Designer's Forum at ASP-DAC

Best Ways to use Billions of Devices on a Chip

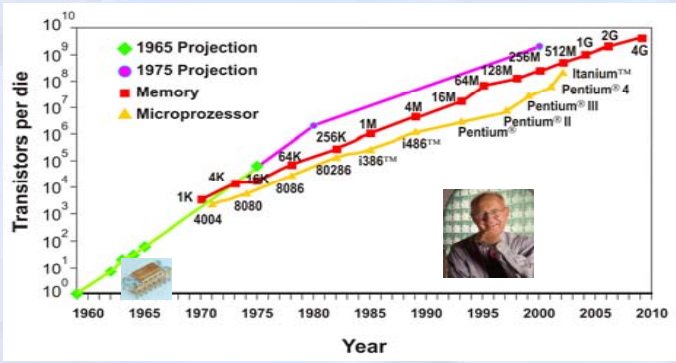
Panel presentation by

J. Henkel, Univ. Karlsruhe

Seoul, Jan. 25th 2008

In the past …

- … Moore's Law provided a win-win- situation:
  - Smaller feature size
  - Higher integration density
  - Lower power consumption
  - Higher speed (performance)
  - Less cost (per-transistor costs)
  - …

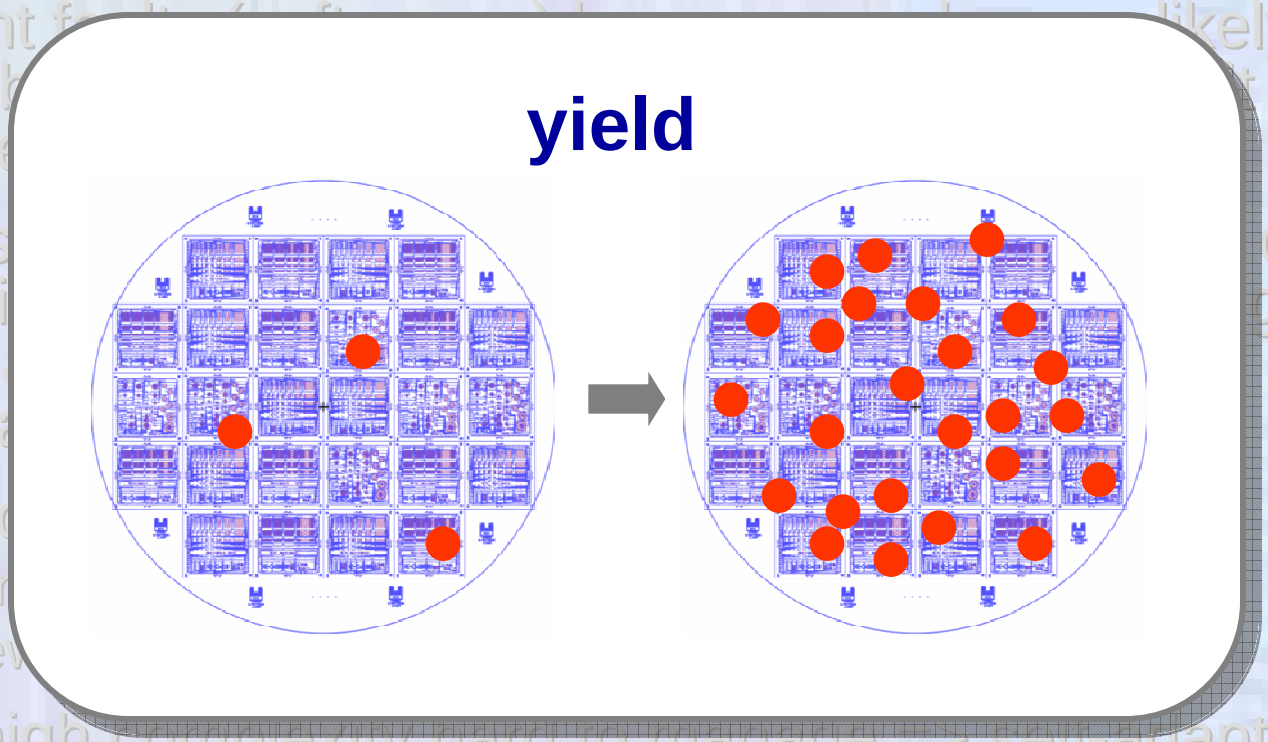


ITRS

Scalability, as we experienced for the last four decades is at its end as we enter the Nano Era!

