

# Application of TIVA in Design Debug

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## Abstract

Thermally-Induced Voltage Alteration (TIVA) is a relatively new technique for locating electrical defects in integrated circuits [1,2]. In this paper a novel application of TIVA, locating design anomalies, is described. A newly designed integrated circuit with high and inconsistent  $I_{DDQ}$  currents was initially diagnosed with limited success using various failsite isolation techniques. The TIVA technique was successful in accurately locating design anomalies. Results from TIVA identified a spurious ring oscillator in the design. Design modifications carried out using a focussed ion beam (FIB) verified the accuracy of the results from TIVA. This study clearly extends the use of TIVA beyond that of locating electrical defects and anomalies and into the realm of design debug.

## Introduction

Electrical failsite isolation techniques form a critical component in analyzing integrated circuit failures. In addition to localizing a failsite, they assist in understanding the electrical characteristics of the physical defects responsible for the electrical failure. Examples of such techniques are Thermally-Induced

Voltage Alteration (TIVA) and Seebeck Effect Imaging (SEI) reported by Cole et al. [1,2]. In these techniques a physical defect is detected when its electrical characteristics are thermally altered through localized heating. The localized heating is accomplished by using an infrared laser beam in a Scanning Optical Microscope (SOM). The schematic of the experimental setup is shown in Fig.1. In this experimental setup the device under test is powered using a constant current source. The voltage across the constant current source is utilized as the input of an SOM image. When the localized heating results in variation of the conductance of an electrically shorted region, the power demand of the device changes which results in a change of the voltage across the constant current source. The resultant image is then known as the TIVA image. On the other hand, when the localized heating occurs on an open conductor, a electrical potential gradient is produced, known as the Seebeck Effect. The change in potential of the floating conductor changes the power demand of the entire integrated circuit. The resultant SOM image is then referred to as the SEI image. While the physical principles underlying the TIVA and SEI images are different, the experimental setup used is the same. Henceforth the generic word TIVA is used in this paper to refer to the experimental setup used.

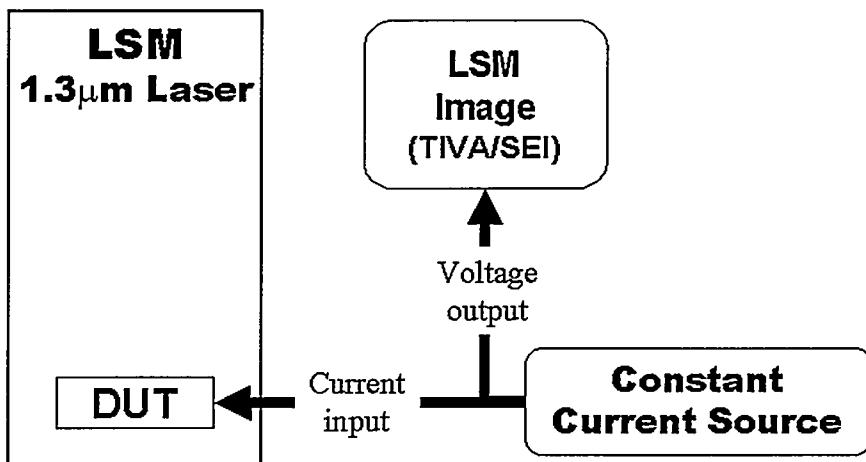


Fig.1 Experimental setup used for TIVA imaging

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Several semiconductor and conductor parameters in an integrated circuit can vary due to localized heating. Localized heating utilized in TIVA, SEI and OBIRCH [3] have been shown to be successful in locating physical defects. In this paper an application of TIVA in detecting design related anomalies in integrated circuits is reported. This study clearly extends the use of TIVA beyond that of locating electrical defects and into the realm of design debug.

## Experiment and Results

A newly designed integrated circuit device exhibited high Quiescent Power Supply Current ( $I_{DDQ}$ ) in a large number of samples. The  $I_{DDQ}$  ranged from  $200\mu\text{A}$  to  $1\text{mA}$  between different units of this device type. Various tests were performed to localize the source of the excess current. Electrical failsite isolation techniques including liquid crystal (LC) hot spot detection, photon emission microscopy (PEM) and fluorescent microthermal imaging (MFI) did not reveal the source of the excess current. Charge-Induced Voltage Alteration (CIVA) [4] was performed in a Cambridge S200 Scanning Electron Microscope. The resultant CIVA image showed a signal in the phase locked loop of the die as shown in Fig. 2. The CIVA signal is expected in the site observed and does not indicate the source of the excess  $I_{DDQ}$ .

