# Introduction to Reliability Simulation with EKV Device Model

**Benoît Mongellaz**

**Laboratoire IXL**
**ENSEIRB - Université Bordeaux 1 - UMR CNRS 5818**

**EKV Workshop november 4-5th, Lausanne**

# Motivation & Goal

- Introduced new activities to EKV modelling development
- Implemented Ageing/Reliability model into EKV
- Developed future experiments on advanced process to Design In Reliability
- Discussed technical needs to R&D works interfacing with industrial partners

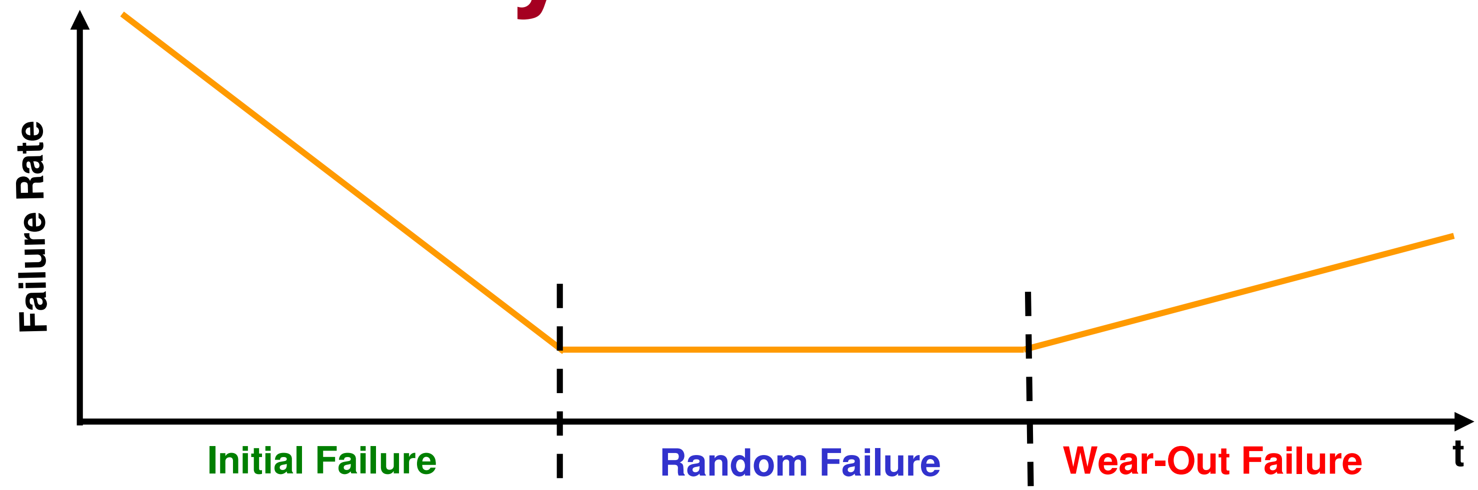
# Context

- Reliability requirements are more and more important for advanced process (CMOS, HVMOS…)
- Shrinked devices are most sensitive to stresses induce loss of performance
- Reliability prediction from process qualification
- What are the method to take into account physic failure mode on IC performances and reliability?

# Outline

- IC Reliability Prediction
- Reliability Simulation Tools
- EKV Reliability Model
- R&D Works

