Proposal for a WLR Monitoring Program

A WLR monitoring program is designed to give customers of a semiconductor foundry confidence that the semiconductor products built by the foundry will be reliable. Such a monitoring program must have the ability to rapidly sample the product as it moves through the fabrication line without neither introducing significant delays nor adding significant cost to the wafers.

At the same time, the results of this testing must be capable of being extrapolated to provide assurance that the products will indeed be reliable over the expected lifetime of the product. These predictions need to be made using conservative industry standard test techniques.

The acceptable industry standard test techniques often require hundreds or even thousands of hours of testing in order to demonstrate the ability to withstand the expected stress conditions for 10 or 20 years. There are limits to the stress conditions that can be forced on a semiconductor device before the failure mechanism changes. This requirement runs contrary to the need to provide an inline monitor of the output of the semiconductor fab.

The solution to this dilemma is to perform the industry standard test conditions for extended periods of time on initial process qualification material produced as the fab ramps up production. The fab volume is typically low at that time, so time is available at this point to conduct these extended tests. At the same time, fast WLR process control tests can also be conducted on these same products. Assuming the qualification tests pass, and the products are shown to be reliable, the process control data taken on these wafers demonstrates will show the distribution of the fast test results shown by material that can pass the extended traditional tests.

The fast tests are designed to measure the rate of degradation at one stress condition. These tests commonly obtain additional acceleration by the introduction of high stress gradients, or worst case construction techniques that make the results of these tests difficult to extrapolate using existing failure mechanism models. Thus these fast test results must be considered only process control tools. The are not intended to replace the longer extrapolation tests, rather, they are intended to show when the process is in control, and when material that is significantly different from the qualification samples has been generated.

The results of the fast tests are compared statistically to the results of the qualification tests. If the results of the fast tests show the rate of degradation is within the distribution of the results of the fast tests for the qualification parts, then the qualification data shows that wafers with the same rate of degradation are reliable. If the new data shows statistically different results than the original qualification material, then the qualification data can not be used to show that this material is reliable. This material must be subjected to specific long-term extrapolation tests, or it must be examined to determine why the material is different. The statistically different material can either be scrapped, down graded or accepted depending on the results of the analysis of cause. In any event, the process should be changed to prevent the future production of anomalous material like this.

Standard Qualification Tests

The Fabless Semiconductor Association (FSA) has a committee, which is in the process of establishing a standard qualification guideline for semiconductor foundries. A copy of a preliminary specification can be viewed on their web site at www.fsa.org (complete address www.fsa.org/committees/sfpq_guidelines.pdf). This specification lists the tests, which must be performed to fully qualify a semiconductor process. This qualification includes random defect (infant mortality) measurement tests (e.g. operation life test) as well as wear out test techniques (e.g. electromigration, HCI, Ionic Contamination…). Some of these tests are quite rapid (e.g. Plasma Process Induced Charging tests) but most will require hundreds or thousands of hours of stress at the test conditions specified in the standard. For instance, the electromigration test is specified to be conducted to measure a time to 20% change in resistance at a current density below about 3MA/sq. cm. and a temperature below 300 C. This sort of test can easily require tests much too long to be considered an in line test, but well within the time frame normally allowed for an initial qualification program.

Chiron's Proposal

The equipment required to conduct a full set of qualification tests must include instrumentation that can complete both the longer qualification tests and the faster in line WLR process monitor tests. Chiron has designed the Centaur tester to accomplish both of these activities. The Centaur can be configured to test many devices in parallel to allow completion of the qualification tests on multiple samples at one time. Additionally, this tester can be configured with a different probe card to allow the testing of multiple devices sequentially in line for the fast WLR process monitoring. One Centaur can be used to perform the initial fast WLR characterization testing of the initial product wafers. This should take less than one day after the samples are prepared. The Same Centaur can then be used to perform the standard qualification tests as described by the FSA standard. Using the sample size requirements of the FSA proposed standard and the stress condition guidelines, the duration of this testing will range from 30 to 90 days to complete all wearout tests using one Centaur. The CentaurT is not designed to conduct product level tests such as the operating life test, but is designed to conduct tests on electromigration, AC and DC hot carriers, Stress Migration, Junction Integrity, Plasma process induced charging, Gate Oxide integrity, TDDB, Ionic contamination and temperature stability.

Following the qualification testing of a process, the same Centaur tester can be used for an inline monitor of the process. Samples can be pulled and tested from each hour, each shift, each day or each week depending on the sample size desired and test time allowed. This monitoring tests typically require between 3 minutes and 15 minutes per site depending on the process and tests selected.

The Centaur can be configured to drive fully automatic probers or semiautomatic probers. All major manufacturer's probers are supported. For qualification testing where it is required to test multiple devices in parallel, the Centaur supports both addressable test structures using standard probe cards, or multisite probe cards depending on the test structure space available. In general, a multisite probe card is recommended. For the fast in-line WLR tests, a standard probe card is recommended.

The temperature stress required for many qualification tests can be provided using on site heaters, or using a hot chuck. In general, a hot chuck is recommended, attached to the prober. A driver for all major hot chuck manufacturers is available with the Centaur. Chiron can offer a fully integrated system including tester, probe cards, hot chuck and prober.

Test Structure Design

Chiron can provide assistance in the design of the test structures for qualification testing and fast WLR testing. These test structures can be designed to fit into a scribe lane, or as a drop in die. In general, the qualification tests will require significant amounts of area and should be constructed as a drop in die or as a die for qualification testing. The fast WLR test structures are designed to fit into scribe lanes between product die so that they can be applied to every product wafer. All are designed to allow for fast parallel testing using the Chiron Tester.