# 3D Packaging and Reliability

Klaus Pressel

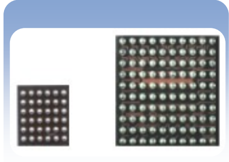
European 3D TSV Summit and CATRENE projects
Grenoble (France), January 22nd, 2014

# Content

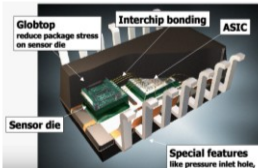
- **Motivation: System Integration Everywhere**
- **System integration: Packaging makes the Difference**
- **Success factors**
  - Understand reliability requirements of customers
  - Innovative assembly and packaging technologies
  - Understand material physics
  - Coherent chip-package-board co-design
  - Management of complexity
- **Conclusions**


Copyright © Infineon Technologies AG 2013. All rights reserved.

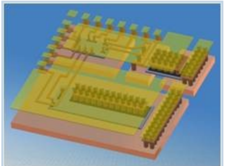
- Communication and Computing



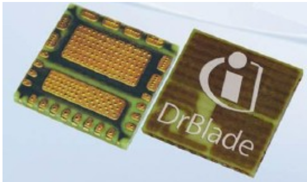
- Automotive Electronics



- Energy generation and energy distribution (e.g. smart grid)



- Industrial Electronics
  (e.g. energy efficient driver)



- And others: e.g. Solid State Lighting, medical, aeronautics, …

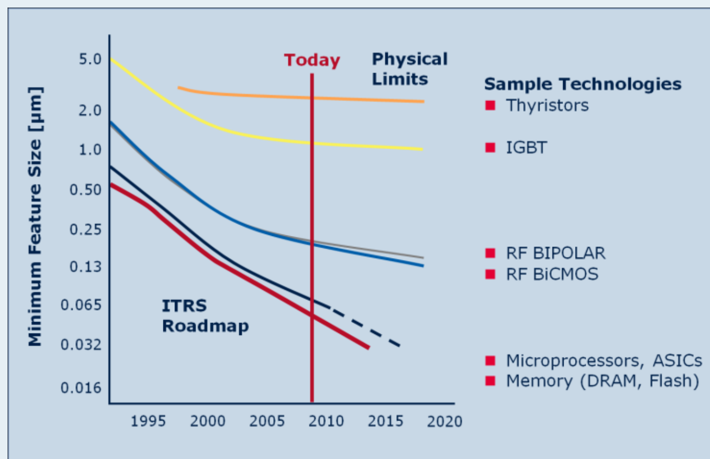

Copyright © Infineon Technologies AG 2013. All rights reserved.

# Technologies:
# More Moore is getting out of steam

## More Moore reaches limits

By shrinking of CMOS
- better performance/speed
- less energy consumption
- miniaturization
- less cost per transistor

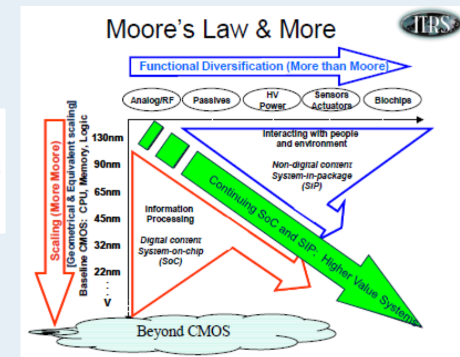
In addition:
- outstanding yield




"More Moore getting out of steam

## More than Moore & High value system

- Packaging has become the limiting element in system cost and performance
- The Assembly and Packaging role is expanding to include system level integration functions.
- As traditional Moore's law scaling become more difficult innovation in assembly and packaging can take up the slack.






Copyright © Infineon Tehnologies AG 2013. All rights reserved.

# Content

- **Motivation**
- **System integration: Packaging makes the Difference**
- **Success factors**
  - Understand reliability requirements of customers
  - Innovative assembly and packaging technologies
  - Understand material physics
  - Coherent chip-package-board co-design
  - Management of complexity
- **Conclusions**


Copyright © Infineon Technologies AG 2013. All rights reserved.

