

Sunday Tutorial 1.3

Fundamentals of RTN, BTI, and Hot Carrier Degradation: A Matter of Timescales

Tibor Grasser, Technische Universitaet Wien

Abstract

Even under stationary bias conditions, fluctuations in the terminal currents of MOSFETs can be observed, a phenomenon which has become known as random telegraph noise (RTN). The magnitude of these fluctuations increases with decreasing device area. The commonly accepted interpretation explains the noise as a result of stochastic trapping of charge carriers into oxide or interface defects. Experimental data show that the average capture and emission times of this trapping process exhibit pronounced temperature and bias dependencies.

Of particular importance is the exponential bias dependence of the capture times, which naturally links RTN to the bias temperature instability (BTI): application of large electric fields results in a dramatic decrease of the capture times, thereby upsetting the dynamic equilibrium typical for RTN. Since the defects present in a MOSFET have a wide distribution of time constants, not all defects capture their charge at the same time. Rather, one defect after the other captures its charge, resulting in slow drifts in the terminal characteristics of the MOSFET. The opposite is observed once the stress field is removed, producing long recovery transients. In nanoscale MOSFETs these degradation and recovery transients proceed in discrete steps, with each step being due to charge exchange of a particular defect with the substrate or the gate. A somewhat more complicated phenomenon is hot carrier degradation, where the above time constants now also depend on the current flowing through the channel.

While the chemical nature of the defects contributing to these various detrimental phenomena is still not fully understood, one unifying feature seems to be inherent in all of them: the wide distribution of the timeconstants, covering many decades in time. As a consequence, many features of these degradation phenomena can be understood by studying the distribution of these timeconstants, an issue which will be discussed in depth.

About the Author

Tibor Grasser received his Ph.D. degree in technical sciences from the TU Wien where he is currently employed as an Associate Professor. In 2003 he was appointed director of the Christian Doppler Laboratory for TCAD in Microelectronics. Dr. Grasser is the co-author or author of more than 400 scientific articles, editor of a book on advanced device simulation, a distinguished lecturer of the IEEE Electron Devices Society, a senior member of IEEE, has been involved in various functions of outstanding conferences such as IEDM, IRPS, SISPAD, IWCE, ESSDERC, IIRW, and ISDRS, is a recipient of the Best Paper Awards at IRPS (2008 and 2010), ESREF (2008) and the IEEE EDS Paul Rappaport Award (2011). He was also a chairman of SISPAD 2007.