DOE/SF/19460--T2

INTEGRATED CIRCUIT TESTER USING INTERFEROMETRIC IMAGING

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Reviewed for Classification 11-27-96

(Date)

UNCLASSIFIED

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ABSTRACT

An interferometric imaging technique can provide time-resolved diagnostics of semiconductor integrated circuits. The semiconductor device is placed in one arm of an interferometer and illuminated with a picosecond pulse from a sub-bandgap infrared laser. As the laser passes through the semiconductor, it samples local variations in the index of refraction. These variations are caused by a number of physical phenomena including dopants in the material such as those used to form device structures, heating due to the flow of electrical currents, and changes in carrier concentration due to injection. These variations have both static and dynamic components. The dynamic components are associated with the normal device operation and are the most interesting. To separate the two components, the device is first imaged in a quiescent state (no external voltage applied), and then a second image is taken after the device enters a known voltage state. Differences between the two images determine where the local index of refraction has changed and by how much. A third image taken with the reference arm of the interferometer blocked, allows device structures to be associated with particular changes in the index of refraction. Activation of the voltage state is synchronized with the pulsed illumination source, and the time delay between the application of the voltage and the laser probe pulse allows us to take a series of images that map the time evolution of the interferogram.

Taking heating as an example, a change in the index of refraction of 0.1% over a length of $5 \mu\text{m}$ ($10 \mu\text{m}$ double pass), which may be considered to be the vertical extent of a point heat source, results in about 0.01 waves of interference. We estimate that the resolution of our imaging system is 0.01 waves limited by the 8-bit CID camera we use. Such a change in the index of refraction can be caused by a temperature rise of 20°C . We can easily see this magnitude of change in the silicon FET circuits we have examined. Much higher resolution should be obtainable with better detectors.

This technique offers an exciting new diagnostic for semiconductor integrated circuits. The technique is noninvasive and compatible with high-speed operation of integrated circuits. The picosecond time resolution enables us to either characterize specific logic states or watch an individual device turn on. This imaging technique is sensitive to all of the index of refraction changes that can be associated with IC's. These include heating due to current flowing through narrow wires and charge injection into the depletion region of a transistor. As more manufacturers shift to flip-chip technology and its associated inaccessibility of surface leads for device testing, the noninvasive, back-surface probe of the interferometric imaging technique could become one of the few external IC testers still capable of operating with the latest chip designs. It should also be able to operate at the IC's rated clock speed.

ACKNOWLEDGMENT

This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC03-92SF19460, the University of Rochester, the New York State Energy Research and Development Authority, and an SBIR contract from the U.S. Air Force Phillips Laboratory. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

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The detection scheme used a Twyman-Green interferometer.

Figure caption

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