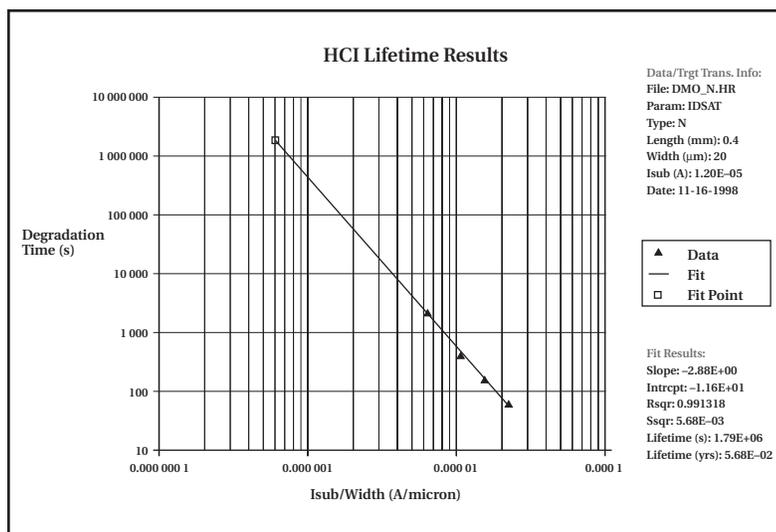# Hot Carrier Stress Testing and Analysis Package

Version 5.0

The HCI Analysis Tool macro performs a least squares fit using a "power law" time dependence in order to extrapolate and interpolate target results and create a device lifetime plot.

- **Stress up to 20 devices in parallel**
- **Measure up to ten device parameters**
- **Stress and analyze both n- and p-channel devices**
- **User-specified test parameters and exit criteria**
- **Displays degradation data in real time**
- **Interactive and automated operating modes**
- **Suitable for process or product development labs**
- **Automated prober control**
- **Excel®-based HCI Analysis Tools**
- **Compatible with S900NT parametric testers**
- **Based on JEDEC 14.2 standard**

As devices are scaled to smaller geometries, the electric fields between drain and source and across the oxide become larger, increasing the probability that impact ionization will occur and charge (hot carriers) will create interface damage or be injected into the oxide. When interface damage or charge trapping occurs in the oxide, device performance may degrade to the point of circuit failure.

Characterizing charge trapping problems like these requires making a set of baseline parametric measurements (V_t, G_m, I_{sub}, etc.), followed by a series of stress cycles designed to accentuate the charge trapping phenomena. The cumulative degradation that results from the stress can be tracked by measuring the transistor parameters after each stress cycle. By extrapolating from these results, it is possible to predict real circuit performance under normal operating or use conditions.

HCI Solutions

Keithley's Hot Carrier Injection (HCI) test environment has been designed to maximize test flexibility and efficiency. Users can monitor both actual change and percent of change in their choice of up to ten different device parameters:

- Linear drain current
- Saturated drain current
- Gate current
- Drain leakage device off current
- Threshold voltage test at specified drain current
- Transconductance at specified drain current
- Extrapolated threshold voltage
- Maximum transconductance
- Substrate current
- Subthreshold slope

In addition to having their choice of test parameters, users can specify unique test conditions for each device, allowing an optimal test sequence. All parameters can measured in both the forward and reverse measurement modes. In the reverse mode, the source and drain are transposed.

The HCI test monitors the parameter values at predetermined intervals during the stress cycle. Stress testing stops when the device parameter changes exceed the user-specified exit criteria. If lengthy stress cycles are required, HCI test times may stretch into days. To alleviate this and provide faster time to information, the software allows the user to specify unique exit criteria for each device, permitting optimization of exit criteria. Up to 20 devices can be stressed in parallel, further speeding test throughput.*

A test module that's compatible with the Keithley Test Environment (KTE) and a user library that enables HCI test programs to run in the user's prober environment are included with the software. This allows increased flexibility in scheduling HCI test times and automated "hands-off" testing of multiple wafer sites.