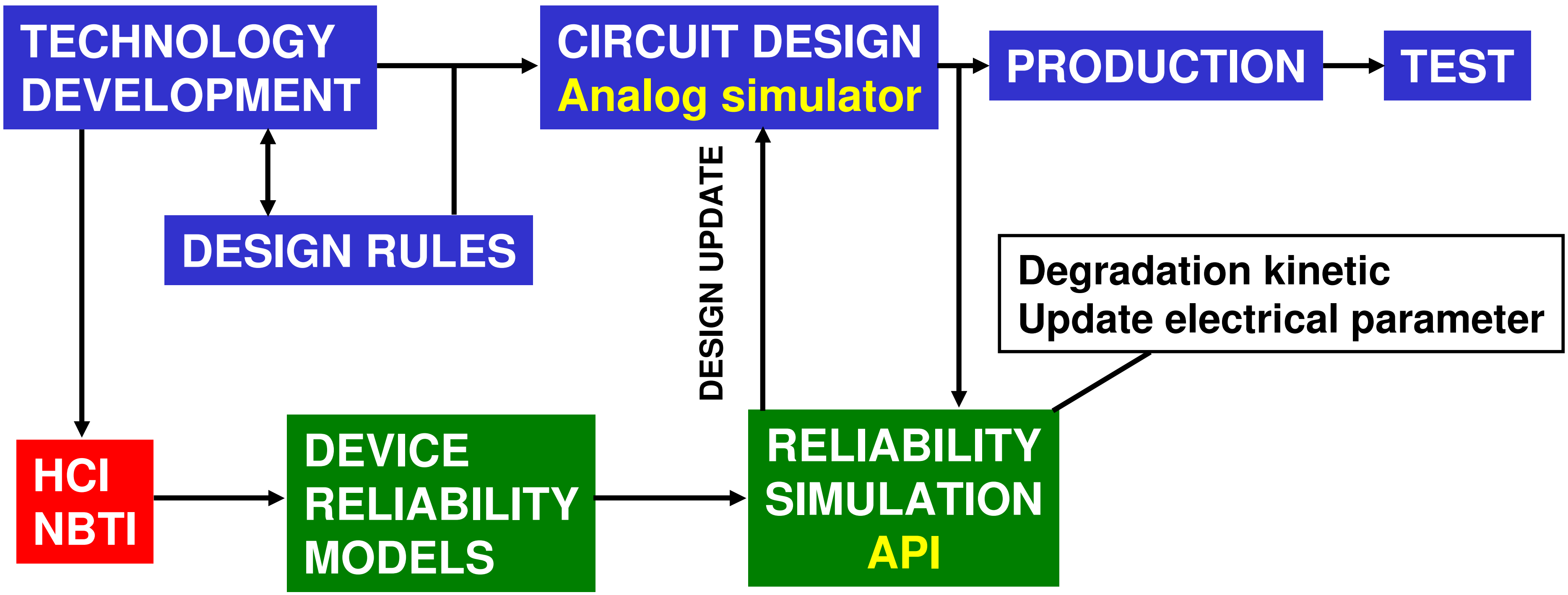
# IC Reliability Prediction




| Failure mechanism | Manufacturer | Customer | Market (end user) |
|---|---|---|---|
| ESD, Lacth-up | | | |
| Oxide Film Destruction | | | |
| Electromigration | | | |
| NBTI | | | |
| HCI | | | |

- How to predict NBTI and HCI wear-out failures effects on IC performances?