# Innovative packaging makes the difference

- Example I: Package enables small form factor
- Example II: Package enables high I/O crossing the interconnect gap
- Example III: Packaging enables high efficiency
- Example IV: Packaging enables high performance mm-wave
- Example V: Packaging enables integration of high functionality

Innovative package allows to overcome barriers


Copyright © Infineon Technologies AG 2013. All rights reserved.

# Content

- **Motivation**
  - Applications: Customer needs drive system integration everywhere
  - Technologies: Growing importance of More than Moore
- **System integration: Packaging makes the Difference**
- **Success factors**
  - **Understand reliability requiremens of customers**
  - Innovative assembly and packaging technologies
  - Understand material physics
  - Coherent chip-package-board co-design
  - Management of complexity
- **Conclusions**


Copyright © Infineon Technologies AG 2013. All rights reserved.

# Reliability: Understand applications and customer requirements

- Different applications have different reliability requirements, e.g. drop test vs. TCoB
- Understand application requirements  e.g. checking of board thickness
- It is not guaranteed that the same package fits to different applications
- We need to better understand physics to avoid one chip in different packages
- Different packages have different failure modus; we need to investigate unknown failure modus


Copyright © Infineon Technologies AG 2013. All rights reserved.

# Content

- **Motivation**
  - Applications: Customer needs drive system integration everywhere
  - Technologies: Growing importance of More than Moore
- **System integration: Packaging makes the Difference**
- **Success factors**
  - Understand reliability and requirements of customers
  - **Innovative assembly and packaging technologies**
  - Understand material physics
  - Coherent chip-package-board co-design
  - Management of complexity
- **Conclusions**


Copyright © Infineon Technologies AG 2013. All rights reserved.

# Miniaturisation and more Functionality require 3D Integration

Package form factor:

Package area / chip area

22 mm

QFP ~ 5,5

13 mm

BGA ~ 2

CSP < 1,2

FCoB/ WLP fan in = 1

9,34 mm

Stacks: could become <1 and external I/O no may be reduced

Package-on-Package (PoP)

3D with TSV allows further density increase



Copyright © Infineon Technologies AG 2013. All rights reserved.

# Examples of BGA based packaging tree - We focus on technologies with low parasitics

- >1 die
  - side-by-side
    - MCM
    - passive integration
      - Side by side SiP
  - stacked die
    - WB/ WB
    - FC/ WB
    - >2 dies
    - face-to-face
      - µ-FlipChip
      - Thru Si via
  - stacked package
    - PoP
    - Pack. on SiP
  - embedded
    - eWLB
    - Embedded power

New Processes

- Wafer level packaging
- Reconstituted wafers
- 2.5D & 3D integration
- Wafer thinning (+ handling thinned wafers)

- **Front-end and Back-end merge**

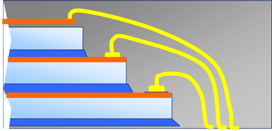


Copyright © Infineon Technologies AG 2013. All rights reserved.