In the future …

- New structures will be hard to integrate => yield decreases drastically => “live” with faults rather than avoiding them (expensive and/or impossible)
- Transient fa… likely => need to h… tolerance
- Errors (s… of abstracti… gning appropri… configura…
- 3-D struc…
  - Routi…
  - => new…
- Future high complexity hard to manage => self-adaptation and self-organization is needed



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- Transient faults (soft errors) become much more likely => need to be considered in the design process => fault tolerance plays a key role
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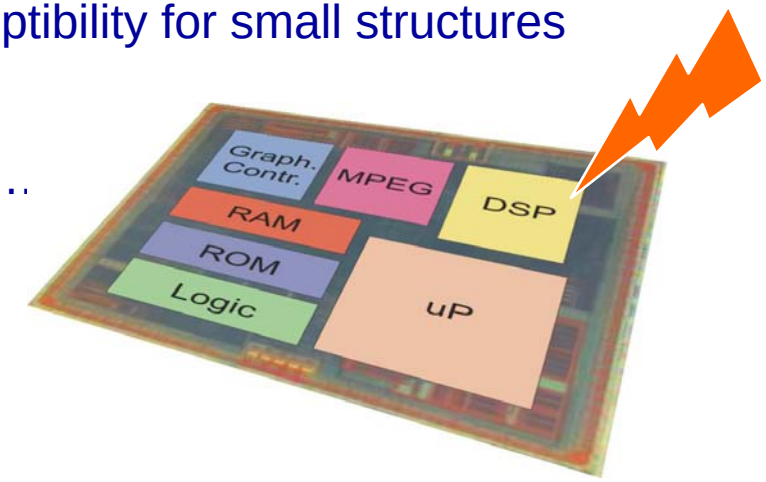
  and self-org

Soft errors

- cause: e.g. through cosmic rays (neutron strike)
- high susceptibility for small structures
  widths

=> bit flips, …



In the future …

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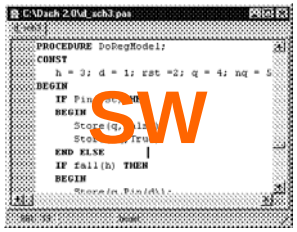
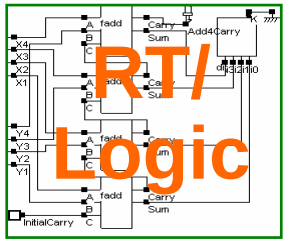
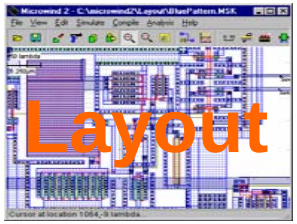
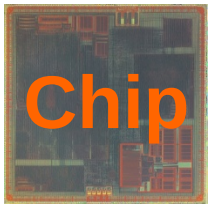








