Relationship between the tunneling distance and stretched-exponential function model on the positive bias stress-induced charge trapping in IGZO TFTs

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Threshold voltage shift (ΔV_T) due to the charge trapping in amorphous InGaZnO (a-IGZO) thin-film transistors (TFTs) under the positive bias stress (PBS) have been frequenty modeled as a single term of stretched-exponential function (SEF), i.e., $\Delta V_T = \Delta V_{tho} \cdot (1-\exp[-(t/\tau)^{\beta}])$ [1]. However, it has been rarely validated if the PBS-induced electron trapping into gate insulator (GI) can be relevantly modeled only by a single SEF.

In this work, it is found by combining the measurement and technology computer-aided design (TCAD) simulation [2], that the PBS-induced electron trapping needs to be modeled by multiple SEFs rather than a single SEF especially when the electron traps exist not only in the border very close to the interface between GI and IGZO but also further from the interface. Here, the tunneling distance (X_T) is defined as $qV_{STR}/T_{GI}=\Delta E_C/X_T$ with V_{STR}=PBS voltage, T_{GI}=GI thickness, and ΔE_C=conduction band offset [Fig. 1(a)] and means the distance that electrons can be tunneled from the conduction band minimum of IGZO ($E_{C,IGZO}$) into the conduction band minimum of GI ($E_{C,GI}$) through Fowler-Nordheim tunneling along. In our case, X_T is 12 nm (V_{STR}=30 V, T_{GI}=100 nm and ΔE_C=3.75 eV).

Our results suggest that a single SEF cannot resproduce the long-time PBS instability when the electron traps are located in beyond X_T from the IGZO/GI interface [Fig. 1(a)~(c)] and the sum of multiple SEFs, i.e., $\Delta V_T = \sum_{i=0}^{25} \Delta V_{tho,i} \cdot (1-\exp[-(t/\tau_i)^{\beta_i}])$ needs to be employed [Fig. 1(d)~(e)]. Furthermore, the GI electron trap location-dependences of SEF model parameters are consistently discussed [Fig. 1 (f)~(h)].

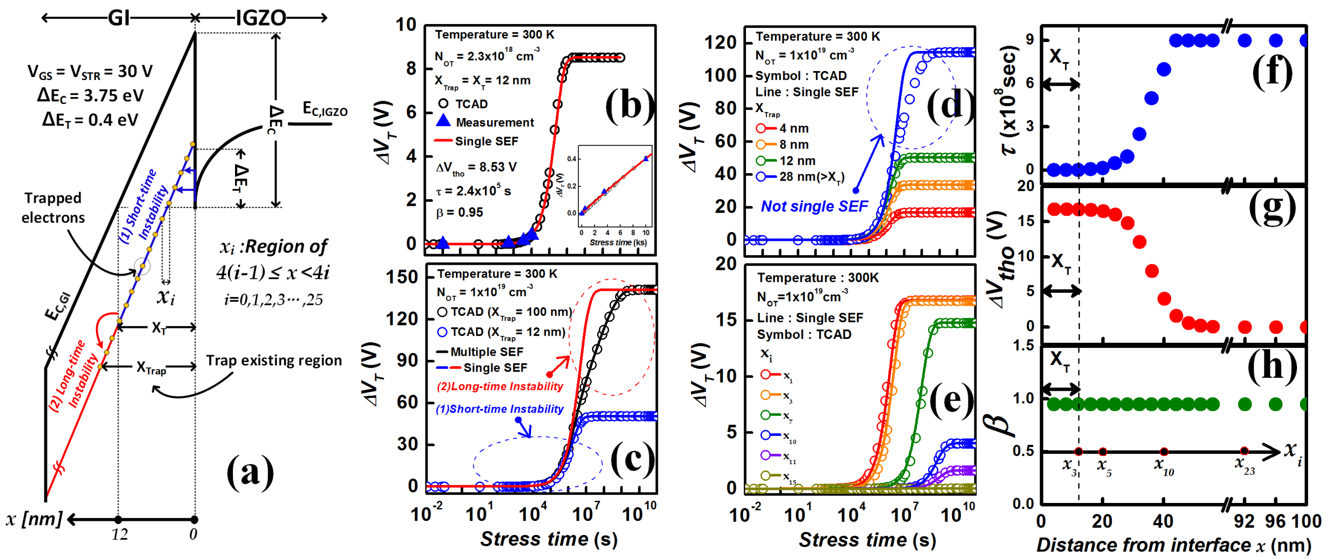

Fig. 1. (a) Schematic illustration of the charge trapping into GI and the effective tunneling distance X_T. The ΔV_T-PBS time relations with comparison of (b) measurement with TCAD simulation, (c) a single SEF with MSEF model, (d) the electron trap region (X_{Trap})-dependence and (e) the trapped electron location (X_i)-dependence in the single SEF case. The X_i -dependences of (f) τ, (g) ΔV_{tho}, and (h) β in the SEF parameters.

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