Threshold Voltage Instability in high-k/metal-gate FETs

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Abstract
Threshold voltage ($V_t$) of a field effect transistor (FET) is observed to shift with stressing time and this stress induced $V_t$ shift is an important transistor reliability issue. $V_t$ shifts that occur under negative gate bias are referred as NBTI and those that occur under positive bias are referred as PBTI or charge trapping. In this paper, we present results of experimental and modeling studies of NBTI and PBTI for a variety of FETs with different gate dielectric stacks ($\text{SiO}_2$/HfO$_2$, SiON) and gate materials (TiN, NiSi, Re, poly Si). In part I, NBTI measurement and modeling results for $\text{SiO}_2$/HfO$_2$/metal pFETs are presented. The main result is that the estimated $V_t$ shifts at 10 years due to NBTI is independent of metal gate material and is comparable to those for conventional SiON/poly-Si pFETs. In part II, PBTI measurement and modeling results for $\text{SiO}_2$/HfO$_2$/metal nFETs are presented. The main results are as follows. PBTI significantly increases as the Hf content in the high $\kappa$ layer is increased. PBTI in TiN and Re gated $\text{SiO}_2$/HfO$_2$ devices is much smaller than those observed for $\text{SiO}_2$/HfO$_2$/NiSi. In summary for $\text{SiO}_2$/HfO$_2$ stacks, NBTI is observed to be independent of gate material whereas PBTI is significantly worse for FUSI gated devices. Consequently, HfO$_2$ FETs with TiN and Re gates exhibit over all superior transistor reliability characteristics in comparison to HfO$_2$/FUSI FETs.

Bio
Sufi Zafar is a research staff member at the IBM T. J. Watson Research Center, Yorktown Heights, New York. She received a Ph. D. in Physics from Syracuse University (1991) and has extensive research experience in nano-structured devices with a focus on defects, charge transport and electrical breakdown mechanisms. In recent years, Sufi has expanded her interest into the area of biophysics and has initiated a project on bio-sensing using field effect transistors. Her research has resulted in over 70 publications and 28 issued/pending patents with h-index of 28. She has presented several invited talks and tutorials at international conferences and has also served on several technical conference committees including IEDM. Sufi has participated as a panelist for NIH and SRC sponsored meeting series with the goal of identifying new opportunities for silicon technology in the area of healthcare (2009-2011). She has received a Materials Research Society Graduate Student Award (1990), Motorola Achievement Award (1998), IBM Research Division Award (2005) and is a fellow of the American Physical Society (2007).