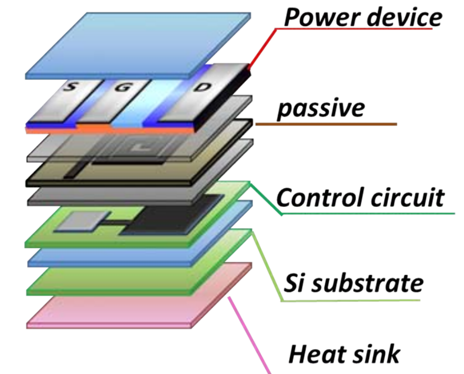
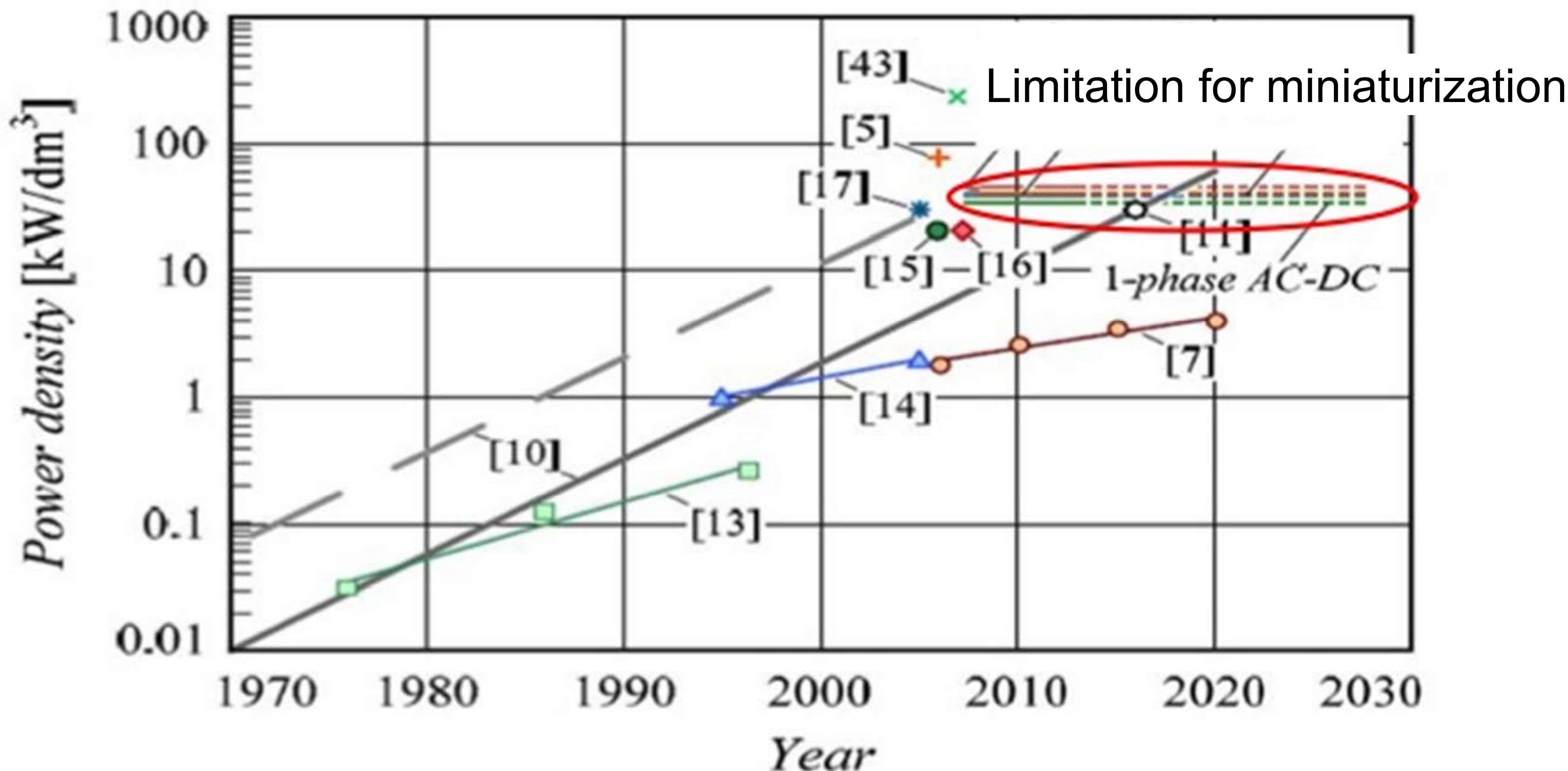