Keithley's HCI Analysis Tool is a macro written in Microsoft Excel's powerful macro language. This macro makes it simple to import HCI data into the Excel application for display and analysis. The HCI Analysis Tool macro performs a least squares fit using a "power law" time dependence in order to extrapolate and interpolate target results and create a device lifetime plot. Degradation and lifetime models are available for both n- and p-channel lifetime

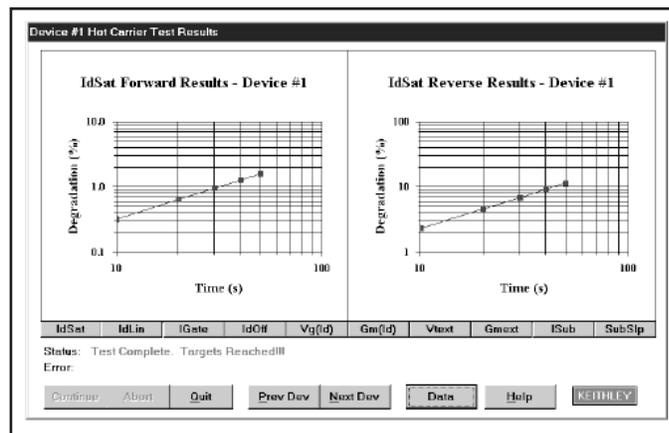*Stressing multiple devices may require several devices to be at the same stress bias conditions.

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Test results are displayed in both tabulated and graphical format. Device testing ends when the exit criteria are met or the maximum specified stress interval is completed.

analysis. These plots can be easily exported to other Microsoft applications, such as Microsoft Word or PowerPoint, for publishing or presenting results.

Choice of Operating Modes

The Windows-NT-based HCI software offers two different operating modes. The interactive mode is designed to explore various combinations of test conditions to determine the ones most appropriate for a particular device. The automated mode is designed to speed and simplify HCI testing through batch program execution.

Interactive Operating Mode

The interactive operating mode employs three Graphical User Interface (GUI) input screens: General Setup, Test Information, and Test Results. The *General Setup* screen defines general test information, as well as the rates at which the HCI results are displayed and logged to the database. Device test and stress information is entered in the *Test Information* screen. The software allows monitoring up to ten parameters of up to 20 devices at once.

The *Test Results* screen displays HCI test results. Test results are displayed in both tabulated and graphical format. Results are updated to this screen and saved to comma-delimited ASCII files at the user-specified stress intervals. Devices are tested sequentially and results are displayed one device at a time. Device testing ends when the exit criteria are met or the maximum specified stress interval is completed. After testing, the user can query the results for all devices under test.

Automated Operating Mode

In the software's automated operating mode, a user library and the Keithley Test Program Manager (KTPM) are used to add HCI test modules to a wafer test plan. The Keithley Test Execution Engine (KTXE) can then run the HCI tests as part of a test plan that includes prober control.

Keithley's Excel-Based HCI Analysis Package

Keithley's HCI Analysis Tool is capable of fitting and displaying percent or actual degradation data in order to calculate the time necessary to achieve a user-specified target value. The user can specify the parameter to be analyzed and the fit range. Output results include the slope and intercept of the "best fit" line through the data and the time to target. In addition to analyzing HCI data, the HCI Analysis package can create a device lifetime plot. The user inputs the transistor width and length and the substrate current at the device use bias voltage; the projected device lifetime results are displayed in seconds and years. Device degradation and lifetime modes are available for both n- and p-channel devices.

System Requirements

The HCI software is designed for use with the S900NT parametric tester. It requires a minimum of three Force-Measure Units (FMU), a Picoammeter Unit (PAU), an Integrating System Voltmeter Unit (ISVU), and S900NT software (version 3.2.3 or later). Each additional FMU allows an additional stress bias level, up to a system maximum of five FMUs. Libraries are provided in Visual C to facilitate automated wafer probing. Microsoft® Excel 97 is required to use the analysis macro.