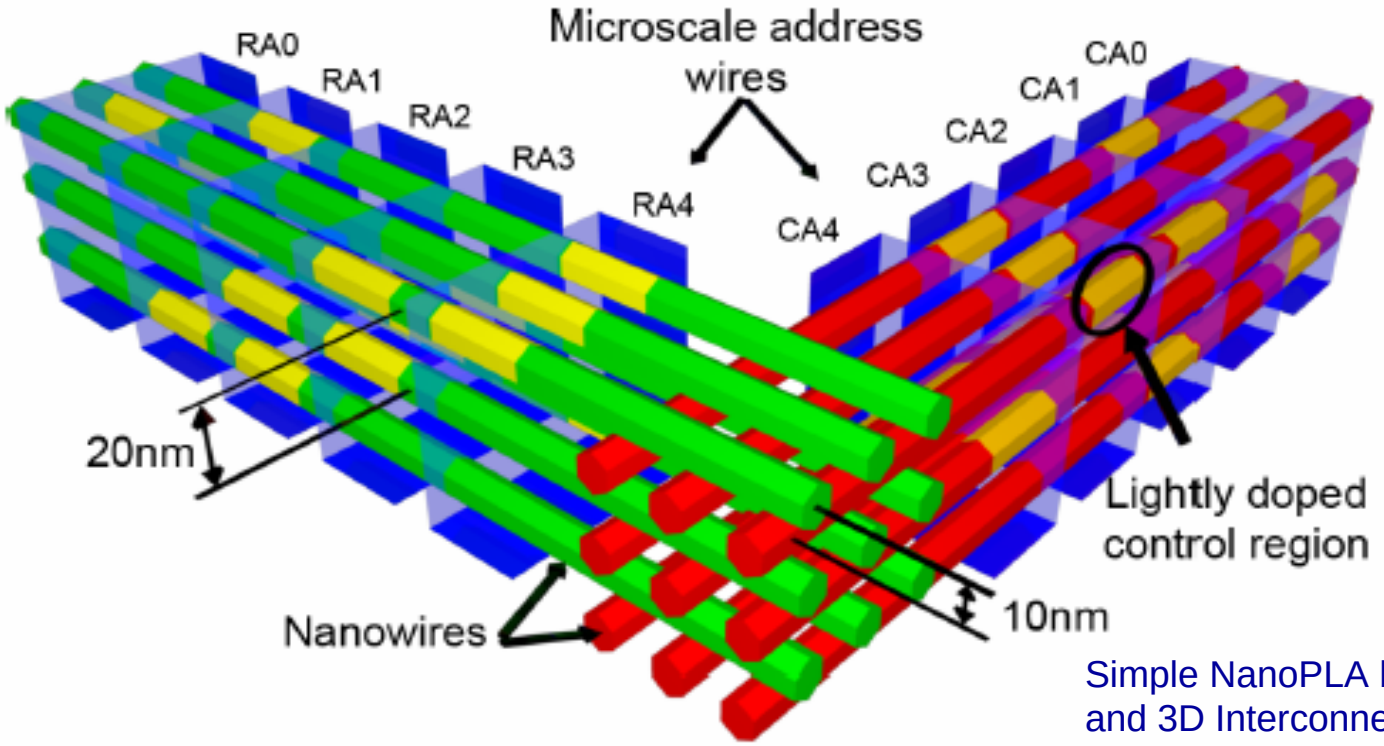
Errors

address at all levels of abstraction !

In the future …

Reconfigurability as a means to address errors

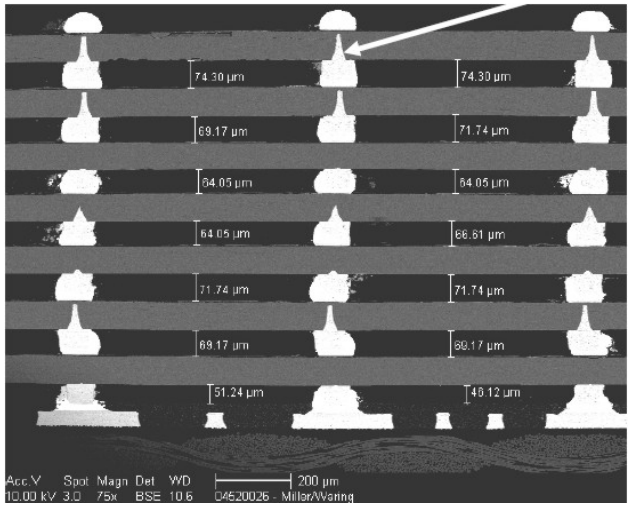
Shown: 3-D PLA

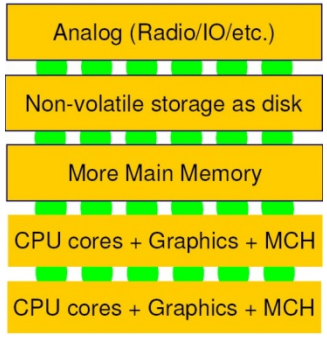


Simple NanoPLA block and 3D Interconnect
Source: DeHon

In the future ...

3-D structures





(src: Yuan Xie)

- 3-D structures imply new problems in
  - Routing, placement, heat, electrical compatibility etc
  - => new design/synthesis methods are needed
- Future high complexity hard to manage => self-adaptation and self-organization is needed

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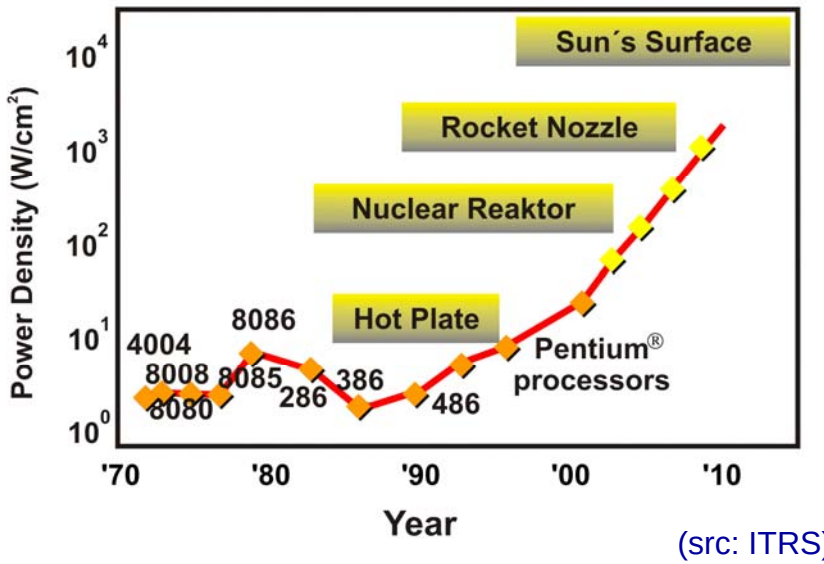
3-D structures: problems



(src: ITRS)