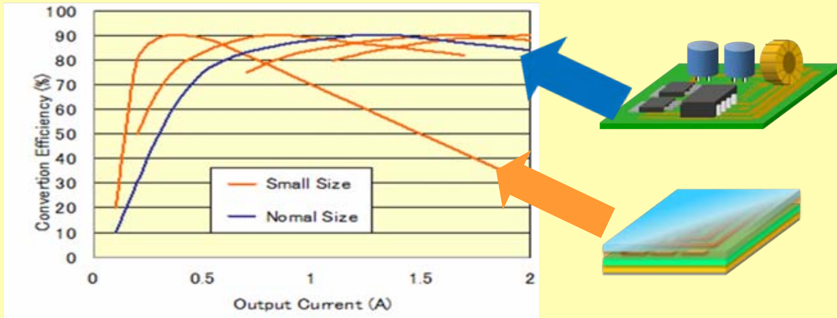
Trend of the miniaturization of the power supply



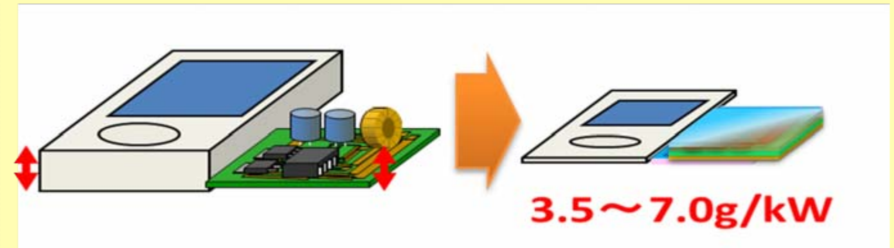
J. Kolar et al., PCC Nagoya, p.9, 2007

Advantages of miniaturization

①High efficiency

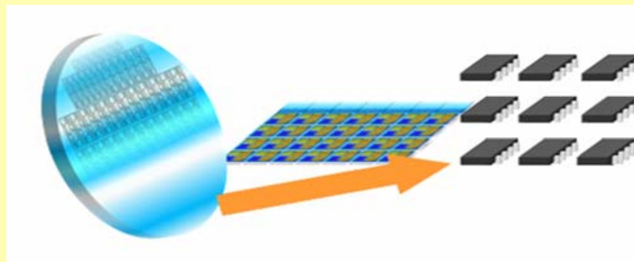


②Size and weight reduction



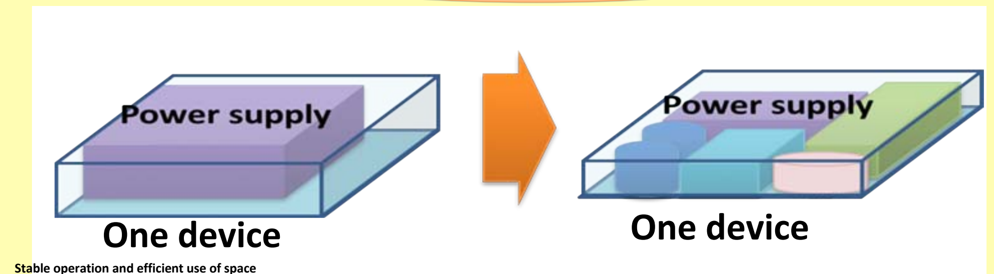
Miniaturization of electronic devices

③Cost reduction



Mass production

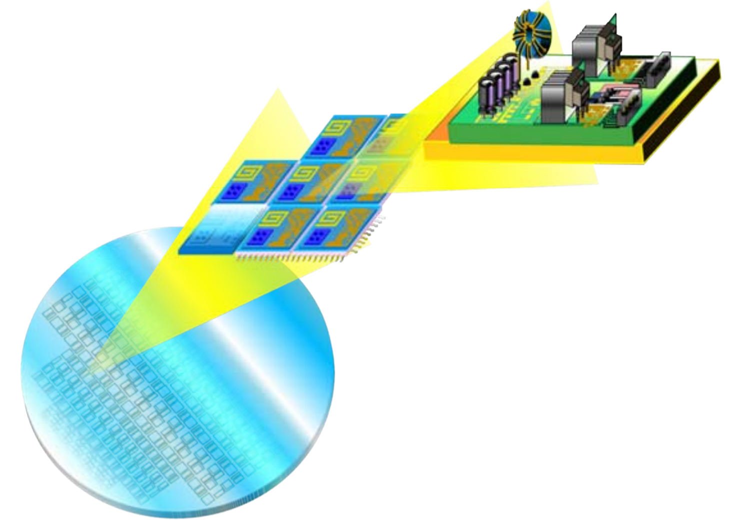
④High functionality



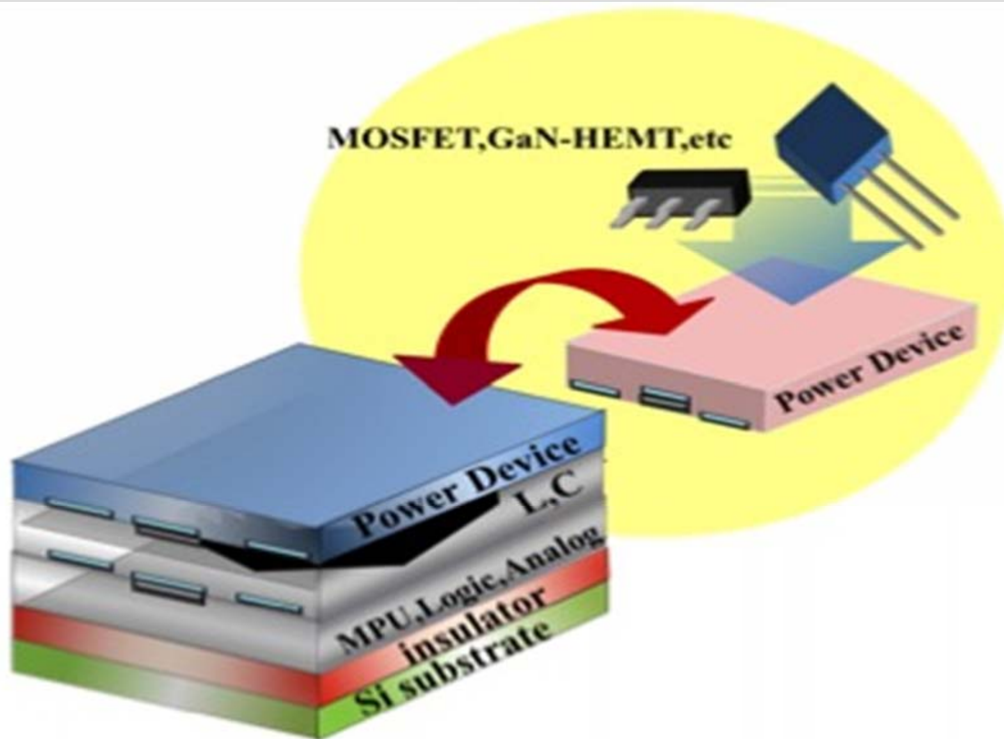
