

## Thermal Modeling, Analysis and Management of 2D/3D Multi-Processor System-on-Chip

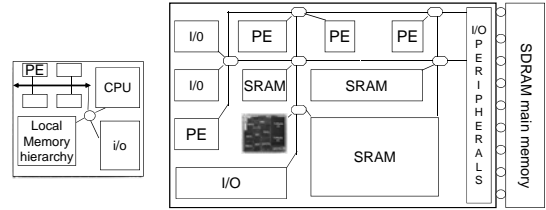
**David Atienza,**  
 Embedded Systems Laboratory (ESL),  
 Institute of EE, Faculty of Engineering,  
 EPFL, Switzerland



ECOFAC 2010, Lannion, 29/03 – 2/04 2010

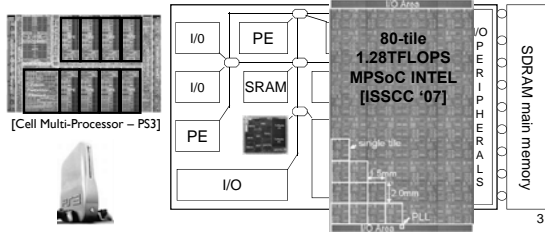
## Evolution of Electronics to Multi-Processor System-on-Chip (MPSoC)

- Roadmap continues: 90 → 65 → 45 nm
- Multi-Processor System-on-Chip (MPSoC) architectures

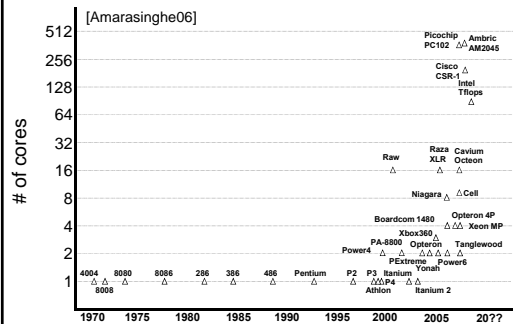


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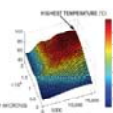


## MPSoCs are Spreading Fast




### Design Issues in MPSoCs

- MPSoCs have very complex architectures
  - Advanced components and CAD tools very expensive
  - Time-closure issues, system speed decreased
- Aggravated thermal issues
  - Hot-spots, non-uniform thermal gradients





[Sun, 1.8 GHz Sparc v9 Microproc]




[Sun, Niagara Broadband Processor]

High chances of thermal wear-outs and very short lifetimes!





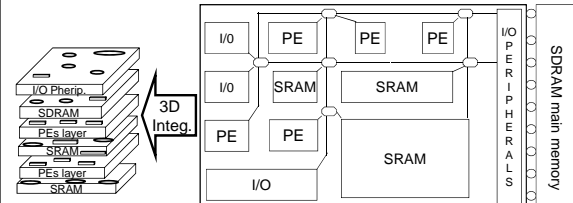
[Santarini, EDN, March '05]



[Coskun et al '07, Sun]

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### Thermal Issues Become More Critical for 3D-MPSoCs




3D Integ.

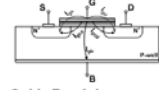
More power and more non-uniform heat spreading!

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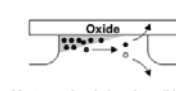
### Reliability Degradation Factors in MPSoCs



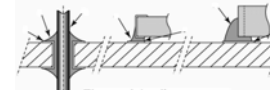
Electromigration (EM)



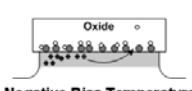
Oxide Breakdown



Hot carrier injection (HCI)




Thermal Cycling



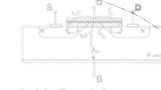
Negative Bias Temperature Instability (NBTI)

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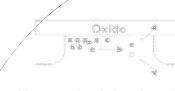
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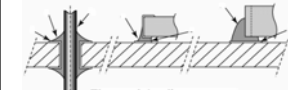
Electromigration (EM)