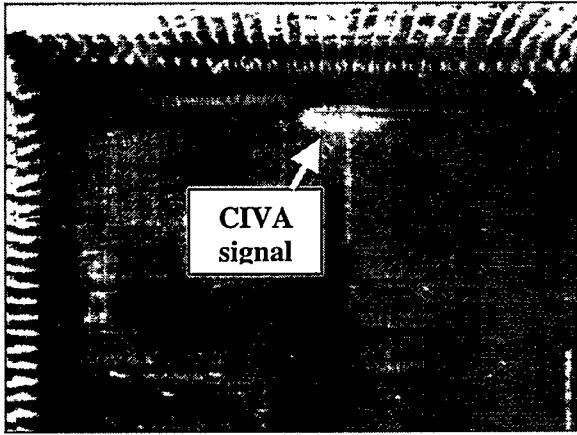


Fig.2 CIVA image of the device showing a signal in the phase locked loop module of the device.

Assuming that the underlying mechanism causing the high  $I_{DDQ}$  is temperature sensitive, the device was tested using the TIVA setup. The device was first decapsulated using nitric acid in a jet etcher to expose the top surface of the die and mounted in a socket. The power pins were connected to a constant current

source configured such that the voltage across the device was the operational voltage. The "static state" TIVA testing as described by Cole et al. was then performed in a Zeiss Laser Scanning Microscope.

An optical image of the die is shown in Fig.1A. The corresponding TIVA image of the die is shown in Fig.1B. It can be seen in Fig.1B that there exists a TIVA signal at three locations on the die labeled A, B and C. Figures 2A and 2B show the high magnification optical and TIVA images respectively at site A. Figures 3A and 3B show the high magnification optical and TIVA images respectively at site B. Figures 4A and 4B show the high magnification optical and TIVA images at site C.

## Discussion

The three locations observed by TIVA were first closely inspected using design tools. It was observed that a chain of inverter circuits is present at the three locations where the TIVA signals were observed. These inverters are part of the spare Focused Ion Beam (FIB) gates designed into the device for future design debug needs. These inverters were linked together which resulted in the formation of a ring oscillator (Fig.5). The presence of the ring oscillator can potentially lead to an increased  $I_{DDQ}$  due to continuous transistor switching processes in the oscillator. Microsurgery using a Focused Ion Beam tool was then performed to verify that the ring oscillator is the source of excess  $I_{DDQ}$ . The interconnections between the transistors wiring the oscillator chain were disconnected and the transistors were then tied to ground.  $I_{DDQ}$  testing of the modified device resulted in an acceptable value for the  $I_{DDQ}$ .

In the current study, localized heating of the ring oscillator chain resulted in a change in the voltage across the current source powering the device. The current through the device is a function of the transistor switching time, which is inversely proportional to the supply voltage. Localized heating can cause changes in several electrical parameters that are sensitive to temperature. These can result in variation of the transistor switching speeds, which result in a corresponding variation of the power demand from the constant current source.

An alternative to the TIVA approach would be localization of the failsite using FIB and probing which are both tedious and time consuming. In the current analysis TIVA enabled rapid resolution of the high  $I_{DDQ}$  problem.

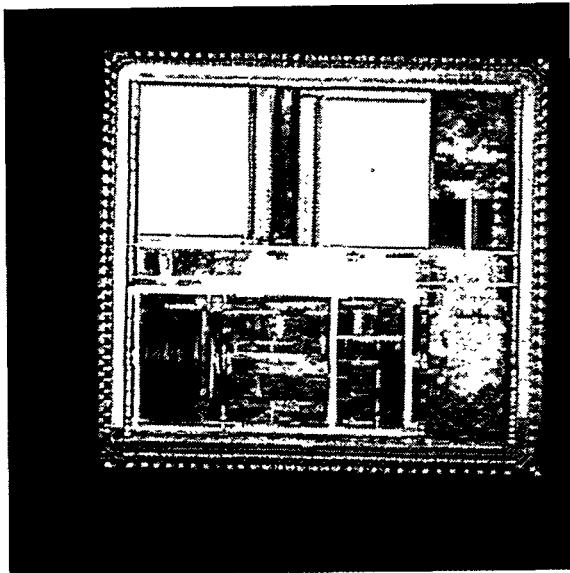


Fig.1A Optical image of the entire die under study.