Stable operation and efficient use of space

Challenges for miniaturization

- **High frequency switching**
  - Minimize the parasitics
    ⇒ 3D power SoC
  - GaN power device
    ⇒ 3D power SoC
  - Control・Topology
- **Heat exhausting**
- **Noise**
- **Fabrication process**
- **Reliability**



3D power SoC

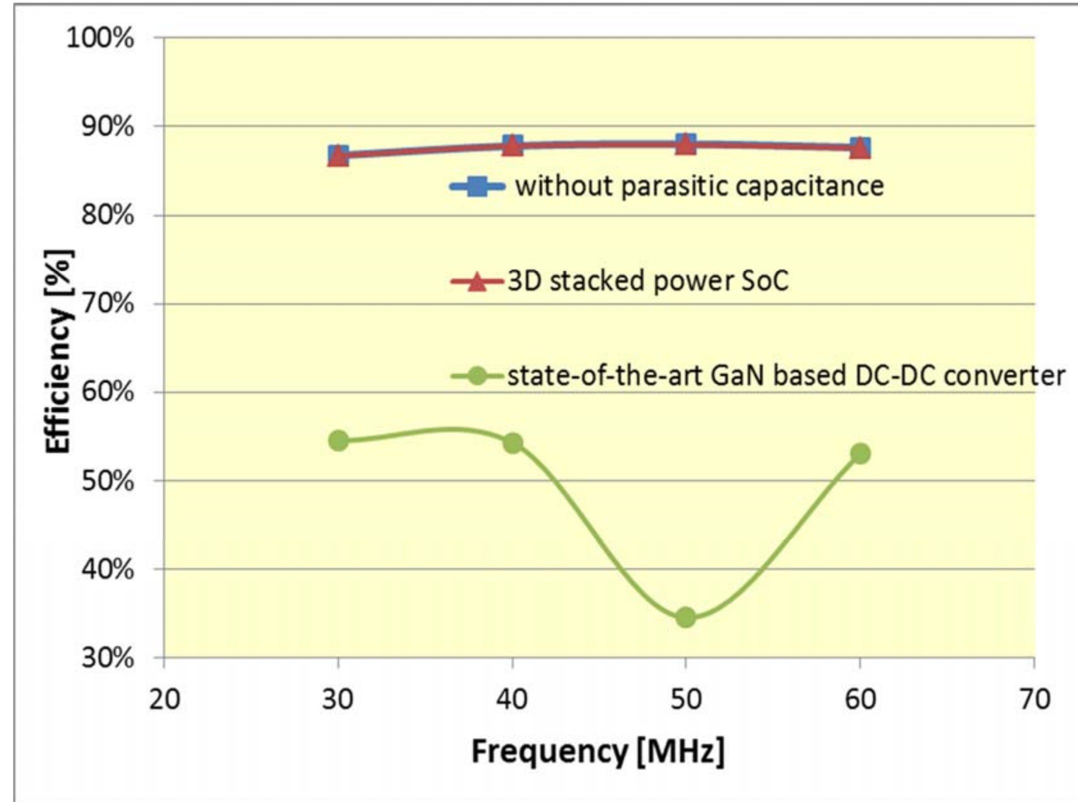


Challenges

- High frequency switching
  → Topology, Control
- Lower loss
  → GaN
- Heat exhausting
  →Silicon on Diamond
- Insulation・Isolation
  → Silicon on Diamond
- Fabrication process

