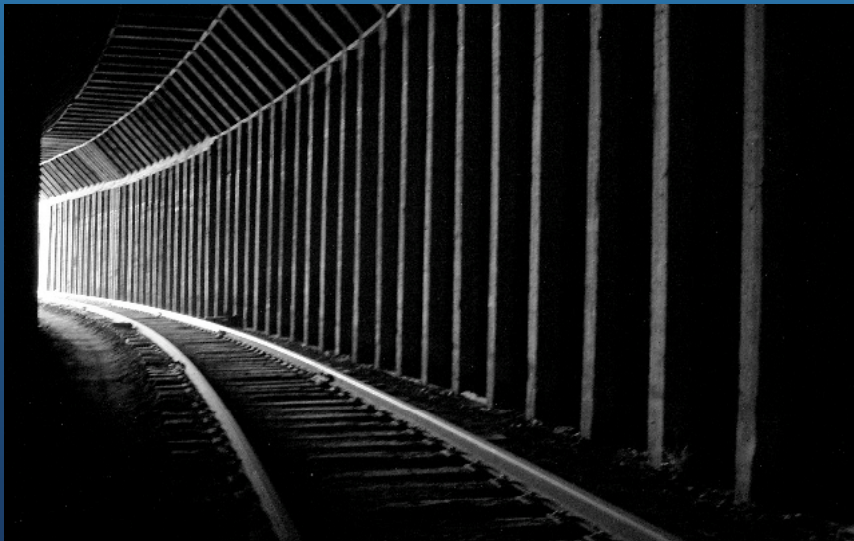
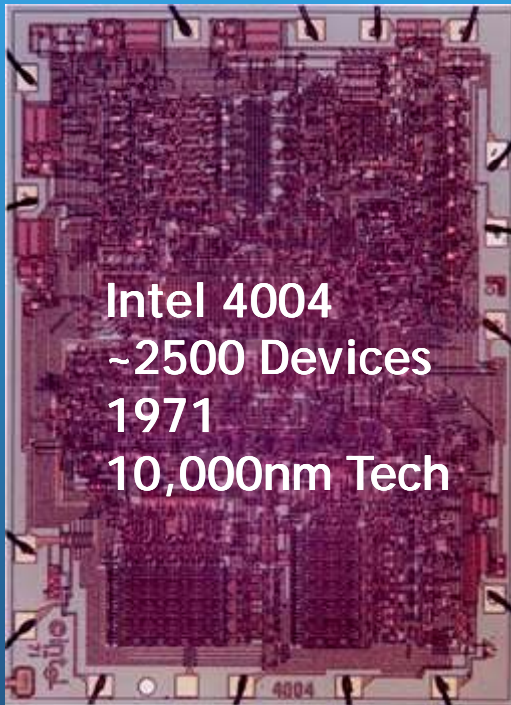


The Light at the end of the CMOS Tunnel



Sani R. Nassif
IBM Research - Austin
nassif@us.ibm.com

A Brief Retrospective



Intel 4004
~2500 Devices
1971
10,000nm Tech

1971 ... 2011

10,000nm ... 20nm

2^9 (~500) reduction in feature size

2^{18} (~65,000) increase in density

~18 process generations

And Still Going...

The Result

- The world relies on electrical engineers to build all the various circuits on which our life runs.
 - Your phone.
 - Your laptop and desktop computers.
 - Your microwave.
 - The ATM at your bank.
 - The X-Ray machine at your airport.
 - The brake controller in your car.
 - Your heart implant.
- We expect these circuits to just “work”.



Failure?

- As we make our systems ever more complex, failure becomes more and more possible.
 - Systems are a mish-mash of software, hardware, sensors, actuators, etc...
- Failure can occur because devices do not behave as expected, or external factors (noise), aging (metal fatigue), design (a software bug).
- **As we scale technology further, understanding and predicting device behavior is becoming more and more important to predicting potential failures!**



Simulation and Prediction

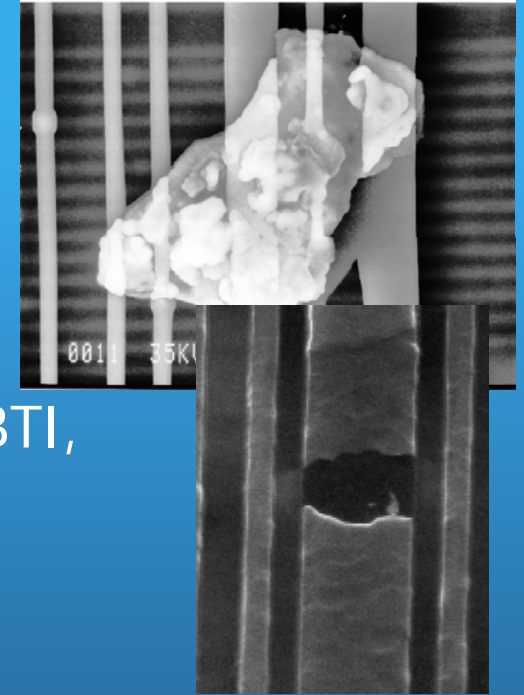
- Key to our understanding of failure is the notion that we expect our circuits to behave according to some **prediction**.
- This prediction is often arrived at using **circuit simulation**.
 - For example, using Spice.
- Simulation requires a **device model**.
 - Something like BSIM.
- In fact, we rely on models to an extreme degree!
 - We do not “crash test” our chips!
 - We do not build full-scale prototypes... First time right is an economic necessity.



Why Semiconductors Fail

Variety of mechanisms:

- Defects...
- High Field effects: Hot Carrier Injection, NBTI, Metal Electro-Migration.
- Noise phenomena (local, or cosmic).
- Model/Hardware mismatch (lack of predictability).
- Big picture: a by-product of scaling... Small features mean:
 - Small contaminants can cause topology changes, and ...
 - A small "extra" charge can cause mistakes, and ...
 - Large fields, a V_{DS} of $1V / 40nm = 250 \text{ KV/cm}$, and ...
 - Increasing variability because of lack of averaging!



Future Possibilities

- We want to make sure that Silicon Technology will continue to amaze and deliver.
- Silicon will be the substrate on which post-Si technology will be built.
- Our ability to confidently predict the behavior of Silicon Devices is the cornerstone!

