3D Capacitors : manufacturing and applications

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IPDIA’s “PICS” passive integration (IPD) technology is a highly efficient way to integrate 10’s to 100’s of passive components such as Resistors, Capacitors, Inductors and Zener Diodes in a single Silicon die.

IPDIA’s Value proposition is:
- Miniaturization
- Performances
- Cost
PICS High Density Trench Capacitor

\[ C = \frac{\varepsilon_0 \varepsilon_S \cdot S}{e} \]

- metal top electrode
- n⁺-polySi
- dielectric
- n⁺-Si
- lower electrode
- n⁻-Si substrate
- lower electrode
Characteristics of the first three generations of PICS

<table>
<thead>
<tr>
<th>Architecture</th>
<th>Pores</th>
<th>Trenches</th>
<th>Stacked structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>PICS1</td>
<td>Depth: 17µm</td>
<td>Depth: 30µm</td>
<td>Depth &gt; 45µm</td>
</tr>
<tr>
<td>PICS2</td>
<td>Depth: ~30µm</td>
<td>Depth: &gt; 45µm</td>
<td></td>
</tr>
<tr>
<td>PICS3</td>
<td>Depth: &gt; 45µm</td>
<td></td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Electrical</th>
<th>PICS Cap (nF/mm²)</th>
<th>VBD PICS (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PICS1</td>
<td>25</td>
<td>30</td>
</tr>
<tr>
<td>PICS2</td>
<td>x 3</td>
<td>x 0.5</td>
</tr>
<tr>
<td>PICS3</td>
<td>x 3</td>
<td>x ~0.8</td>
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</tbody>
</table>

- Increase pore aspect ratio
- Optimize dielectric thickness

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Increasing capacitor surface (S)

- Increasing $\varepsilon_s$
  - High-k materials (ALD, MOCVD, Sol gel)

- Increasing capacitor surface (S)
  - Deeper pores, new pore shapes, more stacks…

- Thinning dielectric (e)
  - Limited to BV & lifetime requirements
The Vertical Cap High Voltage

Key features

- 6 nf/ mm²  Operating voltage =30V , VBD= 100V
- Ground connection to the back of the Silicon capacitor
- Wirebond connection on top for the voltage line.
- Thickness 250 µm
- Lifetime extremely high
Performances

The IPDiA Silicon Capacitor technology offers several technical improvements over the MLCC technology:

- Stability over time and temperature, no aging, no capacitance shift
- Stability with applied voltage, no Voltage derating
- Very good matching capability, < 1.5% per array & tight distribution
- Much higher initial IR values (>1Gohm), no DC leakage
- Low parasitics
- Low thickness capability
High temperature capability of 200°C with no Capacitance shift
High temperature capability of 200°C with less than 0.1 % voltage derating

Example of a Capacitor of 100nF
Low parasitics (ESR, ESL)

ESR < 40 mOhms
ESL < 250 pH
Q factor (> 400)
Very good Capacitance stability vs frequency
Thanks to ultra low ESL performances, frequency rejections can be improved by 15dB.

Application example: Power Supplies decoupling
Low leakage current

Insulation resistance
Between 2 caps is high
> 50G ohm.µF

Leakage current is
< 30nA/µF
under normal operating voltage
IR> 1Gohm
## Inductor value vs Application/ Frequency band

<table>
<thead>
<tr>
<th>Application</th>
<th>0.1nH..0.9nH</th>
<th>1nH..10nH</th>
<th>11nH..99nH</th>
<th>100nH..999nH</th>
<th>1uH..9uH</th>
<th>10uH..99uH</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Micro&quot; DC/DC converters</td>
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<tr>
<td>Power DC/DC converters</td>
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<td>GSM/DCS</td>
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<tr>
<td>Wifi, Wimax, UWB</td>
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<tr>
<td>ISM applications</td>
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<td>EMI filtering</td>
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<td>TV applications</td>
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</table>

Other standard where our technology is: Bluetooth, Zigbee
Standard RF Silicon devices

- Companion for ISM tranceiver
- ISM Coupler
- WLAN Band Pass Filter 2.4-2.5 GHz.
- GSM/DCS Duplexer
- Stub for impedance matching at 70 GHz
- GSM Balun
- GSM LB Balun
- GSM Low Pass Filter
- UWB Balun
- High frequency capacitor 80 GHz

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Packaging

WL-CSP directly flipped on PCB:
Compatible with soldering technologies, such as wave soldering and reflow

Companion chip (package)

Active dies flip-chipped on IPD)
Packaging

Stacked dies)

Embedded die

Chip on board (COB with globtop)
Situation I: Silicon Interposer for on board applications with SMDs

Situation II: Silicon Interposer for WLCSP SIP

Situation III: Silicon Interposer for digital die
PICS with TSV

C7 die
C5 die
C4 + C8 die
C6 die
Laminate / PCB

~600µm with 100µm
die thickness and 50µm
bumps
Custom products
and
their application
Custom PICS realization

**IPD RF module**

**Cellular** (800MHz to 2GHz: W-CDMA)

- **Balun array** flip chipped on laminate (SIP)
- Integration of 42 SMD (RF capacitors, Rf inductors, RF baluns & decoupling capacitors) for multi-band WCDMA transmitter

**IPD RF module** (with 73 SMD embedded)

- **Cellular** (passive part of W-CDMA & GSM RF transceiver)
  850-950MHz & 1.7-1.9GHz

- **RF Silicon carrier** flip chipped on lead frame (SIP)
- Components: RF capacitors, RF inductors, RF baluns, loop filters, decoupling capacitors and RF ESD protections.

1.5 mm x 5 mm

5 mm x 5 mm
An electronic pill with a PICS die on Flex

- **Market:** Medical
- **Application:** Temperature and medicine in-situ monitoring
- **96 SMD components** are integrated and composed of RF capacitors, decoupling capacitors, resistors, inductors, ESD diodes and PIN diodes.
- **3 actives die flipped** over an IPD Substrate including components and interconnects
A DC/DC converter with PICS

- Market Application: Consumer
- Frequency range: **100 MHz**
- Components: Resistors, capacitors, Inductor, Interconnects

**Module architecture**

**Active die flip-chipped on the IPD**

**2nd interconnect bumps on IPD**

**Double flip-chip on lead frame**

**HVQFN40 final package**
A DC/DC converter with PICS for a LED driver

- Die size: 4.4 x 4.2mm
- 27 passive components
  (19 resistors, 8 capacitors)
Full DECT RF Module

- Market Application: **Cordless**
- Frequency range: **1.8-1.9GHz (DECT)**
- Components: RF capacitors & matching, Decoupling capacitors, Inductors for balun, loop filter, serial resistors...

System in Package in a HVQFN32 package (5mm x 5mm)

Previous RF application size

~450mm²

New RF application size

~30mm²

Assembly: 2 active dies flip-chipped on the IPD

Only one HVQFN chip + 2 external capacitors
Checklist to start a study

- More information we will have, deeper the analysis will be...
  - Application domain
  - Electrical schematics
  - Application layout
  - Pictures, datasheet
  - Bill Of Materials (capacitor size, type, quantity, price, from which company…)
  - Voltage supply and electrical signals (Voltage, current, frequency, duty-cycle…)
  - Life time
  - Reliability

![Partial Schematic]

![Micro photograph of application]

![BOM]

![Complete schematic of application]

![Complete layout of application]
Conclusion

• The technology is proven in the consumer market

• It’s being adopted in the medical domain

• We are adapting our technology to the customer needs to make it a success
Thanks for your attention