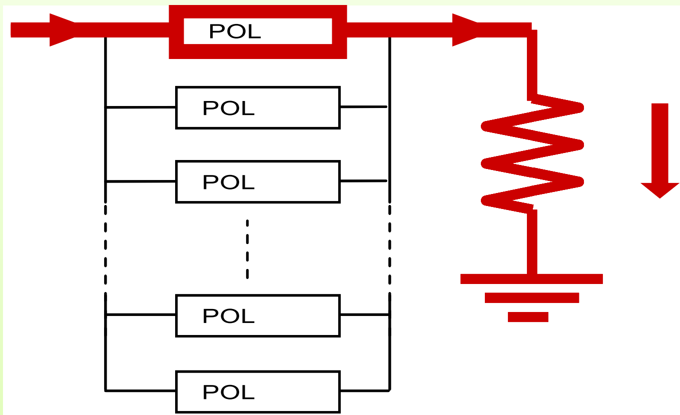
➡ TSV?

3D power SoC : high frequency switching

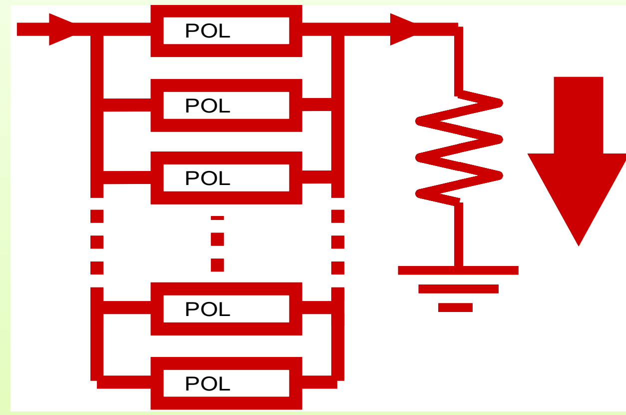


Y. Ikeda et al., to be presented at pwr-SoC2016

Control technology



Light load (low-current)



Heavy load (high-current)

$$V_{out} = D \cdot V_{in} - \frac{r}{N} I$$

① **Regulating output voltage without PWM control**

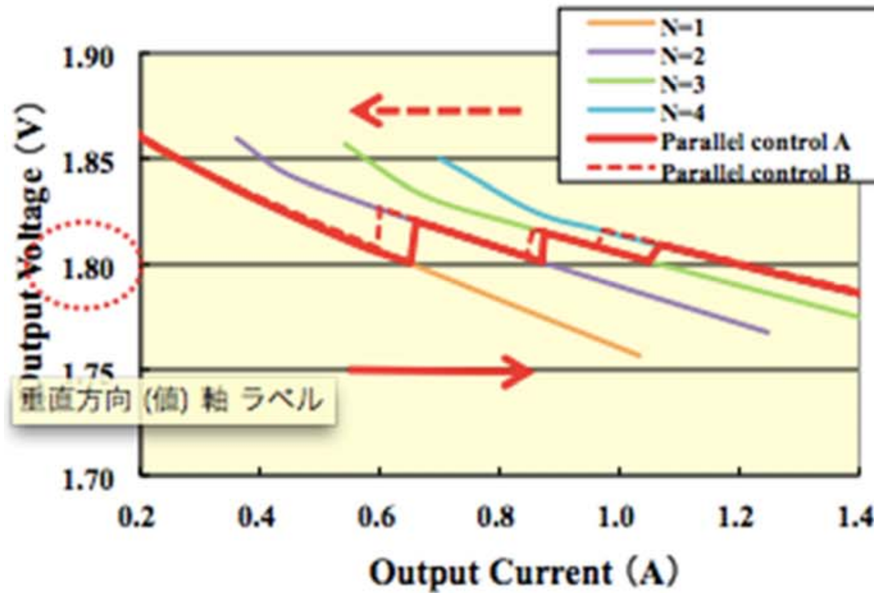
② **Higher efficiency**

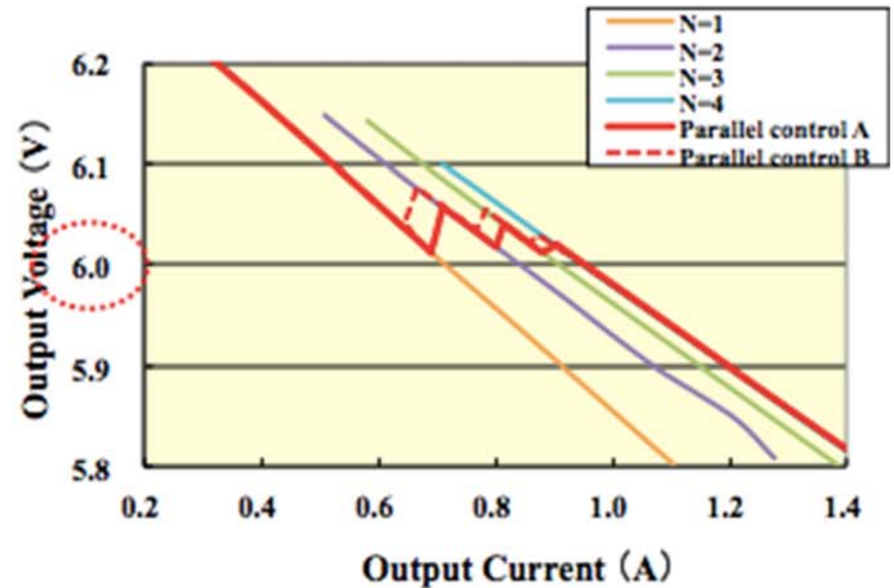
T. Yamamoto et al., Proc. IEEE PEDS, p.109, 2013.

