

JEDEC STANDARD

A Procedure for Measuring P-Channel MOSFET Hot-Carrier- Induced Degradation Under DC Stress

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Introduction

Hot-carrier-induced change of MOSFET parameters over time is an important reliability concern in modern microcircuits. High-energy carriers, also called hot carriers, are generated in the MOSFET by the large channel electric fields near the drain region. These hot carriers transfer energy to the lattice through phonon emission and break bonds at the Si/SiO₂ interface. The electric fields accelerate locally the carriers to effective temperatures well above the lattice temperature. Carriers also are injected into the SiO₂ and can be trapped there. The trapping or bond breaking creates oxide charge and interface traps that affect the channel carrier mobility and the effective channel potential.

In this document we will describe a procedure to characterize the hot-carrier-induced degradation of P-MOSFETs during channel conduction (i.e., $V_{GS} < 0$ V, $V_{DS} < 0$ V). In the case of p-channel devices, electrons, generated by impact ionization, can be trapped in the gate oxide near the drain region where the channel electric fields are maximum. These trapped electrons attract positive charge to the oxide interface and shorten the effective channel length. Depending on the device sensitivity to short channel effects, the electron-trapping enhances the p-channel MOSFET drive current, increases the channel mobility and transconductance, and decreases the absolute magnitude of the threshold voltage with consequent increase in off-state current.

In advanced submicron CMOS technologies (gate length < 0.25 μm , gate oxide thickness < 20 - 30 Angstroms), the p-channel devices' hot-carrier-induced damage has been observed to be dominated by hot-hole injection. This hot carrier degradation mechanism results in interface-state generation as well as positive fixed charge formation. P-MOSFET devices stressed under the hot-hole injection exhibit decreased p-channel MOSFET drive current, decreased channel mobility and transconductance, and increased absolute magnitude of the threshold voltage.

Both electron and hole injection can be a problem depending on the device operation in the circuit. The physical damage mechanism depends on the oxide thickness, vertical and channel electric field as well as the injection conditions.

Oxide (both positive and negative) charge and interface traps affect transistor performance in all operating regimes. Parameters such as threshold voltage, input and output transconductance, and drive currents are commonly monitored to identify performance change. The rate of change of each parameter is determined by the MOSFET design and IC process details. Both p- and n-channel MOSFETs are affected by hot carriers. This document addresses only p-channel MOSFETs that are operating with a conducting channel.