# We develop toolbox elements for SiP integration: example: different types of vertical 3D contacts

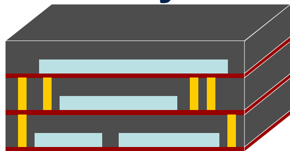
## Traditional

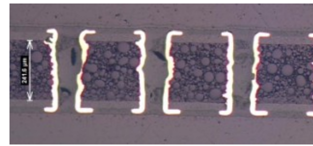
### 3D by Wire Bonding



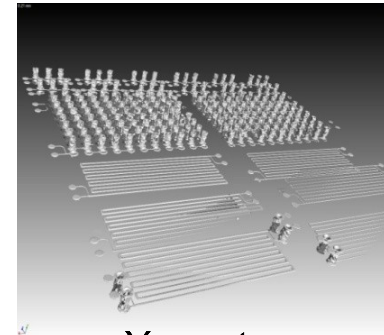
## Innovative

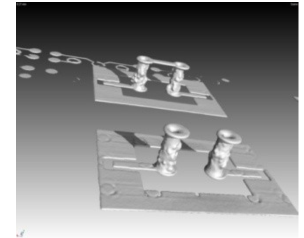
### 3D by TEV





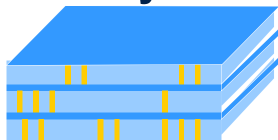
Normal cross section

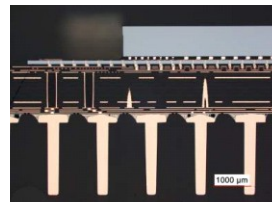


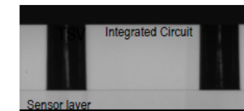


X-ray tomography

### 3D by TSV



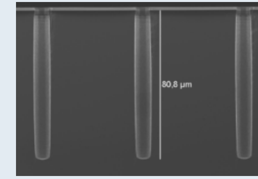




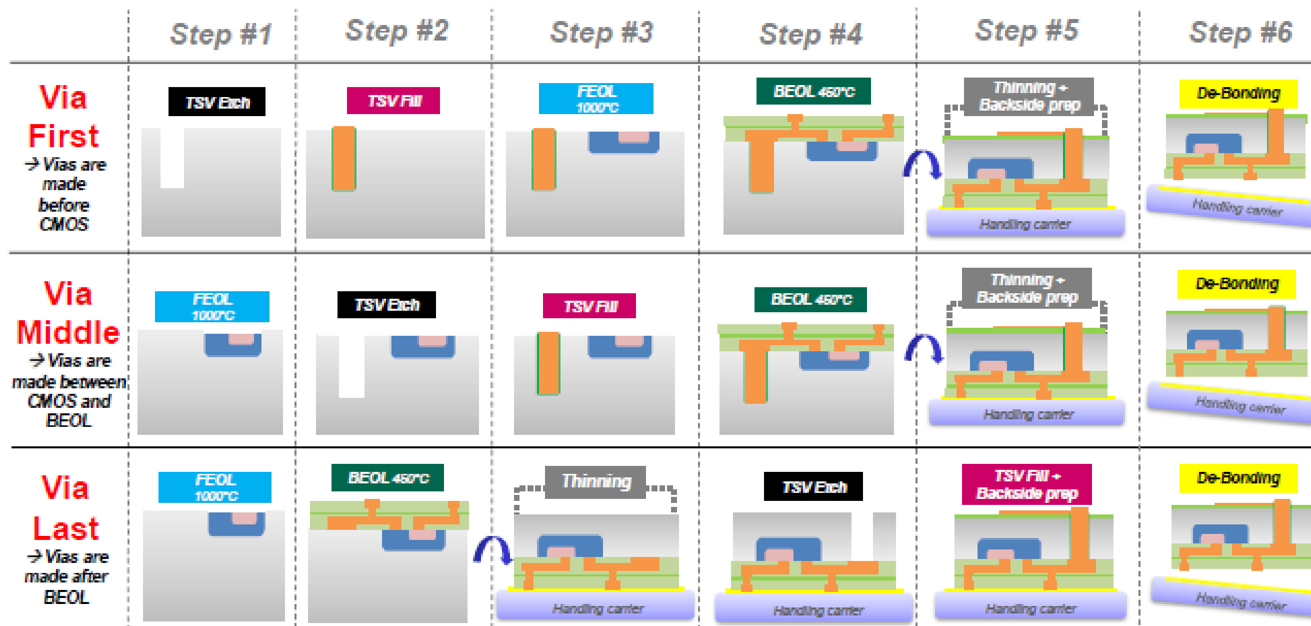
(courtesy of ams AG)


Copyright © Infineon Technologies AG 2013. All rights reserved.