Control technology

Buck converter
Target voltage : 1.8[V]

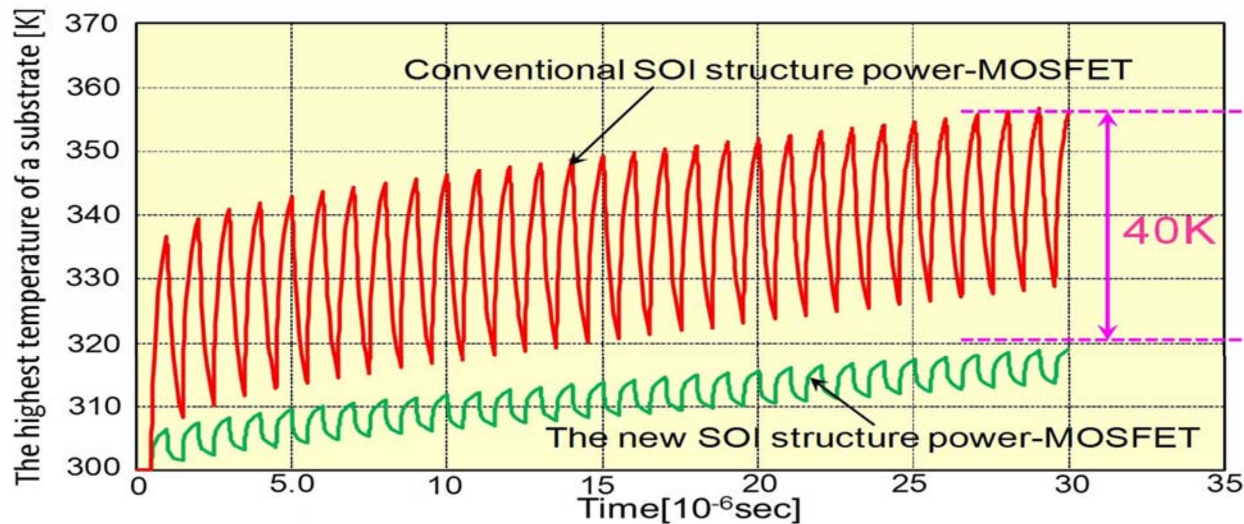
Boost converter
Target voltage : 6.0[V]



