BEOL/MOL TDDB discussion group

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Outline

- Kinetic models?
- Statistical models?
- Qualification strategy for some difficult failure modes?
- Industry scaling trends?

Kinetic models

- **Voltage/E-field acceleration**
  - **E-model:** $t_{BD} \propto e^{-\gamma_E E}$ Kim et. al., IRPS 2007
  - **Square Root E-model:** $t_{BD} \propto e^{-\gamma_E \sqrt{E}}$ Chen et. al., IRPS 2006
  - **Power Law Model:** $t_{BD} \propto E^{-n}$ Wu et. al., IEDM 2005; Croes et.al., IRPS 20
  - **Impact Damage (Lucky e):** $t_{BD} \propto \frac{1}{E} e^{\left(-\gamma\sqrt{E}+\frac{\alpha}{E}\right)}$ Lloyd et. al., JAP 2005
  - **1/E-model:** $t_{BD} \propto e^{-\frac{\gamma_E}{E}}$ Zhao et. al., APL 2011
  - **Progressive breakdown:** Lee et al., IITC 2016

$$t_{HBD} = t_{nucleation} + t_{growth} = t_0 \left(L / a_0 \right)^{\frac{-1}{\beta_n}} e^{-\gamma\sqrt{E}} + B_{growth} e^{-\gamma\sqrt{E}}$$

Area dependent

Area independent

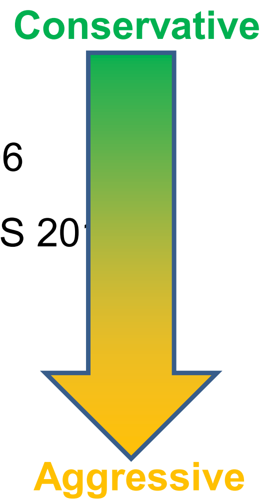
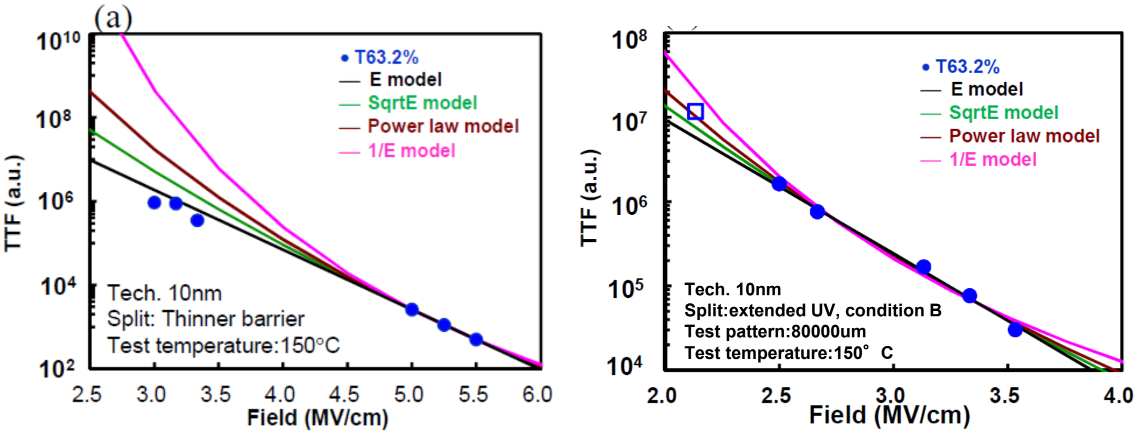


Table I Process splits and TDDB results using short-to-long term TDDB bias

Tech.	Splits	Lifetime Model
10nm	ELK1,ESL1, extended UV cure, condition A	Better than Power law
10nm	ELK1,ESL1, extended UV cure, condition B	Better than Power law
10nm	ELK1,ESL1, no extend UV cure	Better than Sqrt-E
10nm	ELK1,ESL1, thinner barrier	E model
10nm	ELK1, thinner ESL2	E model
20nm	ELK1, ESL2	1/E model
40nm	ELK2, ESL1	SqrtE model



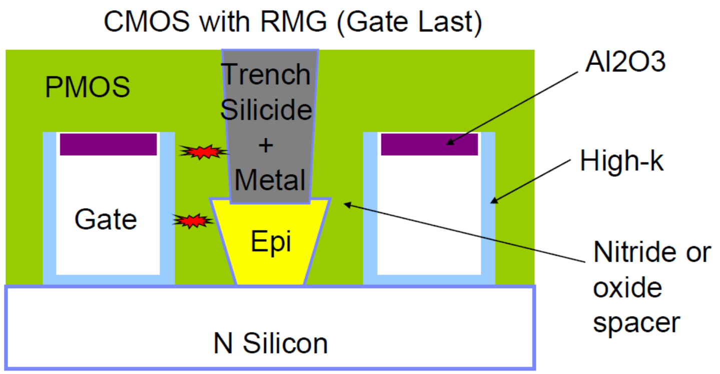
Chang et al., IEDM 2015

- **Or model is process dependent?**

Statistical models?