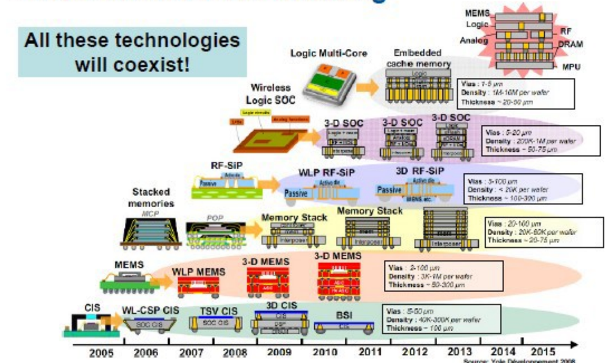
# Make the right choice for your toolbox: TSV with (via first), via middle, via last



## Complexity requires careful technology choice for application



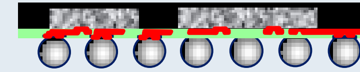

Source: YOLE Developpement 2010
3D IC integration & TSV interconnects



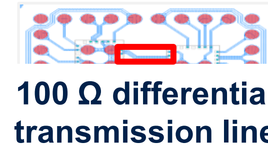



Copyright © Infineon Technologies AG 2013. All rights reserved.

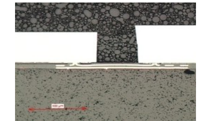
# SiP Toolbox elements based on eWLB:



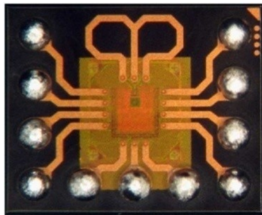
i) Opportunities for side by side connected by RDL



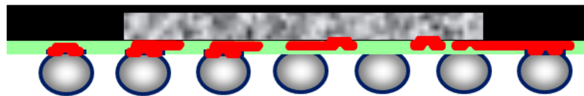
100 Ω differential transmission line



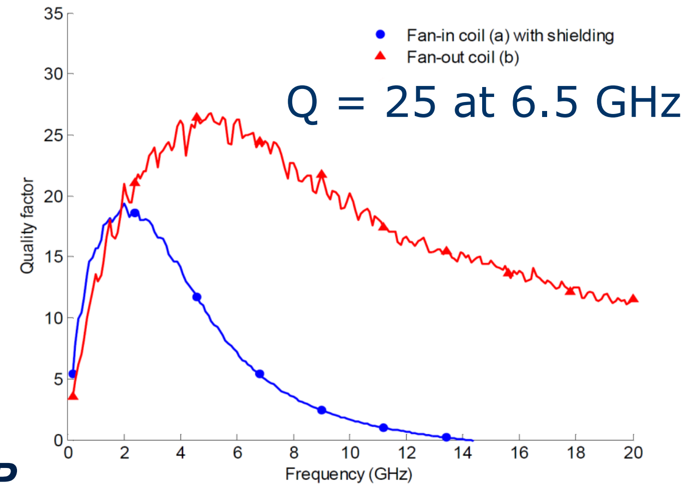
ii) Integration of inductor in fan-out region



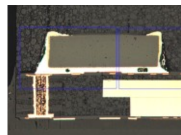
M. Wojnowski et al (Infineon) ECTC 2011

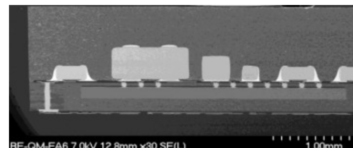


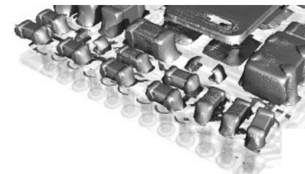
CoSiP



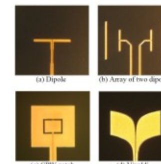

iii) Example for 3D integration of discrete passives (2 dice with stacked & double sided RDL)

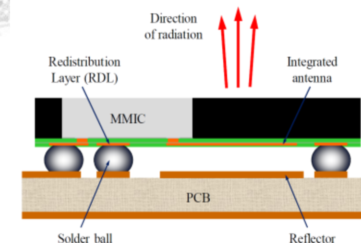






iv) Example of integrated antenna (CATRENE project 3DIM3)







