MONITORING FLASH EEPROM RELIABILITY BY EQUIVALENT CELL ANALYSIS

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Outline

- Introduction
- Equivalent-cell (EC) technique
- Comparative study
- EC applications
- Leakage mechanisms
- Conclusions
Introduction

• Reliability analysis requires a statistical study of all the cells
• EC technique allows for fast statistical characterization of the array
• EC accuracy has not been demonstrated so far
Data retention experiment: $V_T$ are monitored for increasing time under accelerating gate bias.
Basic assumption: any cell maintains its position within the $V_T$ cumulative distribution
• The complete array can be described by as few as 50-100 ECs
• Large advantage in computational time and memory consumption
EC and single cells

Real cells do not conserve their position within the cumulative probability!
Comparative study

• EC technique cannot be used for describing single-cell behavior
• Are parameter distributions conserved? ⇒ Need for a comparative study

- Data retention characterization for Flash EEPROM arrays with $t_{ox} = 5-8$nm
- Real-cell and EC analysis
- Comparison between SILC distributions
SILC distribution ($t_{ox}=8\text{nm}$)

Good agreement between the EC results and real distributions for any $V_{FG}$
Gate-bias dependence

The accuracy of EC method does not depend on experimental conditions
SILC distribution (\(t_{\text{ox}}=5\text{nm}\))

The accuracy of EC method does not depend on sample parameters
Parameter B

B = slope of the I-V on the Fowler-Nordheim plot
B distribution

Large accuracy for characterizing parameter B
EC applications

• EC technique yields the SILC distribution, which is a universal monitor allowing for reliability comparison as a function of:
  – Product architecture (e.g. NOR vs. NAND)
  – Cell parameters (e.g. $\alpha_G$, equilibrium $V_T$)
  – Oxidation technology (e.g. dry, wet, nitrided)
  – Tunnel-oxide thickness (aided by a model accounting for the $t_{ox}$ dependence of SILC)
Leakage mechanisms

Kinks appear in distributions of both current and $B$: separation between one-trap and 2-trap leakage
Thicker oxides

No kinks in current distribution $\Rightarrow$ the B distribution is most accurate for separating SILC mechanisms (data from D. Ielmini et al., IEDM Tech Dig. 2001)
Conclusions

• EC method provides a fast technique for reliability assessment
• The accuracy of the EC technique has been demonstrated
• EC can be used for:
  – Reliability comparison between different technologies, architecture, thickness, etc.
  – Accurate monitor of different leakage mechanisms