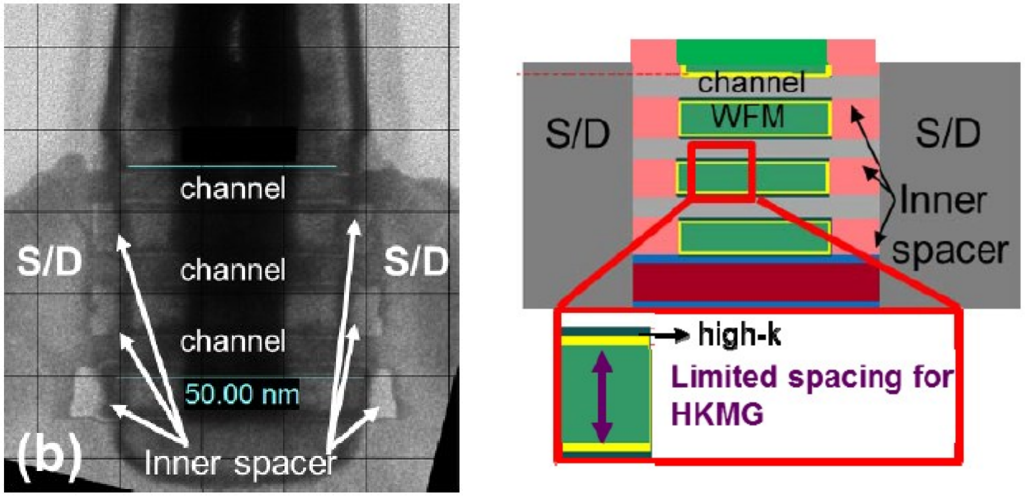
Poisson system	$F = 1 - e^{-\left(\frac{t_{BD}}{t_{63.2}}\right)^{\beta}}$	$\frac{t_{BD1}}{t_{BD2}} = \left(\frac{A_2}{A_1}\right)^{\frac{1}{\beta}}$	$F_2 = 1 - (1 - F_1)^{\left(\frac{A_2}{A_1}\right)}$
Non-Poisson system	$F = 1 - e^{-\left(\frac{t_{BD}}{t_{63.2}}\right)^{\beta}}$ $\frac{t_{BD1}}{t_{BD2}} = \left(\frac{A_2}{A_1}\right)^{\frac{r}{\beta}}$ $F_2 = 1 - (1 - F_1)^{\left(\frac{A_2}{A_1}\right)^{r}}$ $\beta_{Area} = \beta / r$	$t_{63.2use}$ $= t_{63.2str} \times \left(\frac{A_2}{A_1}\right)^{-1/\beta}$ $\times e^{\left[-\gamma_E \times \left(\sqrt{\frac{V_{use}}{s}} - \sqrt{\frac{V_{str}}{s}}\right)\right]}$ $F_{total} = \int_0^{\infty} cdf(s) \times pdf(s)\, ds$ $= \int_0^{\infty} \left(1 - e^{-\left(\frac{EOL}{t_{63.2use}(s)}\right)^{\beta}}\right) \times pdf(s) ds$	$F = 1 - \left(1 + \frac{1}{\alpha}\left(\frac{t_{BD}}{\tau}\right)^{\beta}\right)^{-\alpha}$ $\frac{t_{BD1}}{t_{BD2}} = \left(\frac{A_2\{(1-F)^{-1/\alpha} - 1\}}{A_1\{(1-F)^{-1/\alpha} - 1\}}\right)^{\frac{1}{\beta}}$ $F_2 = 1 - \left\{1 + \frac{A_2}{A_1}\left((1 - F_1)^{-\frac{1}{\alpha}} - 1\right)\right\}^{-\alpha}$
	Compound Weibull (Chen. et al, TED2011)	Fail Rate Integration (Chen. et al, IRPS2014)	Clustering model (Wu. et al, IRPS2014)

Qualification strategy for some difficult failure modes?



Gate-to-diffusion leakage and breakdown sources:
1) PC-to-TS; 2) PC-to-epitaxial layer with silicide

F. Chen IRPS 2014 Tutorial



Zhang et al., IEDM 2017

How to qualify PC-epi TDDB?

How to qualify inner spacer TDDB?

Industry scaling trends?

- What is final TDDB limit for pitch scaling? (28nm, 20nm?)
- Does new metallization scheme help? (Co,Ru,…)
- Will k value continue to scale down? Or stay, or scale back up?