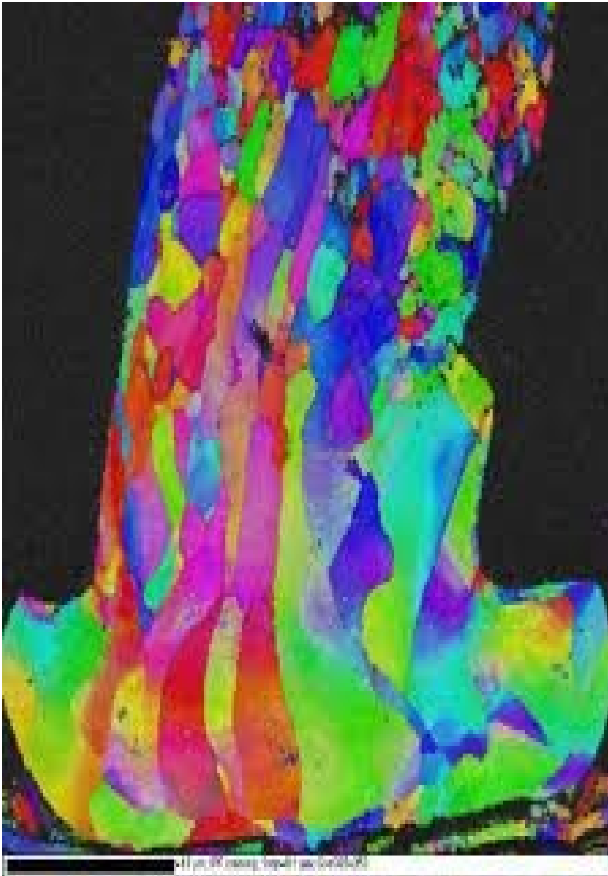

Copyright © Infineon Technologies AG 2013. All rights reserved.

# Content

- **Motivation**
  - Applications: Customer needs drive system integration everywhere
  - Technologies: Growing importance of More than Moore
- **System integration: Packaging makes the Difference**
- **Success factors**
  - Understand reliability requirements of customers
  - Innovative assembly and packaging technologies
  - **Understand material physics**
  - Coherent chip-package-board co-design
  - Management of complexity
- **Conclusions**


Copyright © Infineon Technologies AG 2013. All rights reserved.

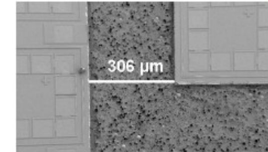
# New materials enable package innovations



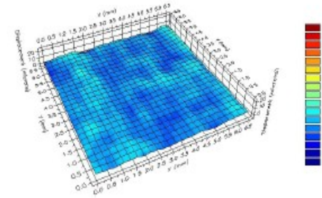
- Dielectrics e.g. isolation for RDL, …
- Inductors & Caps, e.g. in thin film RDL
- Cu wire, ….
- Barrier layers e.g. diffusion barrier, ...
- Adhesives e.g. die attach, …
- Nano-materials e.g. sintering, printing
- Composite materials e.g. advanced mold compound (> 200°C)


Copyright © Infineon Technologies AG 2013. All rights reserved.

# Success factor: Material Know How
# Example for importance of materials in eWLB



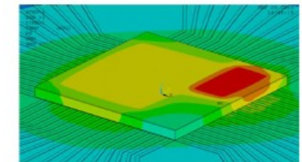

1) Mold compound with small filler size and low viscosity for side by side SiP (experience from TSLP)



2) CTE of materials allows low warpage
=> advantageous for package stacking

3) Plating resist and temporary adhesive
4) Understand and improve interfaces of materials (adhesion, avoidance of electromigration, …)

5) Material parameters capable for mm-wave application
6) Understand coherence of chip-package-board materials
7) Thermal properties =>
design opportunities for hot spots & thermal balls



⇒ Miniaturisation and System Integration with new materials need an advanced failure analysis (FA) capability

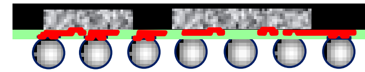

Copyright © Infineon Technologies AG 2013. All rights reserved.

