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ランダム・テレグラム・ノイズにおける欠陥時定数ばらつきに関する物理機構の考察

Investigations on Time Constant Variations in Random Telegraph Noise Phenomena and its Underlying Physical Mechanisms

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Random telegraph signal noise (RTN) has been continuously studied for a long time due to its serious impacts on ultra-scaled circuits and non-volatile memories [1-4]. With the traditional simplified RTN model, no correlations of parameters can be observed with mass data, such as time constants and couplings to the gate bias. On the one side, it could be attributed to trap diversities since it is still unknown if we are talking about traps with same physical mechanisms. On the other side, traditional RTS noise model might be inaccurate to describe actual trapping process. In this work, aiming at further understandings on RTN physical mechanisms, comprehensive studies are done on RTN with main focus on traps time constant variations, including its strong correlations to thermal activation energies.

In Fig.1, the simplified RTN model is shown, together with definitions of time constants (τ_c, τ_e, τ_c/τ_e , τ_0) and their couplings to applied gate biases ($\alpha\tau_c$, $\alpha\tau_e$, $\alpha\tau_c/\tau_e$). From scatter plot of τ_0 and $E_{a,\tau0}$, no correlations can be distinguished and large τ_0 variations can be obviously observed. With detail experiment data, it is confirmed that interface trap densities or surface orientations has no impacts on the τ_0 distributions, except thermal activation energies ($E_{a,\tau0}$, $E_{a,\tau c}$, $E_{a,\tau e}$). As shown in Fig.2, strong correlations between τ_0 and $E_{a,\tau0}$ can be observed with a narrow distribution strip. The upper limit of the distribution strip can be understood by taking the measurement window and band-gap shrinking impacts into account. The measurement window is determined by the measurement sampling rate, while the band-gap shrinking at the interface will shift the defect level. An Interesting thing is that there exists a void region under the distribution strip. This can be explained by the multi-phonon-assisted model [5-6], which indicates that the time constant τ_0 should be expressed as τ_0~$\exp(E_a/k_BT)\exp(x_t/x_0)$, where x_t is the trap depth form Si-SiO_2 interface and x_0 is the dioxide thickness. This means that for traps with same E_a, τ_0 increases along with its location depth. In other words, for traps with slow τ_0, only those with large E_a can be detected due to dioxide thickness limitations.

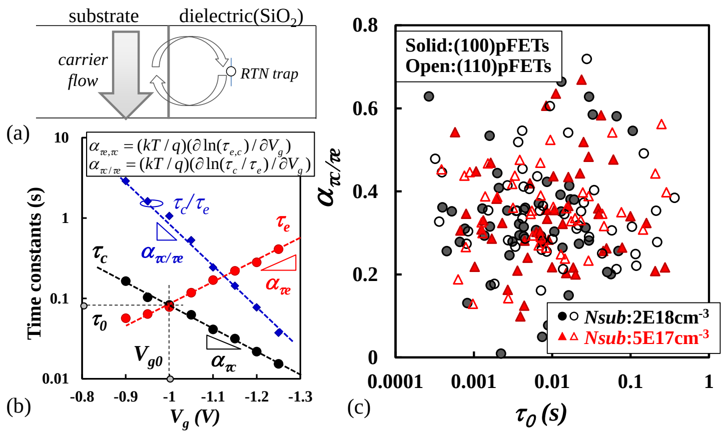

Fig.1 (a) The simplified RTN model to explain carriers exchanging between the transport channel and a trap center; (b) typical time constant (τ_c, τ_e, τ_c/τ_e) dependence on V_g; (c) scatter plot of V_g couplings ($\alpha_{\tau c/\tau e}$) and time constant (τ_0).

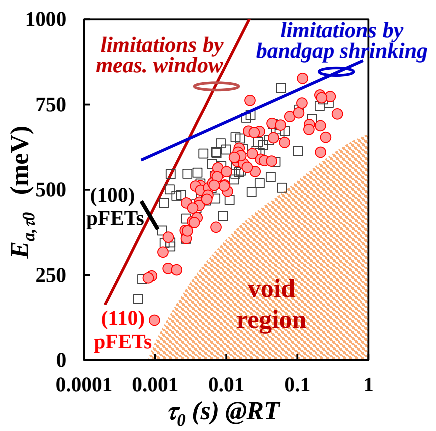

Fig.2 strong correlations between τ_0 and $E_{a,\tau0}$ are observed in (110) and (100) pFETs. Besides the upper limit of the strip, there exists a void region.

References: [1] J. Chen *et al.*, VLSI, 2013, p.184; [2] C. M. Compagnoni *et al.* TED, 59(9), p.2459; [3] T. Nagumo *et al.*, IEDM, 2010, p.628; [4] H. Miki *et al.*, VLSI, 2012, p.137; [5] M. Kirton *et al.*, Adv. Phys. 38, p.367; [6] T. Grasser *et al.*, IEDM, 2009, p.729.