Accurate NBTI Characterization Using Timing-on-the-fly Sampling Mode

Application Note B1500-6

- Controlled dynamic recovery with 100 µs accuracy
- No voltage dip between stress and Id measure cycles
- Full-scale resolution of 20,000 counts with 100 µs intervals assures accurate NBTI characterization
- Timing-on-the-fly NBTI EasyEXPERT library available

Agilent B1500A Semiconductor Device Analyzer

Introduction

Negative bias temperature instability (NBTI) has been a dominant reliability issue in PMOS transistors, and will become more important in future nano-scale PMOS technology. A dynamic recovery of the device degradation during the characterization portion of the NBTI test is a major concern, since it will cause an underestimation of the actual degradation in PMOS transistor performance in the field.

The Agilent B1500A Semiconductor Device Analyzer provides a new NBTI characterization solution for PMOS transistors using timing-on-the-fly sampling mode (timing-on-the-fly NBTI) of the Agilent B1500A Device Analyzer.

This application note introduces the new timing-on-the-fly NBTI test method that solves many of the concerns of traditional NBTI test methods.

Timing-on-the-fly NBTI Test

Figure 1 shows the timing diagram of the timing-on-the-fly

NBTI test method for the drain voltage and current and the gate voltage in the stress and measure cycles. The gate and the drain bias voltages are changed with the same timing, without the voltage dip to zero volts that is typically seen in traditional NBTI tests.

In addition, the drain current is measured continuously prior to the starting of the measurement cycle (with 100 µs sampling intervals), so that the change in the NBTI transition after the stress cycle can be observed in detail.

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This test method is only available when you use the negative hold time feature of the fast time sampling mode of the B1500A or Agilent 4155/56 series precision parameter analyzers. We call this NBTI measurement method the "timing-on-the-fly NBTI".

There are several methods to characterize NBTI behavior, and figure 2 shows an example of a traditional NBTI test sequence. There are two problems with this traditional NBTI characterization approach:

1. The stress voltage discontinuity, that occurs when the applied stress returns to zero before and after the degradation characterization, allows the device to recover from the applied stress.
2. The slow Vth measurement time also allows for recovery during the measurement phase.

The NBTI results vary by these two factors, and Figure 3 illustrates an example of these problems. Damage caused by stress immediately starts recovering after the stress is removed, and the IV characteristic varies while the Vth is being measured. In other words, the test results depend on the timing with which the drain characteristics are measured. Because of these errors, the measured NBTI degradation is performed with the device in a partially recovered condition that tends to underestimate the effects of the stress.

The timing-on-the-fly NBTI approach shown in Figure 1 overcomes many of these sources of error that are caused by dynamic recovery during the measurement phase.
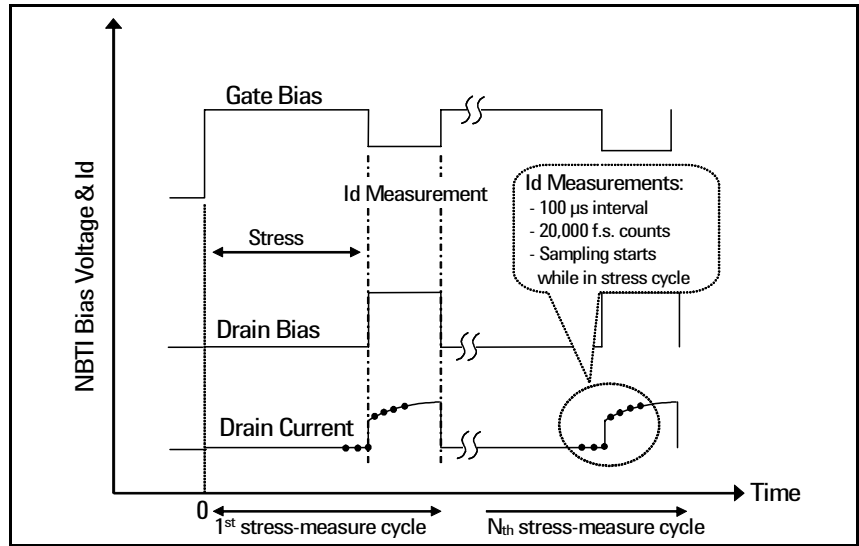