Oxide Breakdown



Hot carrier injection (HCI)



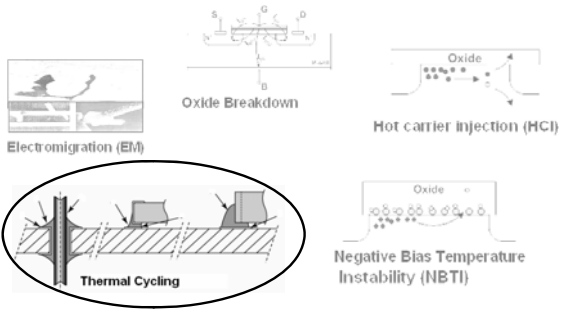
Thermal Hot Spots



Negative Bias Temperature Instability (NBTI)

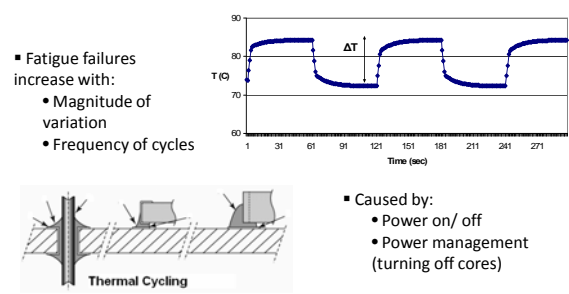
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## Reliability Degradation Factors in MPSoCs



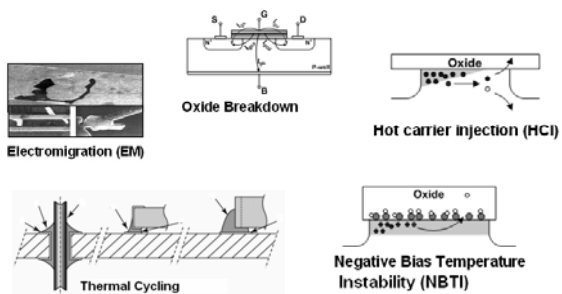
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## Reliability Degradation Factors in MPSoCs



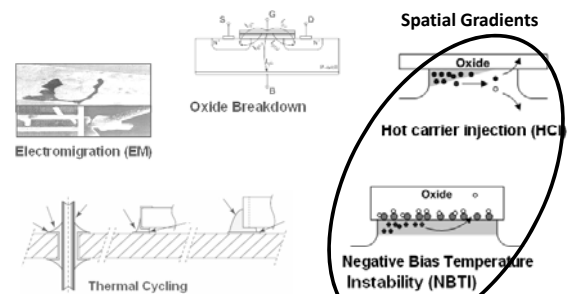
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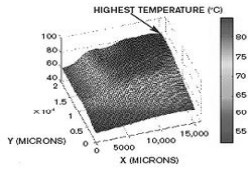
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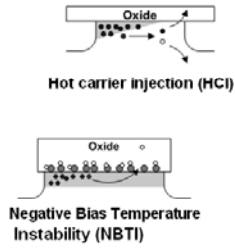


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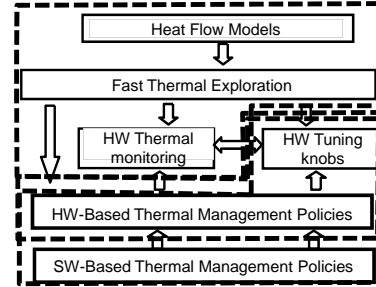
- Spatial gradients:
  - NBTI & HCI: Parametric reliability problems
  - Delay problems
  - Clock skew issues



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## Advocating Thermal-Aware 2D/3D MPSoC Design

- Integration of HW/SW modeling and management



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## Outline

- Part 1: Thermal Modeling and Management for 2D MPSoCs
- Part 2: Thermal Modeling and Management for 3D MPSoCs with Active Cooling

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