# IC Reliability Prediction




- Included external interface to take into account EKV reliability models

# Outline

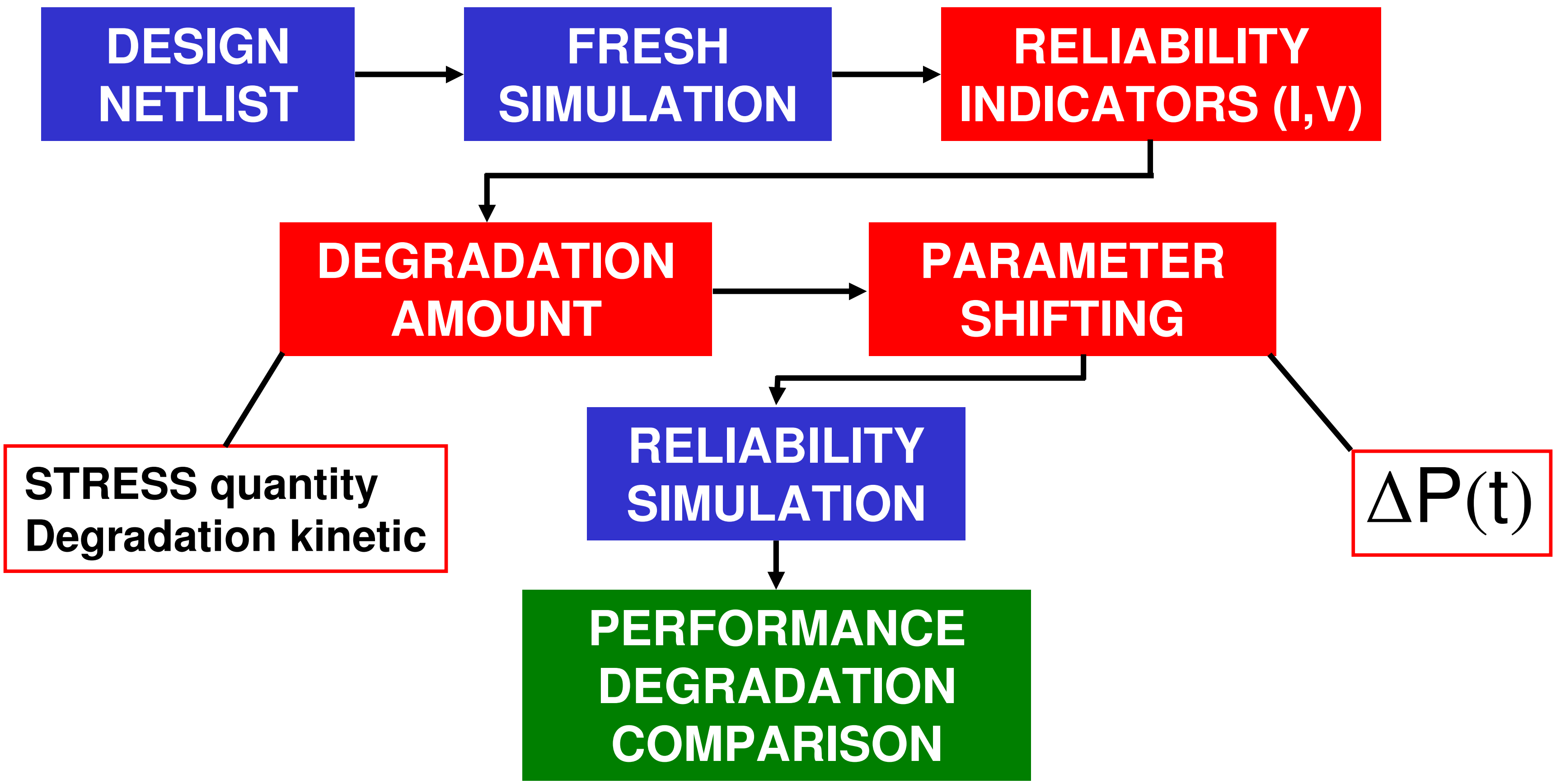
- Reliability Prediction
- Reliability Simulation Tools
  - Functionalities
- EKV Reliability Model
- R&D Works

# Reliability Simulation Tools

| Tool | Owner | Model | Simulator |
|---|---|---|---|
| **BERT** | UC Berkeley | **HCIM**, HCIB, TDDB, EM, ESD, SEU,TDRE | **SPICE** |
| **HOTRON** | Texas Instrument | **HCIM**, EM, MS | **SPICE** |
| **PRESS** | Philips/MESA | **HCIM**, EM, ESD | **PSTAR** |

**HCIM = Hot-Carrier injection MOS** ,
HCIB = Hot-Carrier injection Bipolar,
TDDB = Time Dependent Dielectric Breakdown,
EM = Electromigration,
ESD = Electro-Static Discharge,
SEU = Single Event Upset,
TDRE = Totale-Dose Radiation Effects,
MS = Mechanical Stress

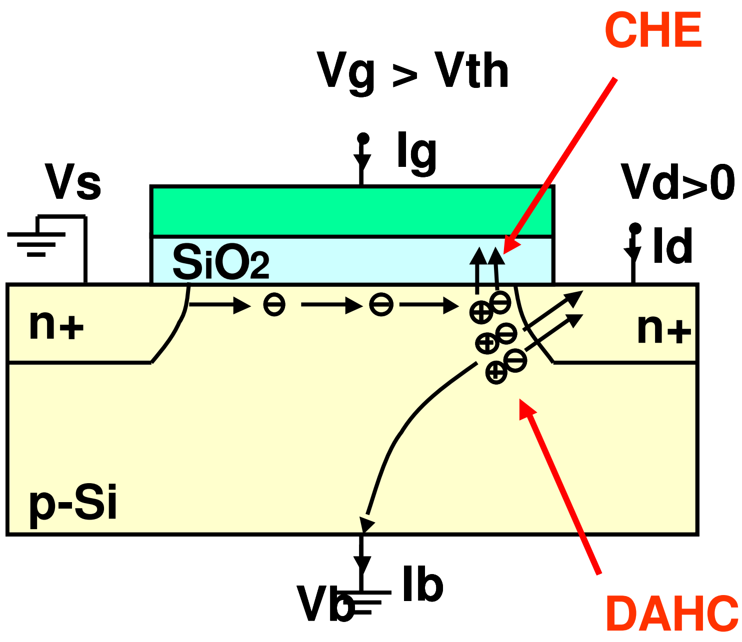
# Reliability Simulation Tools



# Outline

- Reliability Prediction
- Reliability Simulation Tools
- EKV Reliability Model
  - A Wear-Out Failure : Hot-Carrier Injection
- R&D Works