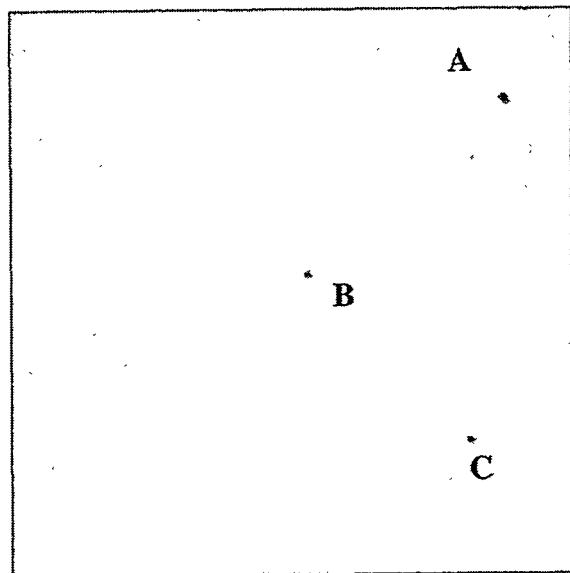


Fig.1B TIVA image of the device shown in Fig.1A. Image shows three locations, labeled A, B and C, which exhibit the TIVA signal.

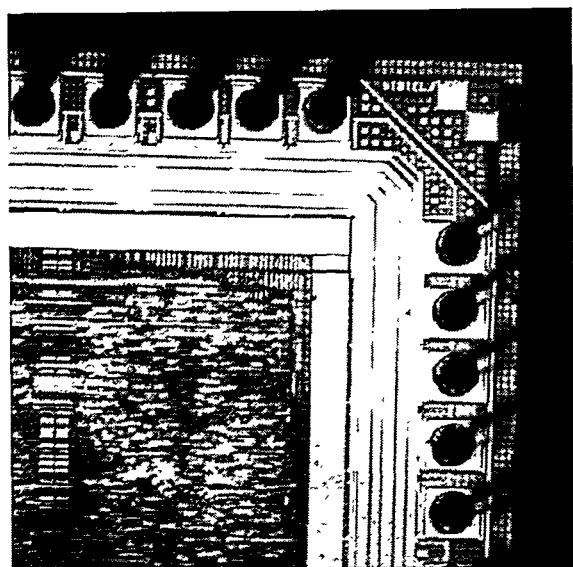


Fig. 2A High magnification optical image of the die pinpointing the location A.

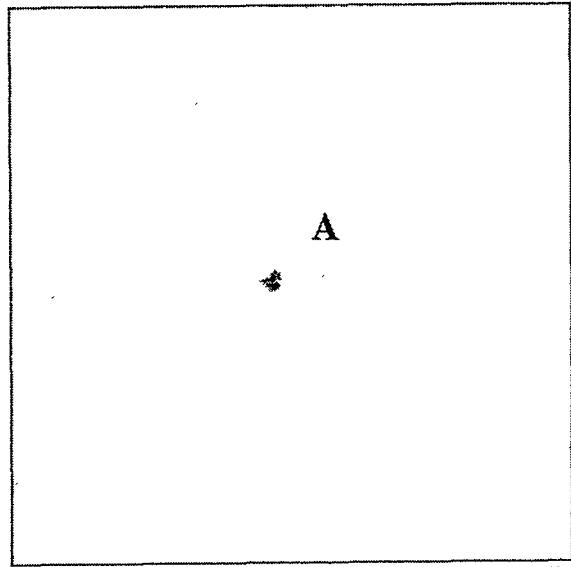


Fig. 2B High magnification TIVA image of the die shown in Fig.2A indicating the location of the failsite.

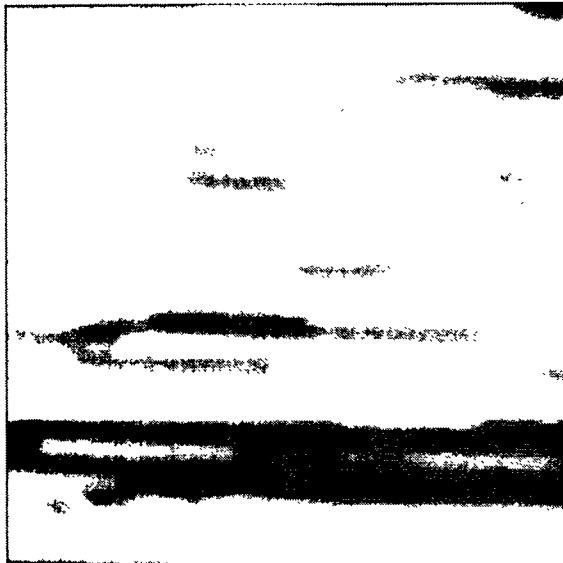


Fig. 3A High magnification optical image of the die pinpointing the location B.