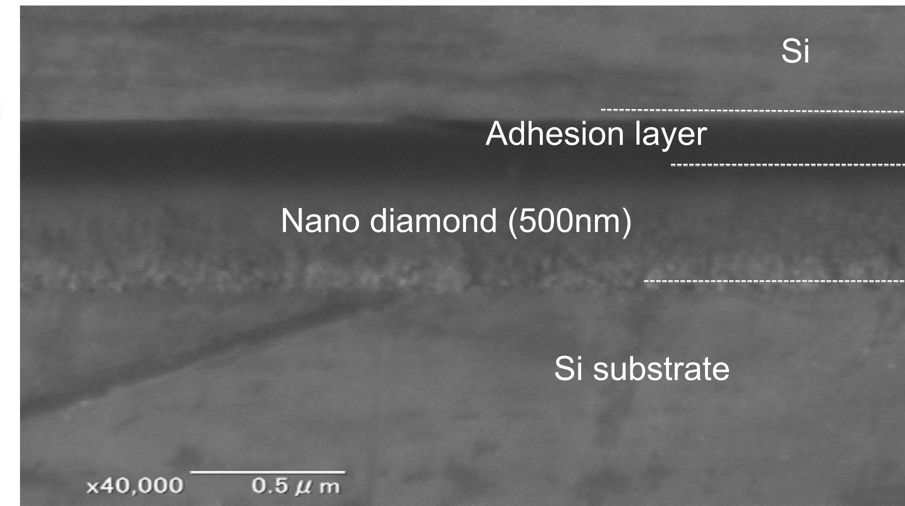


M. Higashida, EPE 2015, LS1e.4, 2015.

Heat exhausting and insulation: Silicon on Diamond



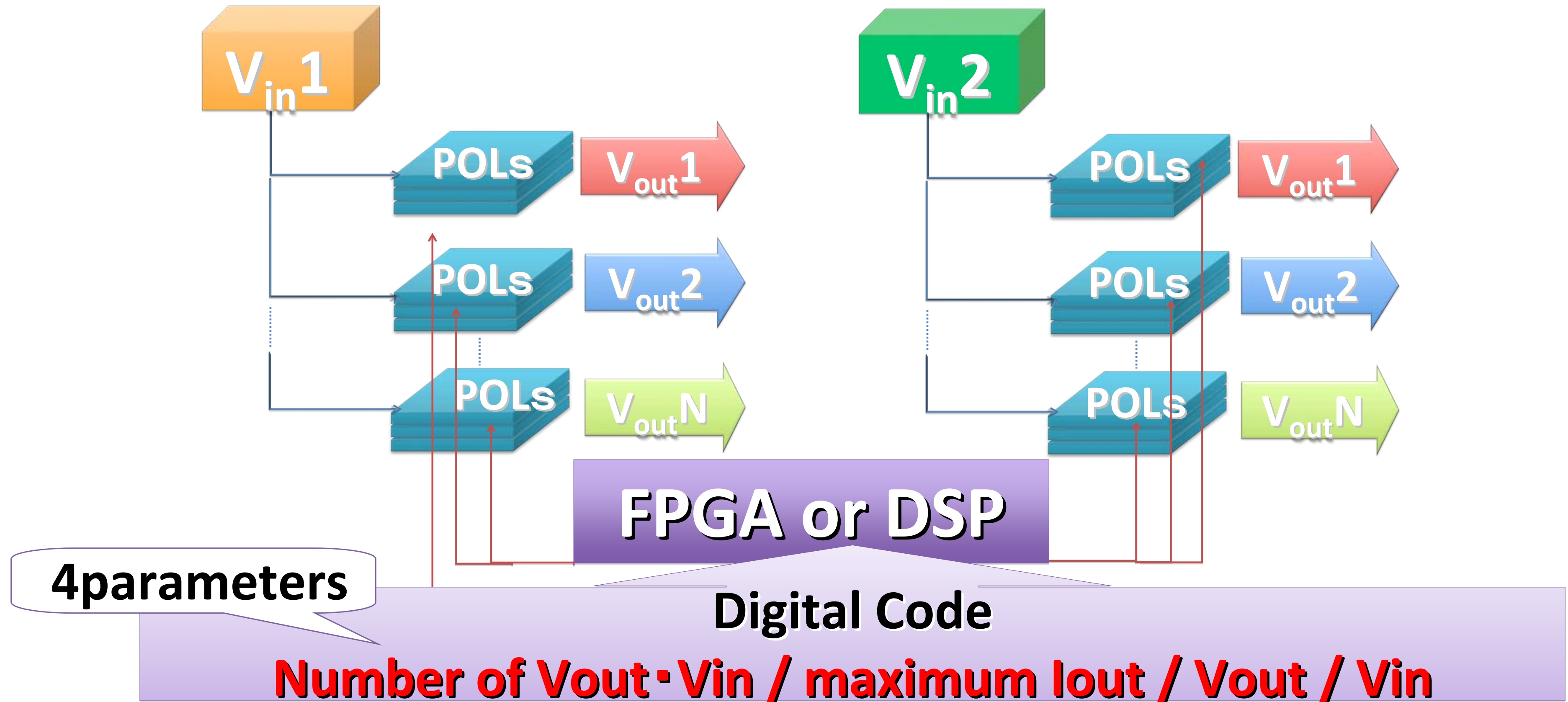
Transient thermal response [1]



SOD substrate (Room Temperature Wafer Bonding [2]

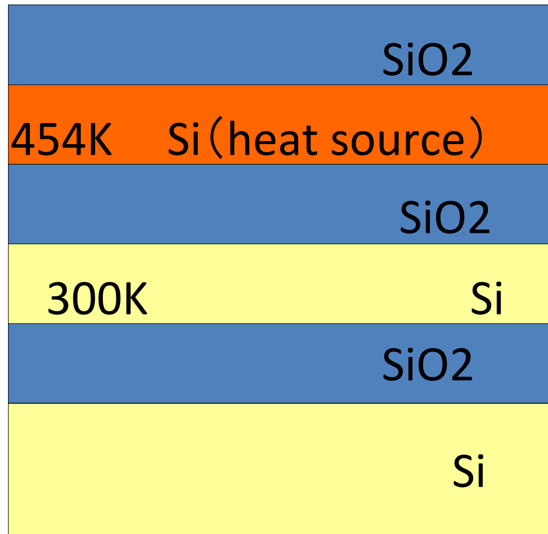
[1] K. Nakagawa, et al., Japanese Journal of Applied Physics, vol.53, No.4, 04EP16, 2014.
[2] S. Duangcham, et al., IEEE Electric Components and Technology Conference 2015

