Electronically Active Defects in Ultrathin Oxynitrides Produced using Plasma Nitridation

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Ultrathin oxynitride films are current the current gate dielectric of choice within the CMOS semiconductor industry. With the scaling of the gate dielectric down to but a few mono-layers, the reduction of gate leakage currents, increasing reliability, and minimizing boron penetration have become paramount for the use of ultrathin gate dielectrics. [1,2] In an effort to minimize the deleterious effects of the ultrathin thin gate dielectrics, the nitrogen concentration within the films have increased. To date, this is mostly achieved using plasma-enhanced nitridation, although some thermal nitridation are still being used.

It has long been established that the presence of nitrogen with in an oxide film can produce electrically charged and active defects.[3-7] These types of defects have been referred to by a number of different names including anomalous positive change, slow states, border traps among others. These defects tend to act like donor-type traps defects where it is electrically neutral until an electron is emitted after which it becomes positively charged. In most cases these “nitrogen-related” defects have been found to lie in the lower portion of the silicon band gap. In cases where the nitrogen is close to the dielectric/silicon in interface, whether it is anomalous or not, the defect may now “communicate” with the silicon substrate such electrons can be exchanged. The emission or capture of an electron on a nitrogen-related defect depends strongly on the position of the Fermi-level at the oxide/silicon interface. When the Fermi-level is in the lower portion of the gap, as it is for pFET during normal operation, the existence of the trap will be felt as the defect emits its electron into the silicon leaving behind a positive change. In the case of the nFET, the Fermi level is usually above the defect energy level and as such, the defect is not “seen” electrically. It is for this reason, that instabilities and threshold shifts have been found to be more significant for pFETs, rather than nFETs with extremely thin, nitrided gate oxides.

In this presentation, the dependence of the nitrogen related defect density upon processing, specifically for plasma nitridation, will be discussed in detail. Techniques used for the electrical characterization will be presented to demonstrate the required optimization of not only the nitrogen concentration, but also the nitrogen profile within the dielectric.

1 D. Buchanan, IBM J. Res. and Develop. **43,** 245 (1999).
2 M. L. Green, E. P. Gusev, R. Degraeve, and E. Garfunkel, J. Appl. Phys. (Review) **90,** 2057 (2001).
3 L. Dori, J. Sun, M. Arienzo, S.Basavaiah, Y. Taur, and D.Zichermann, in *Very thin nitride/oxide composite gate for VSLI CMOS*, 1987, p. 35.
4 H. Hwang, W. Ting, B. Maiti, D. L. Kwong, and J. Lee, Appl. Phys. Lett. **57,** 1010 (1990).
5 H. Fukuda, M.Yasuda, T. Iwabuchi, and S. Ohno, Appl. Surf. Sci. **60/61,** 359 (1992).
6 K. S. Krisch and C. G. Sodini, J. Appl. Phys., **76,** 2284 (1994).
7 C. H. F. Peden, Physical Review B **47,** 15622 (1993).