In the future …

- New structures will be hard to integrate => yield decreases drastically => "live" with faults rather than avoiding them (expensive and/or impossible)
- Transient faults (soft errors) become much more likely => need to be considered in the design process => fault tolerance plays a key role
- Errors (soft or hard) need be considered at all levels of abstraction from manufacturing the hardware to designing appropriate software => higher flexibility => re-configurability
- 3-D structures imply new problems in
  - Routing, placement, heat, electrical compatibility etc
  - => new design/synthesis methods are needed
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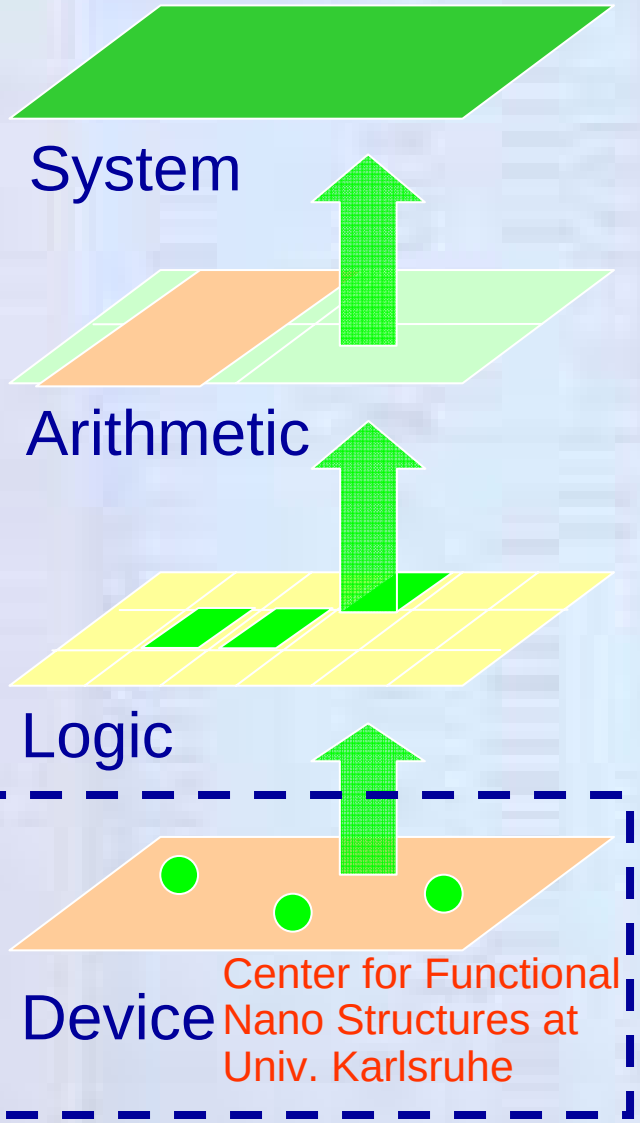
Summary Problems

- Power (Reduction, Delivery, Distribution)
- Heat (Reduction, Removal, Dealing with hot spots)
- Interconnects (Reduce length/delay, Reduce number)
- Testability / Verification (Reducing associated costs)
- Reliability (Economical redundancy factors, Reconfiguration, Adaptive)
- Communication (Low-power, Non-flooding, Reliable)
- Hybrid integration (Mixed design, Interfacing)
- Logic and coding (Non-Boolean(?), Error correction, Spikes)
- Algorithms (Stochastic / Probabilistic)
- Design complexity (Reduce associated cost by reuse)

Solutions

- **Near term solutions:**
  - Massively parallel, modularity (cells, blocks)
  - Regularity (grid processing, cellular arrays)
  - Locally connected (near-neighbor connections, crossbar)
  - Higher functionality (multiple valued logic, threshold logic)
  - Reconfigurability (self-mapping)
- **Medium term solutions:**
  - Asynchronous (including GALS)
  - Fault-tolerance (noise immune,, redundant, self-testing, self-correcting)
  - **Defect-tolerant (adaptable/reconfigurable)**
  - Redundant, adaptive (self-adaptive, self-organizing, evolvable)
  - **Bio-inspired (complex functions, self-organizing, self-healing)**
  - Nanophotonic (optical communication, GOLE)
  - Nanofluidic
  - 3D interconnects
  - Probabilistic (algorithms, encoding, communication)
- **Long term solutions:**
  - molecular, quantum
  - quantum-dot cellular automata
  - Adiabatic / reversible
  - Bio-compatible



Multidisciplinary Research Effort at Univ. Karlsruhe

- Creation of a NEW FIELD GROUP (est. 2007) to address the high-lighted problems
- Multidisciplinary Research
  - Computer Science
    - J. Henkel, W. Karl, …
  - Electrical Engineering
    - J. Becker, J. Leuthold, …
  - Physics
    - G. Schoen, H. Hahn, …

We do not have as many devices available for computation/communication as we may think we have!

Devices from CFN Karlsruhe