Hot-carrier Degradation in Si Devices – from Experimental Observations to Accurate Physical Modeling

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Abstract:

The breath-taking development of modern microelectronics resulted in transistor dimensions shrunk below tens of nanometres. However, this scaling is being accompanied by a much slower reduction of the supply voltage, thereby resulting in high electric fields in the modern ultra-scaled FETs, which, in turn, substantially shift the carrier ensemble from equilibrium. These non-equilibrium carriers are also called “hot” and responsible for the most detrimental reliability concern in modern FETs, i.e., hot-carrier degradation (HCD). The degradation phenomenon of HCD is very challenging to model because it is driven by the reaction converting neutral precursors (Si-H bonds) to electrically active defects (P_b centers) and this reaction can be triggered by severely non-equilibrium, hot, carriers as well as by multiple cold carriers interacting with the Si/SiO_2 interface. Even more cumbersome, HCD can be accelerated/inhibited by self-heating and mixed this another reliability effect of bias temperature instability.

This tutorial provides a summary of main characteristic featured of HCD, discusses phenomenological/empirical models, and finally presents physics-based approaches to HCD modeling. Attention will be paid to stochastic modeling of HCD capturing the impact of random dopants and random traps, as well as to coupling with bias temperature instability and self-heating.

Biography:

Dr. Stanislav Tyaginov received his PhD degree in physics at the post-graduate school of the Ioffe Physical-Technical Institute in 2006. Starting from 2008 he has been working at the Technical University of Vienna where he led the physics-based hot-carrier degradation model development group. For the period of 2018-2020 he was a Marie Curie postdoctoral fellow at *imec*, where he is currently employed as a principal researcher. Dr. Tyaginov serves as a technical program committee member at the IIRW, IRPS, ESREF, IPFA and has authored/co-authored more than 100 publications in peer reviewed scientific journals as well as in conference proceedings. Among them, more than 50 are journal papers. His scientific interests include HCD, BTI, TDDB in Si, SiGe/Ge, and SiC devices as well as tunneling phenomena.