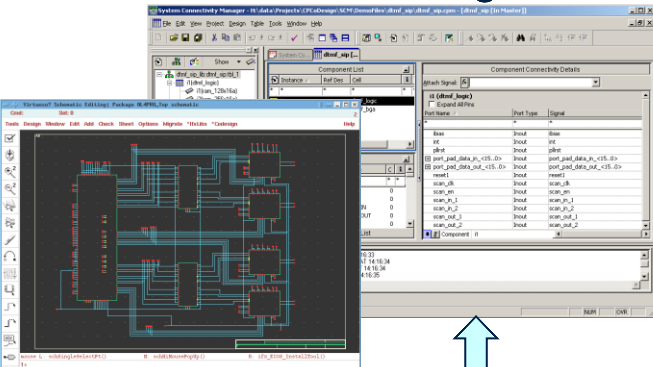
# Content

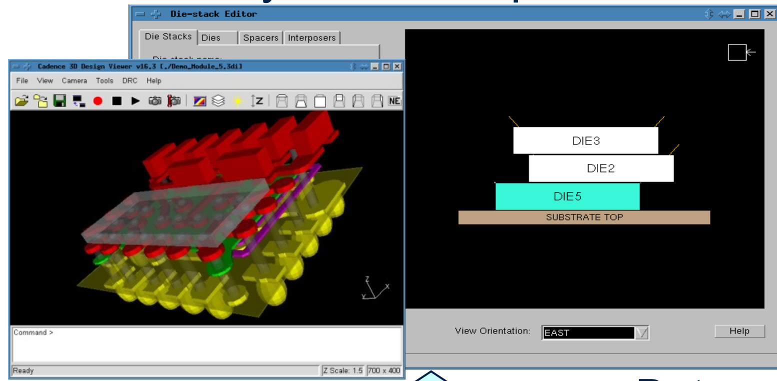
- **Motivation**
  - Applications: Customer needs drive system integration everywhere
  - Technologies: Growing importance of More than Moore
- **System integration: Packaging makes the Difference**
- **Success factors**
  - Understand reliability requirements of customers
  - Innovative assembly and packaging technologies
  - Understand material physics
  - **Coherent chip-package-board co-design**
  - Management of complexity
- **Conclusions**


Copyright © Infineon Technologies AG 2013. All rights reserved.

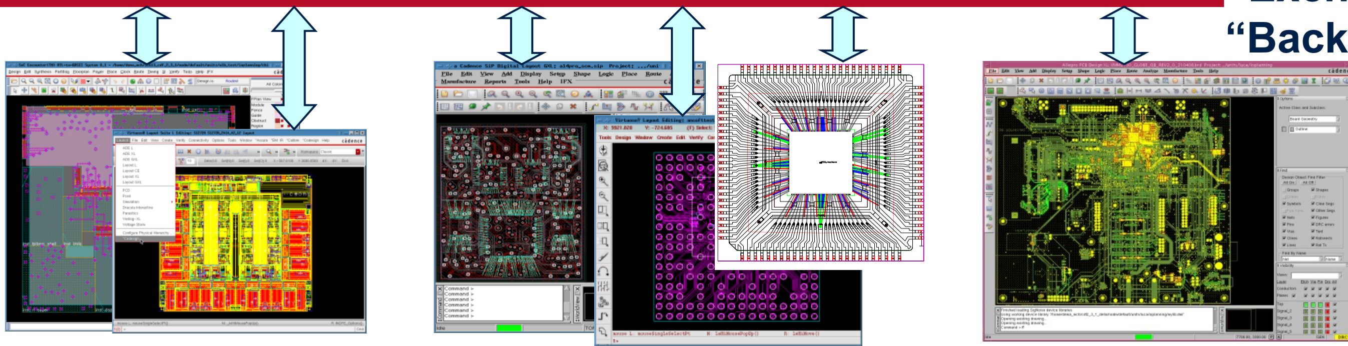
# First work on electrical design & layout in CoSiP project but needs to be extended by multi-physics and more






**Data Exchange "Backbone"**



***CoSiP***

<u>Next steps:</u>

Implement Multi-physics

=>

thermal
mechanical
thermo-mechanical

&

manu-facturability
&
costs


Copyright © Infineon Technologies AG 2013. All rights reserved.