Field programmable power supply array



M. Higashida, EPE 2015, ECCE Europe , LS1e.4, 2015.

3-D stacking structure



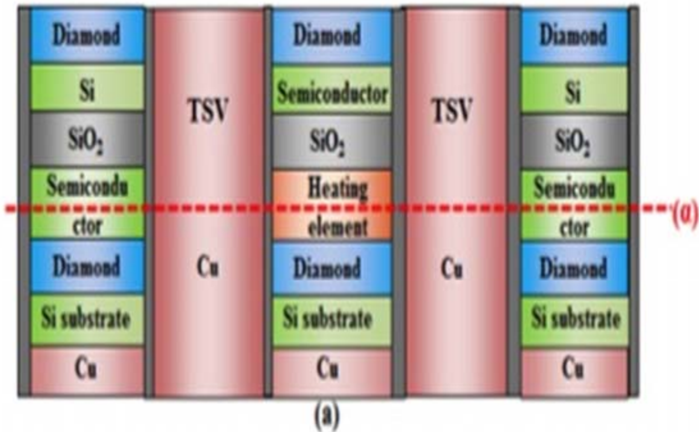
(a)

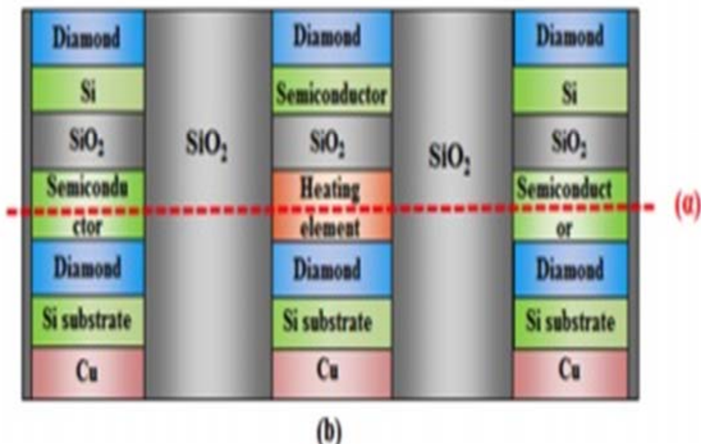
(b)

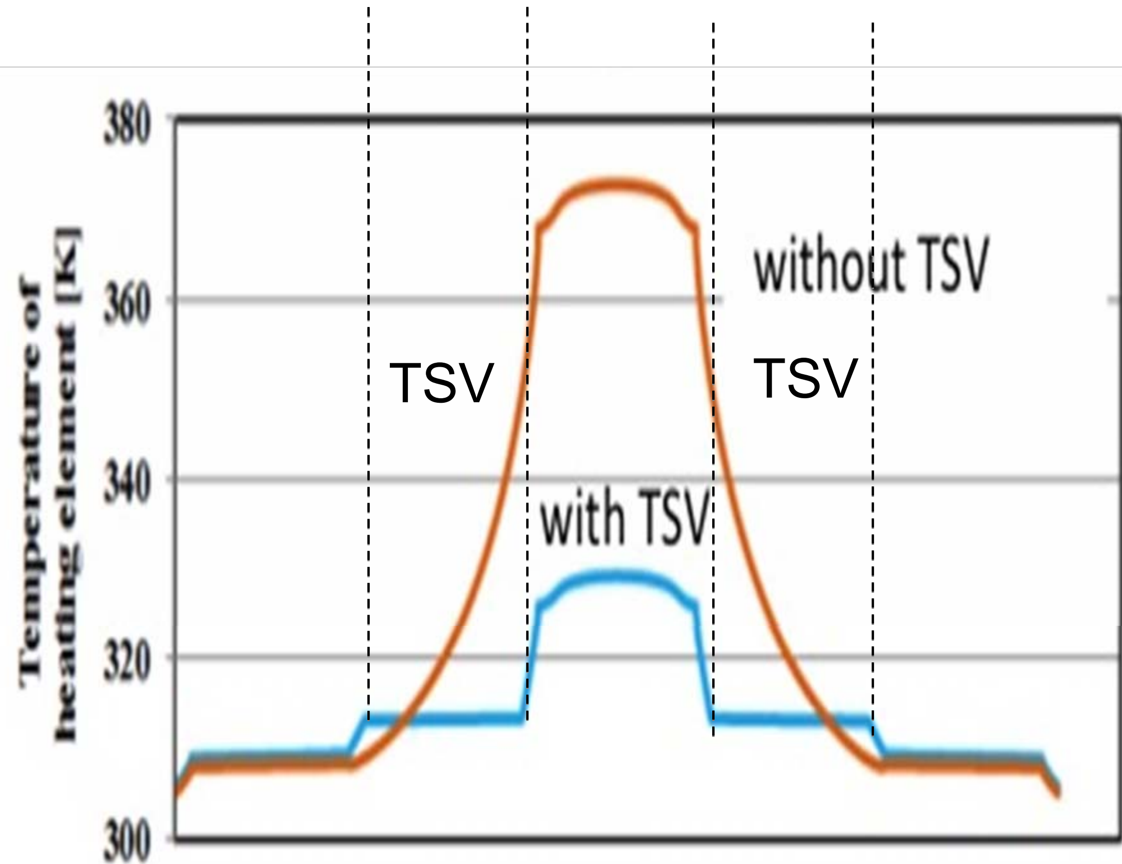
(c)