# Hot-Carrier Injection




- Injection mechanism
  - **CHE** : Channel Hot Electron
  - **DAHC** : Drain Avalanche Hot Carrier
- Effects :
  - Electrical parameter shifting
  - Reduce device lifetime
  - Loss of performance
- Reliability indicators :
  - Substrate current Ib
  - Gate current Ig
  - Drain-source voltage Vds

# Outline

- Reliability Prediction
- Reliability Simulation Tools
- EKV Reliability Model
  - Operational device lifetime
  - Electrical parameter shifting
- R&D Works

# EKV Reliability Models

- JEDEC standard method [1]
  - I-V characterization
- Taken into account degradation criteria :
  - 100 mV threshold voltage shift
  - 10 % gm variation
  - 5 % linear or saturation current
- Used indicators to device lifetime :
  - Vds, Ib, Ig
- Extracted parameter shifting model versus ageing time

# Operational Device Lifetime

- Takeda model [2]
  - drain-source voltage method

$$\tau = t_0 \exp\left(\frac{B}{V_{DS}}\right)$$

- Hu model [3]
  - substrate current method

$$\tau = \frac{HW}{I_{DS}}\left(\frac{I_B}{I_{DS}}\right)^m$$

  - gate current method

$$\tau = k\left(\frac{I_G}{W}\right)^m$$

# Electrical Parameter Shifting

- Evaluated device performance degradation
- Depend on the stress applied to device
- Taken into account effects of gradually changing bias condition
- The amount of degradation : $\mathbf{stress}(T) = \frac{1}{T}\int_0^T \tau(t)\,dt$

# Electrical Parameter Shifting

- The parameter time evolution : $P(t) = P_0(0) + \Delta P(t)$

- The parameter shifting models :

  – Power law [2] : $\Delta P(t) = A(\text{stress}(t))^n$

  – Logarithmic law [4] : $\Delta P(t) = B(\ln(1 + C\text{stress}(t)))^n$

  – Exponential law [5] : $\Delta P(t) = D\exp\left(E\text{stress}(t)^n\right)$

# What are the needs?

- Use EKV 3.0 release
  - Substrate, gate currents are defined
- Do I-V and reliability experiments
  - Calibrate EKV electrical model
  - Define the degradation trend of each electrical parameter (VT0, KP, LAMBDA…) to build reliability models
- Use EKV device model is a key point thanks to a minimum set of parameters

# Outline

- Reliability Prediction
- Reliability Simulation Tools
- EKV Reliability Model
- R&D Works

# R&D Future Works

- Collaboration with industrial partners
- Target process : CMOS, HVMOS…
- Access to device samples and IC demonstrators
  - Digital blocks and analog blocks
- Develop WLR process qualification experiments at LEG/EPFL Laboratory
- Build EKV reliability models
- Include EKV model in a reliability simulation tool

# Reference


[1] JEDEC standard JESD-28, *"A procedure for measuring N-Channel MOSFET hot carrier induced degradation at maximum substrate current"*, June 1995.

[2] E. Takeda, N. Suzuki, *"An Empirical Model for Device Degradation Due to Hot-Carrier Injection"*, IEEE Electron Device Letters,vol. EDL-4, n°4, pp. 111-113, April 1983.

[3] C. Hu and als, *"Hot-Electron Induced MOSFET Degradation Model, Monitor and Improvement"*, IEEE J. Of Solid-State Circuits, vol. SC-20, pp. 295-305, February 1985.

[4] D. R. Wolters and als *« Trapping of Hot Electrons"*, Proc. 6th INFOS, 1989.

[5] B. Marchand and als, *« A New Hot Carrier Degradation law for MOSFET Lifetime Prediction"*, Microeleectronics Reliability, 1998, 1103-1107.