technical brief ...

October 21, 1996

Relating CHARM®-2 results to charging damage . . .

Charging damage observed on antenna capacitors is due to charge transport and trapping in the gate oxide and at gate oxide-silicon interfaces. The magnitude of damage is proportional to the amount of charge per unit area transported through the oxide, Qox, which is given by Qox = J (A_r) t, where A_r is the ratio of the area of the charge collection electrode to the area of the gate oxide (the "antenna ratio"), J is the current density arriving at the "antenna", and t is the exposure time of the capacitor to the charging source. Recognizing that for the charging source to inflict damage, it must deliver this current density at the oxide conduction voltage, the oxide current density J(A_r) may be obtained from the intersection of the oxide conduction plot (Fowler-Nordheim plot) with the J-V characteristics of the charging source obtained with CHARM®-2 charge flux sensors, scaled by the antenna ratio, A_r. As illustrated in Fig. 1, $J^+(A_r)$ is the oxide positive current density, and $J^-(A_r)$ is the oxide negative current density, which could be responsible for damage to the gate oxide characterized by this particular F-N plot.

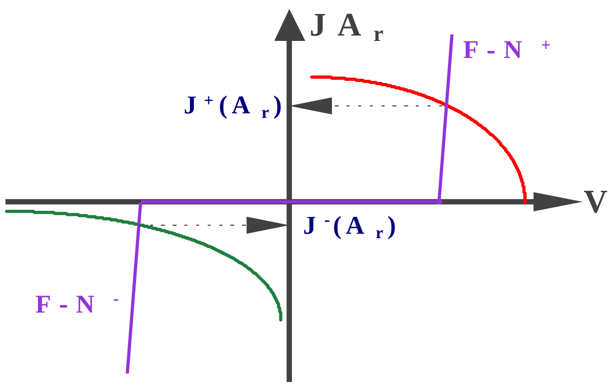

Fig. 1. Antenna-ratio-scaled CHARM®-2 positive J-V plot (red), negative J-V plot (green), and their intersection with the Fowler-Nordheim (F-N) oxide conduction plot.

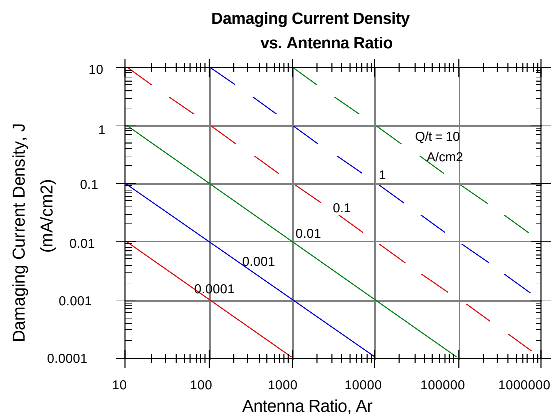

Fig. 2. Graph of the relation between the damaging current density and antenna capacitor ratios.

Since the damage charge varies due to different product sensitivities, the oxide current density responsible for damage, Qox/t = J(A_r), is graphed in Fig. 2 for several values of Q/t, representing different damage criteria and different plasma damage times characteristic of different processes. Fig. 2 may be used to determine if the oxide current densities $J^+(A_r)$ or $J^-(A_r)$ obtained at the intersection of the gate oxide F-N plot with the antenna-ratio-scaled CHARM®-2 J-V plots can cause device damage. For example, if the onset of damage occurs at Qox = 0.001Qbd, Qbd = 10 coul/cm^2, and the damage time (the fraction of process time when damage is done) t = 10 seconds, then Qox/t = 0.001 A/cm^2, corresponding to the solid blue line in Fig. 2. Consequently, for antenna ratio of 100, onset of damage will occur at J = 0.01 mA/cm^2. J > 0.01 mA/cm^2 will cause increasing amounts of damage. The presence of underlying wells or other device structural features may have additional beneficial or adverse effects on the observed damage. They are discussed in Technical Note 2: "Understanding CHARM®-2 Data and its Relationship to Charging Damage", available from Wafer Charging Monitors, Inc.

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