# Content

- **Motivation**
  - Applications: Customer needs drive system integration everywhere
  - Technologies: Growing importance of More than Moore
- **System integration: Packaging makes the Difference**
- **Success factors**
  - Understand reliability requirements of customers
  - Innovative assembly and packaging technologies
  - Understand material physics
  - Coherent chip-package-board co-design
  - **Management of complexity**
- **Conclusions**


Copyright © Infineon Technologies AG 2013. All rights reserved.

# Managing Complexity: Summarized we observe 5 trends

| Trend | Details |
|---|---|
| Demanding system reliability & thermal management | Expansion towards high reliability applications (automotive, aviation power distribution, medical)<br>High reliability of system requires even higher reliability of sub components! |
| Diversity of technology | Various analog & digital specific IC technologies (memories, RF, processors, power…)<br>MEMS (sensors, actuators…)<br>Passives |
| Complex material mix | Wide range of material properties (Si, metal, ceramics, polymers, composites etc.) |
| Convergence of IC/Package/PCB technology | Wafer level packaging<br>Chip embedding in laminate<br>Through silicon via & through encapsulant via<br>Further shrink of interconnects (fine pitch wire bond, thinfilm technology, TSV)<br>Integration of passives or functions in RDL/TSV |
| 3D designs | Stacked die approaches<br>Multiple stacks of sub-packages, interposers…<br>PoP (package on package)<br>MEMS |

**Set-up Know How and investigatwe standardization**


Copyright © Infineon Technologies AG 2013. All rights reserved.

# Content

- **Motivation**
  - Applications: Customer needs drive system integration everywhere
  - Technologies: Growing importance of More than Moore
- **System integration: Packaging makes the Difference**
- **Success factors**
  - Understand reliability requirements of customers
  - Innovative assembly and packaging technologies
  - Understand material physics
  - Coherent chip-package-board co-design
  - Management of complexity
- **Conclusions**

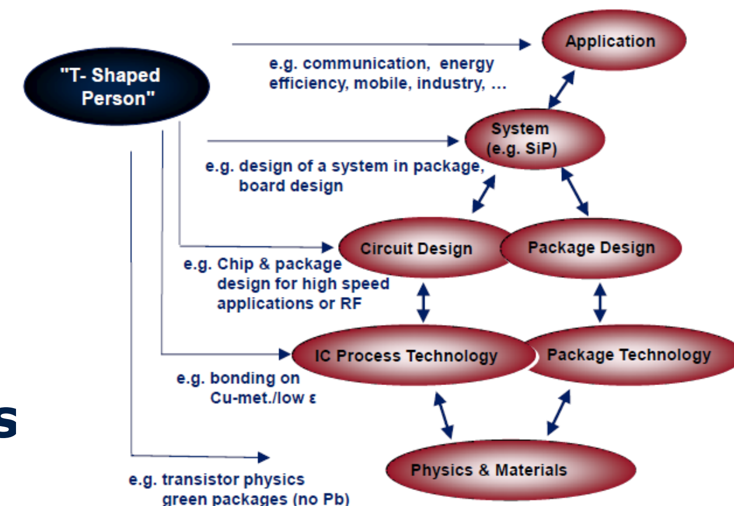

Copyright © Infineon Technologies AG 2013. All rights reserved.

# What do we need?

- Understand your application requirements (reliability)
- Understand your customer (price, performance, …)
- Understand trade-offs between technologies (TSV, TEV, … )
- Understand and develop the appropriate toolbox elements
- Understand physics of processes, failures, performance, …
- Understand your supply chain
- …….

⇒ **We need T-shaped persons**

⇒ **The EUREKA CATRENE Program opens collaboration opportunities**





Copyright © Infineon Technologies AG 2013. All rights reserved.