TDDB Physics: Transitioning From Silica to High-k Gate Dielectrics

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The IC industry has spent decades trying to understand the time-dependent dielectric breakdown (TDDB) physics of silica-based dielectrics. It is critically important that we be able to transfer that TDDB physics understanding to high-k dielectrics.

First, we discuss the general features of dielectric leakage and dielectric degradation and why the IC industry needs to transition from silica-based gate dielectrics to high-k based gate dielectrics. The various TDDB models, commonly used to describe dielectric leakage and TDDB in silica-based dielectrics, are reviewed in some detail. The high-k dielectrics tend to show two important general reliability trends that must be considered: (1) the breakdown strength (E_{bd}) is lower for the high-k gate dielectrics versus silica while (2) the field/voltage acceleration factor is higher. We will attempt to explain these two important reliability observations, for high-k dielectrics, using the knowledge developed over the years from studying the TDDB physics of silica-based dielectrics. Also, we discuss the fundamental physics and chemistry of high-k dielectric materials and show how the molecular bonding (and related microstructure) can play a critically important role in determining the reliability of such films. Arguments will be presented for why the high-k dielectric films should be linear, isotropic and homogeneous (minimal phase change and separation can occur during high temperature processing). Also, the films must show adequate diffusion-barrier characteristics so that the films can withstand the processing challenges associated with metal gates. One of the potential high-k gate dielectrics that will be discussed in some detail is HfSiON. This is a medium-k dielectric (k~7-15), can be fabricated to remain amorphous, and it is found to be: linear, isotropic, and homogeneous. It also tends to have the necessary electrical, thermal, and TDDB stability characteristics needed for successful integration with metal gates.

About the Speaker -----

Joe McPherson received the *Ph.D. in Physics* from Florida State University. Prior to joining *Texas Instruments*, he was an assistant professor with the *University of North Carolina* and a visiting scientist with the *Argonne National Laboratory*. He joined TI in 1980 as a process development engineer and was instrumental in bringing silicides and laser redundancy into IC production. Since 1983, his primary focus has been on *reliability physics* where he has received numerous *Best/Outstanding Paper Awards*, published over *200 papers on Semiconductor Reliability*, authored the *Reliability Chapters for four Books*, and holds *12 Patents*. He was the 1995 *General Chairman of the IEEE International Reliability Physics Symposium (IRPS)* and still serves on its Board of Directors. In 2004, Joe received the *IEEE Engineer of the Year Award* from the Texas Society of Professional Engineers. In 2006, he was the *Chairman of the Sematech Reliability Council*. Joe is a *Texas Instruments Senior Fellow Emeritus* and an *IEEE Fellow*. Most recently, he authored a textbook: ***Reliability Physics and Engineering**, Springer Publishing, 2010.*