

# Defect Detection with Transient Current Testing and its Potential for Deep Sub-micron CMOS ICs

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## Abstract

*Transient current testing ( $I_{DDT}$ ) has been often cited as an alternative and/or supplement to  $I_{DDQ}$  testing. In this article we investigate the potential of transient current testing in faulty chip detection with silicon devices. The effectiveness of the  $I_{DDT}$  test method is compared with  $I_{DDQ}$  as well as with  $Sb$ -based voltage testing. Photon emission microscopy is used to localize defects in several faulty devices. Furthermore, the potential of  $I_{DDT}$  testing for leaky deep sub-micron devices is investigated.*

## 1 Introduction

Quiescent current testing ( $I_{DDQ}$ ) is an important ingredient of the test suite for digital VLSI. The contributions of  $I_{DDQ}$  testing in quality improvement, test cost reduction, burn-in elimination have been well recognized [1]. However, the effectiveness of conventional  $I_{DDQ}$  testing in deep sub-microns is expected to be eroded owing to the increased sub-threshold current in MOS transistors [2-5]. Many solutions have been proposed to contain the increased sub-threshold leakage and are documented elsewhere [3,5,6]. These solutions include utilization of reverse biasing techniques to reduce the sub-threshold leakage in the test mode [3,5], utilization of Silicon On Insulator (SOI) technology for a steeper sub-threshold swing [7,8], or utilization of multi-threshold transistors to contain the sub-threshold leakage [9]. Moreover, containment of sub-threshold leakage is an important parameter for low power and device reliability consideration. Therefore, many low power circuit-level techniques have been devised to significantly reduce the sub-threshold leakage current.

Typically these solutions require non-trivial changes in the standard cell library or in the process. In many applications such as high performance VLSI, these solutions may pose several restrictions. CMOS processes for such devices are aggressively scaled ( $V_T$  and gate oxide) and optimized for switching speed. As a result, these devices are not  $I_{DDQ}$  testable. Therefore, ensuring gate oxide quality and reliability is becoming an increasingly difficult as well as an expensive task.

In this article, we investigate the potential of transient current testing ( $I_{DDT}$ ) as an alternative/supplement to  $I_{DDQ}$  testing. The motivation of this research comes from the following reasons: (i) To compare the effectiveness of  $I_{DDT}$  with respect to  $I_{DDQ}$  and voltage testing. For a production test method, the reproducibility of the test method is of prime importance. (ii) To investigate the feasibility of  $I_{DDT}$  based test techniques in a deep sub-micron environment. Current-based test techniques are much more sensitive compared to voltage-based counter parts. Owing to several factors, in deep sub-micron voltage-based test strategies are unlikely to guarantee quality expectations. (iii) To investigate the speed-up factor. For  $I_{DDQ}$  measurements, one does not have to wait till the current has reached the quiescent level. Hence, it is possible to enhance speed of the measurements. In other words, it is possible to perform  $I_{DDT}$  measurements at a significantly higher rate compared to  $I_{DDQ}$  measurements.

## 2 Previous Work

Some of the initial work on  $I_{DDT}$  was done by Frenzel and Marinus [10]. They simulated a small TTL circuit (few logic gates) assigning different sinusoidal waveforms on the inputs. They described complete power supply current as a signature of the Device Under Test (DUT). The signature of the DUT was compared with that of a golden device. In this manner a pass/fail criterion was established. So and Misaki [11] applied dynamic current monitoring techniques on SRAMs. To improve the defect detection capabilities of the dynamic current, they incorporated an extensive DFT strategy. The DFT scheme included separate  $V_{DD}$  and  $V_{SS}$  supplies for transient measurements, distributed switches to switch between the normal  $V_{DD}$  ( $V_{DD}$ ), and a test  $V_{DD}$  ( $V_{DD}$ ) only for dynamic current measurements. Furthermore, two dynamic current monitors and a set of controls are needed on the DUT. In their subsequent paper [12], the authors implemented the concept in silicon. The results reported showed that  $I_{DDT}$  is a better test method compared to  $I_{DDQ}$  and logic testing for open defects. However, the DFT implementation required is non-trivial and has implications for performance and test overhead.

Musipacific et al. [13] proposed the concept of Transient

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