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Advanced SOI MOSFETs with buried alumina and ground plane: self-heating and short-channel effects ☆

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Abstract

SOI circuits exhibit excellent performance and scalability but suffer from self-heating. This critical problem is systematically analyzed by using an equivalent thermal circuit and 2-D simulations. We demonstrate that the thermal dissipation and self-heating in SOI MOSFETs can dramatically be improved by modifying the generic SOI structure: replacement of the buried oxide with buried alumina. However, alumina is a high-*K* dielectric which also affects the electrical properties: the drain-to-substrate fringing fields are enhanced, leading to more severe short-channel effects. The trade-off between the thermal and electrical performance of very advanced SOI transistors (10–100 nm long, 5–100 nm thick) is examined by comparing various SOI materials and MOS architectures. The optimum solution consists of a ground plane located underneath a relatively thin buried alumina.

1. Introduction

The horizon of bulk-Si MOSFETs is clouded by the difficulty to control the short-channel effects (SCEs) [1]. Further scaling requires thinner junctions and a heavier channel doping which hampers the carrier mobility. In fully depleted silicon-on-insulator (SOI) transistors, the scaling rules are totally different because the thin silicon film and buried oxide (BOX) serve as additional tunable parameters [1–7]. The Si film thickness is even more important than the film doping. The superior scalability of SOI MOSFETs comes with an enhanced performance (higher-speed, lower voltage/power operation, etc.) of SOI CMOS circuits. These key advantages explain why the SOI technology has been included in the International Technology Roadmap for Semiconductors and has been adopted by major companies.

However, the self-heating of thin and short SOI devices stands as a very serious problem. As the film becomes thinner, the heat path through the source/drain regions is squeezed which increases the thermal resistance and makes the transistor body temperature rise. Self-heating is responsible for performance degradation in SOI MOSFETs: mobility and threshold voltage lowering, increase in leakage current and subthreshold swing, etc. [8–13].

Self-heating in SOI devices is primarily due to the poor thermal conductivity of the buried SiO_2 which acts as a barrier for heat dissipation. It has recently been proposed to replace the standard silicon dioxide with buried alumina or other dielectric, able to offer excellent thermal conductivity [14,15]. The aim of our paper is to elaborate on this innovative concept of generalized SOI structure. Remark that the letter **I** in SOI is no longer restricted to SiO_2 and now recovers the universal sense of buried *insulator* (still named BOX). We examine the critical role of the BOX from the viewpoint of both

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