New Mechanism of Body Charging in Partially Depleted SOI-MOSFETs with Ultra-Thin Gate Oxides

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Abstract

The aggressive scaling of the gate oxide leads to direct gate tunneling current, which affects the floating-body effects in partially-depleted SOI MOSFETs. Experiments and simulations show that the gate-to-body current charges the body causing an unexpected 'kink' effect to occur at low drain voltage. This kink results in a second peak of transconductance, whose time-dependent behavior and practical consequences are investigated.

1. Introduction

With the shrinking of the gate oxide in the ultra-thin range (sub-2 nm), the increasing gate tunneling current adversely impacts the consumption and performance of CMOS circuits [1]. An interesting consequence of tunnel currents is the modification of the floating-body voltage in partially-depleted (PD) SOI MOSFETs. The gate-to-body current becomes strong enough to charge ($V_{G1} > 0$ for NMOS) or discharge the body of the device, hence resulting in unusual *Gate-Induced Floating-Body Effects* (GIFBE).

In this paper, we examine for the first time the impact of GIFBE on transconductance and drain current characteristics. Systematic experiments, presented in section 2, demonstrate that specific GIFBE appear, even at low V_D, in SOI MOSFETs with ultra-thin gate oxides. Dimensional and temporal aspects are investigated and their practical importance is outlined. In section 3, numerical simulations are performed which corroborate the experimental data and clarify the behavior of GIFBE.

2. Experimental basis

2.1. Devices

PD-SOI MOSFETs were fabricated on conventional Unibond wafers (t_{BOX} = 400 nm) with a 0.12 µm CMOS technology from STMicroelectronics. The silicon film was 150 nm thick, the body doping was ≈ $1x10^{18}$ cm^{-3} and the gate oxide was 2 nm thick. The results discussed next correspond to N-MOSFETs with channel lengths and widths in the range 0.1–10 µm.

2.2. Electrical characteristics

The drain current characteristics (Figure 1), measured at low drain voltage (V_D = 0.1 V), show a sudden increase of the drain current near $V_G \approx 1$ V. This unexpected 'kink' on the drain current gives rise to a second peak in transconductance, which can exceed by up to 40 % the normal peak (for $V_G \approx 0.5$ V).

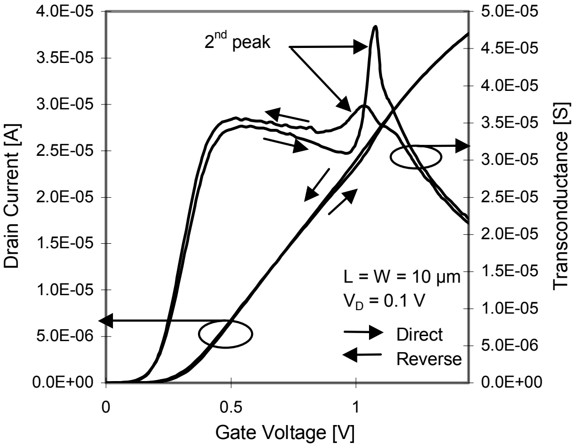

Figure 1. $I_D(V_G)$ and corresponding $g_m(V_G)$ characteristics measured by scanning the gate voltage in the direct and the reverse directions.

An immediate consequence is that this kink alters the accuracy of conventional parameter extraction methods. For example the 'linear' function $Y(V_G) = I_D/\sqrt{g_m}$ is frequently used to determine the threshold voltage and carrier mobility [2]. However, as illustrated in Figure 2, $Y(V_G)$ curves become non-linear (with a strong distortion in the kink region, for $V_G \approx 1$ V), and rather inefficient.