W. Yoshida et al., International Power Supply on Chip Workshop 2014, p.73, 2014.

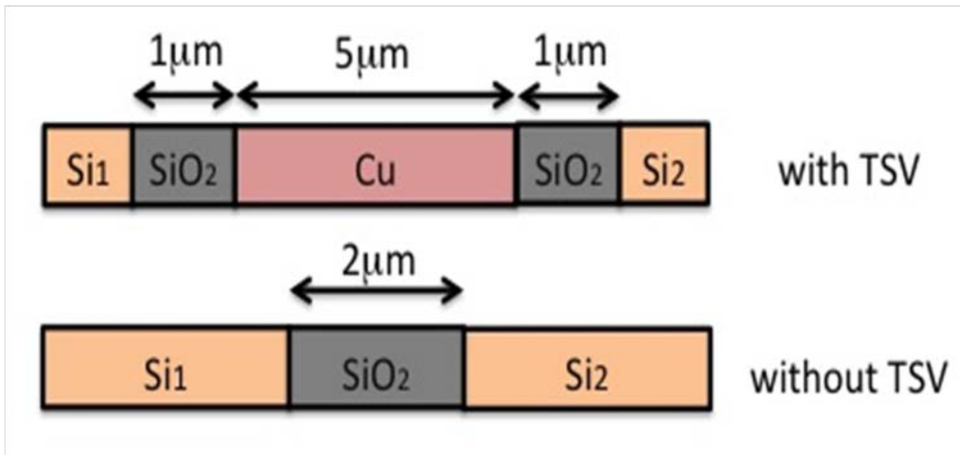
Impact of the TSV -- heat exhausting --

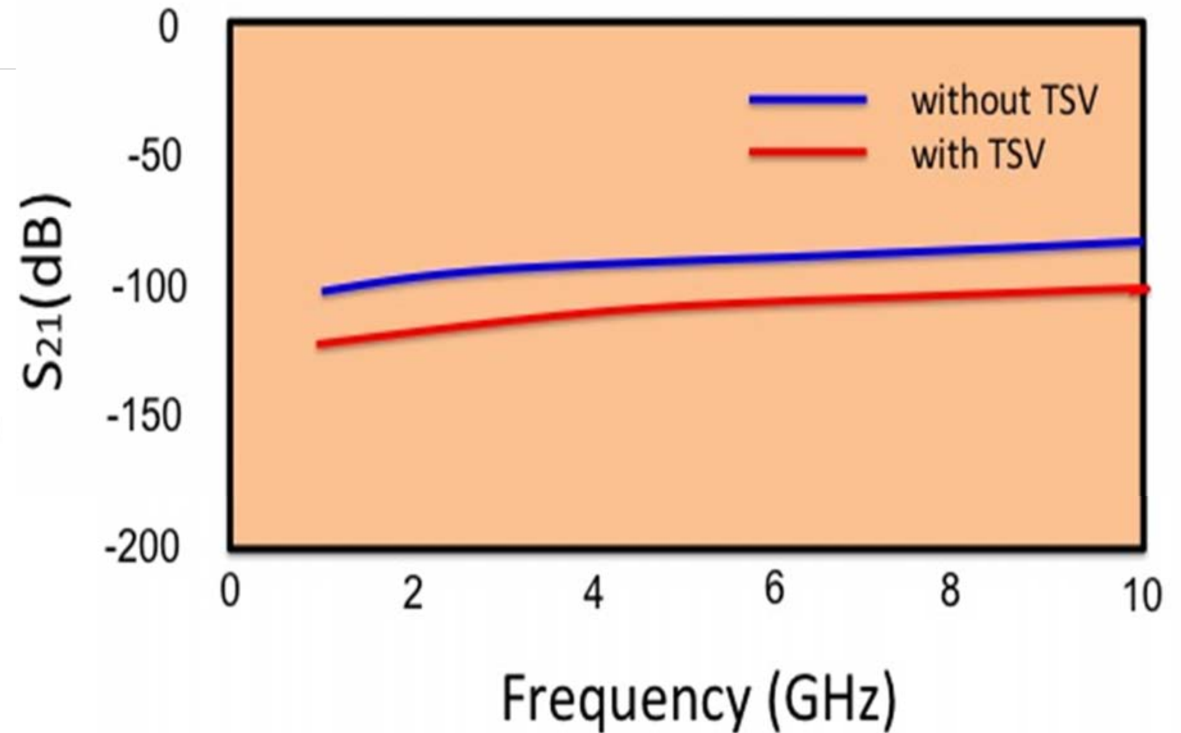






Impact of the TSV -- Noise --





Summary

3D stacked power SoC

Si-LSI with GaN power devices

TSV

Good heat exhausting

Good noise shielding