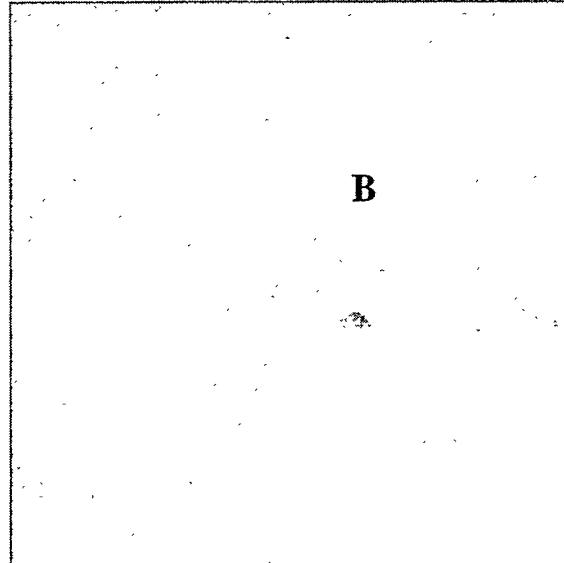


Fig. 3B High magnification TIVA image of the die shown in Fig.3A indicating the location of the failsite.

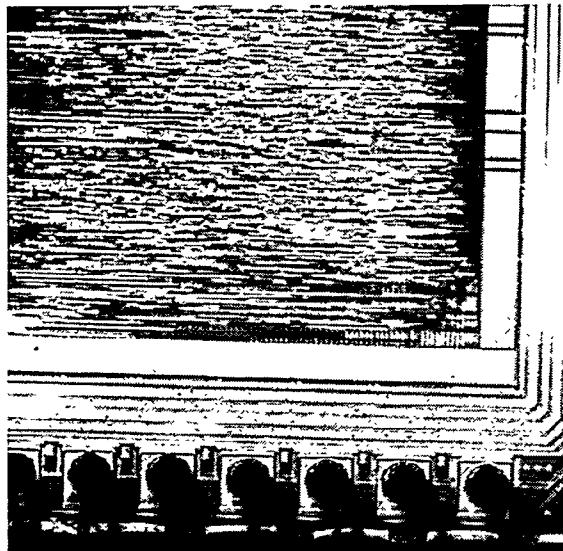


Fig. 4A High magnification optical image of the die pinpointing the location C.

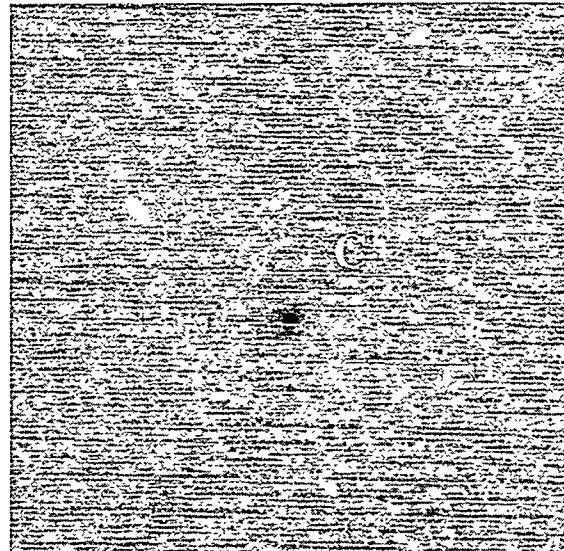


Fig. 4B High magnification TIVA image of the die shown in Fig.4A indicating the location of the failsite.

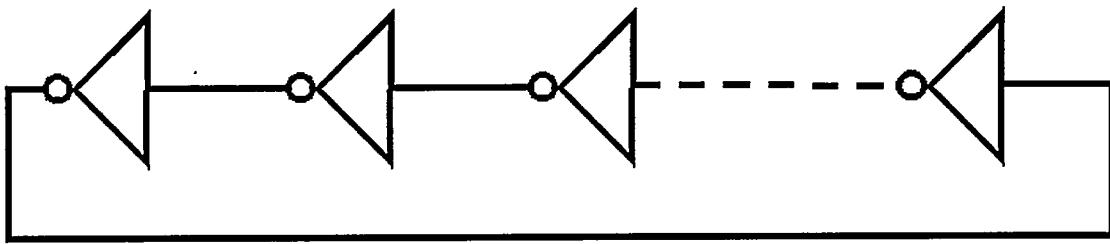


Fig. 5 Schematic of a ring oscillator. In the device analyzed with TIVA, many spare FIB gates were linked together resulting in the formation of the oscillator.

## Conclusion

An application of TIVA in successfully isolating a design anomaly is presented. TIVA analysis resulted in localization of the source of excess  $I_{DDQ}$ . Instead of a physical defect, the source of excess  $I_{DDQ}$  was found to be a set of spare gates which inadvertently formed a ring oscillator. Modifications with FIB corroborated the conclusion drawn from the TIVA analysis that the ring oscillator is the source of the excess  $I_{DDQ}$ . It was thus shown that the TIVA setup could be used to localize non-physical defect related anomalies.

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