Reliability Simulation & Modeling

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WILL YOUR PRODUCT PERFORM AS EXPECTED TILL THE END OF WARRANTY?
MOSFETs degradation sources

- Negative Bias Temperature Instability (NBTI) (PMOS)
- Hot Carrier Injection (HCI) (NMOS and PMOS)
- Positive Bias Temperature Instability (PBTI) (Hi-K material)
Simulation/ Modeling Approaches

1. Extraction of several model cards for a fresh device and other devices which are DC-stressed for different periods of time.
   - **Advantages:**
     - This approach is simple and generic
     - It models the effect of degradation as a change in the parameters values of the originally used device model, which results in consistent results for all the device characteristics.
   - **However, this approach has two major drawbacks, which are:**
     - Extraction process introduces some fitting errors especially when the degradation percent is small.
     - It is impossible to use this approach to model more than one degradation mechanism if they have different measures for the stress level.

2. Using additional components over the device
   - **Advantages**
     - Not dependant on the device model
     - Can model more than one mechanism
   - **Disadvantages**
     - Each mechanism modeled by new component/s
     - May loss some of the modeled mechanism effects
     - May introduce discontinuities or non-smooth transitions

3. As a change in the parameters values
   - **Advantages**
     - Change in parameter values is generated from equations, this eliminate the errors in the extraction process.
     - Can model more than degradation mechanism accurately
   - **Disadvantages**
     - Same mechanism may affect different model parameters for different device models (BSIM4, PSP)
Eldo Reliability Simulation Flow

- Parse .AGE command
  - Tag = ?
  - Number of Runs = ?
  - Time Division = Lin/Log

- Fresh transient simulation
- Stress = 0
  - i = 0
- Calculate stress integral for each device
- Stress += Stress_integral x T_i / T_transient

- Parameters Update
- New Transient Simulation
  - i = i + 1
- i < Number of Runs
  - yes
  - End
  - no

- Reliability commands
  - .age/.age_lib

- Monitoring stress values
  - .plot tran stress(M1,1)
Eldo UDRM Linkage

Extended model card

- Standard BSIM model
- Reliability model (Eldo UDRM)
- Description of Transistor Stress as function of Activity
- Description of BSIM parameters evolution as function of Stress

Extra object Library

Netlist

- Model Parameters (Fresh)
- Aging related commands

Simulate Fresh

Stress analysis

Updated BSIM3/4 parameters

Simulate Aged

Stress File

Optional

Nominal Results

Aged Results

Comparison

.COM [TAG=value]
+ [TSTART=value] [TSTOP=value]
+ [MODE=AGEin | AGEload | AGEsave] [AGELIB=file_name]
+ [AGEBAL=[YES OR | l] [NC OFF] 0]]
+ [ASCI=[YES OR | 1] [NO OFF] 0]]
+ [COMPUTE_LAST=[YES OR | 1] [NC OFF] 0]]

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UDRM Interface

- UDRM interface gives the ability to define arbitrary models.
- It is very flexible and allows development of rather sophisticated models to meet specific advanced needs.
- Available for BSIM family (bsim3v3, bsim4, bsimSOI...), Hicum, PSP, HiSIM.
- Can be easily extended for other models.
- Aging models are confidential info, IP is well protected through this flow.
- Very simple, doesn’t add any effort for the designer other than just defining the .age command.
Simulation Results NMOS-HCI
Simulation Results PMOS-NBTI

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Conclusion

- Reliability effects such as HCI, NBTI and PBTI are real threats with advanced process nodes.
- Simulating these mechanisms, however, can mitigate their effects.
- Advanced model definitions allow designers to take those effects into account as early as possible.

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