Gate Oxide Breakdown

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A resistance of the gate oxide in MOS structures to the electric filed stress is a key element defining reliability of any MOS/CMOS device. Failure of the gate oxide manifests itself in its “breakdown” resulting from the formation of a conductive path across it under the influence of very high electric field or a prolonged stress. Allowing an uncontrolled flow of a very high density current to occur, oxide no longer acts as an insulator between metal gate and semiconductor substrate and the MOS Field Effect Transistor does not function. Such an irreversible, catastrophic event means the destruction of the device and ultimately malfunction of the entire circuit.

A thin oxide in MOS gate structures subjected to a high electric field breaks down due to the wearout caused by trap generation. At first randomly distributed, traps will eventually combine to create a conductive path across the oxide. Resulting flow of very high density current permanently damages the oxide. This behavior is an intrinsic property of thin insulator films and is unavoidable once gate voltage, and hence an electric field in the oxide, reaches certain critical value V_{bd} (Fig.1). In practice, reliability of gate oxide is often determined not by its intrinsic breakdown characteristics but rather by defects in the oxide causing breakdown at the lower gate voltage (V'_{bd} in Fig. 1).

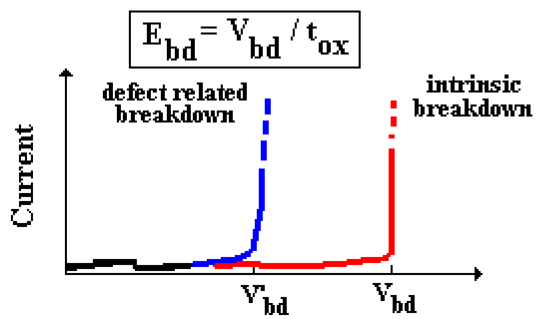

Fig. 1

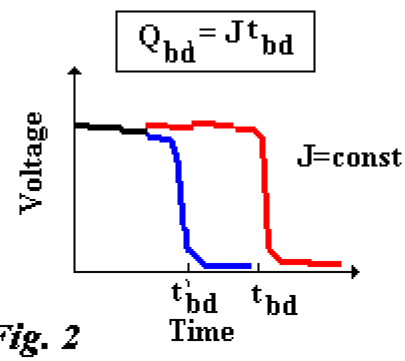

Fig. 2

To determine gate oxide integrity (GOI) and to predict its long-term reliability the measurements of gate oxide breakdown characteristics are routinely carried out using MOS test structures. There are several methods that can be used for this purpose depending on the thickness of gate oxide. In general, these methods fall into one of the following categories.

Time-Zero Dielectric Breakdown (TZDB)

To perform measurement the voltage applied to the gate contact is ramped until oxide breaks down. Accordingly, the method is know as “ramp voltage oxide breakdown”. The term “time-zero” stresses the fact that voltage is ramped rapidly and the electric field in the oxide, not a duration of the stress, is a factor driving breakdown. Quantitatively, results are presented in terms of the breakdown field E_{bd} [MV/cm] (see Fig. 1 where t_{ox} is oxide thickness).

Time-Dependent Dielectric Breakdown (TDDB)

Certain types of oxide defects that may cause its failure can only be revealed as a result of a prolonged stress, and hence, may remain undetected by TZDB method. It is therefore imperative that besides TZDB measurement, gate oxides are subjected to *Time-Dependent Dielectric Breakdown* tests . In this case (Fig. 2) a voltage is applied to the gate (Constant Voltage Stress, CVS) to enforce certain pre-determine density of current, J, across gate oxide. Measuring time after which oxide breaks down, which manifests itself in an abrupt drop of the gate voltage, an important parameter know as “charge-to-breakdown”, or $\mathbf{O_{bd}}$, can be determine (see formula in Fig 2). Alternatively, a test involving a Constant Current Stress, CSS, can be employed in TDDB mode.