Fig. 1 Timing-on-the-fly NBTI test sequence and Id measurement timing
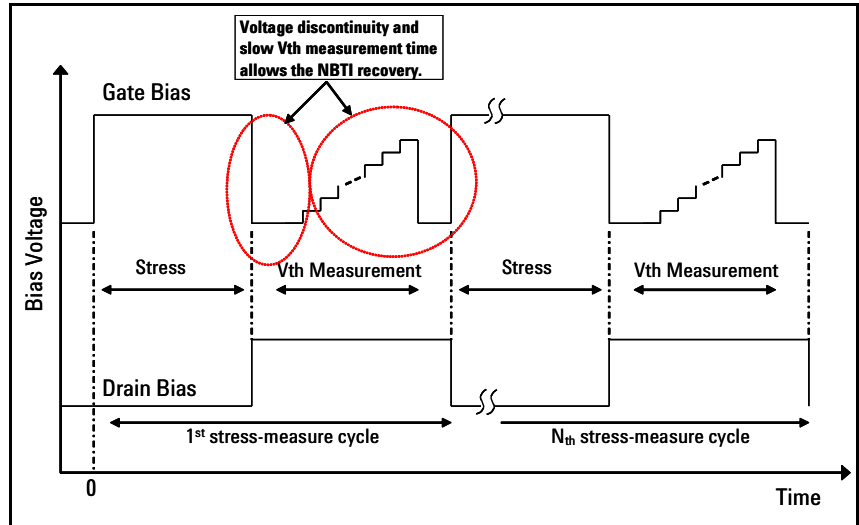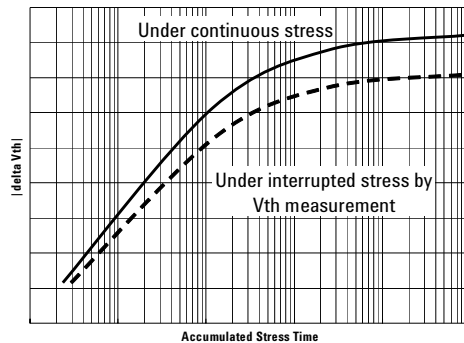

Fig. 2 Traditional NBTI test sequence

Fig. 3 Problem with traditional NBTI test

Timing-on-the-fly NBTI Design

The timing-on-the-fly sampling technique utilizes the following two features of the B1500A:

1. The negative hold time sampling measurement feature, which allows the sampling to start before the time zero sampling start time.
2. The bias hold mode feature, which holds the output voltage constant after the sampling measurement completes. This prevents the bias voltage from returning to zero between the stress and measure cycles.

Figure 4 shows the user interface for the timing-on-the-fly NBTI library of B1500A EasyEXPERT software. You can download this from the Agilent web site. You can set the NBTI characterization parameters for both the stress phase and the on-the-fly Id measurement phase, including the sampling parameters.

Figure 5 shows a sample plot of the on-the-fly Id sampling measurements from -500 μs to 2.5 ms with 100 μs interval for (1) a normal FET that does not show NBTI degradation and (2) a special device that shows the equivalent behavior of the dynamic NBTI recovery. The figure indicates that the timing-on-the-fly NBTI can detect even a small change of dynamic recovery in the NBTI characterization. The actual output waves of the timing-on-the-fly NBTI test are shown in Figure 6. Figure 6 shows that the output waves for the drain and gate have the exact same timing, and that there is no dip to ground level in the transition from the stress phase to the measurement phase. How the drain current is sampled is added in the figure for easier understanding of the test method.
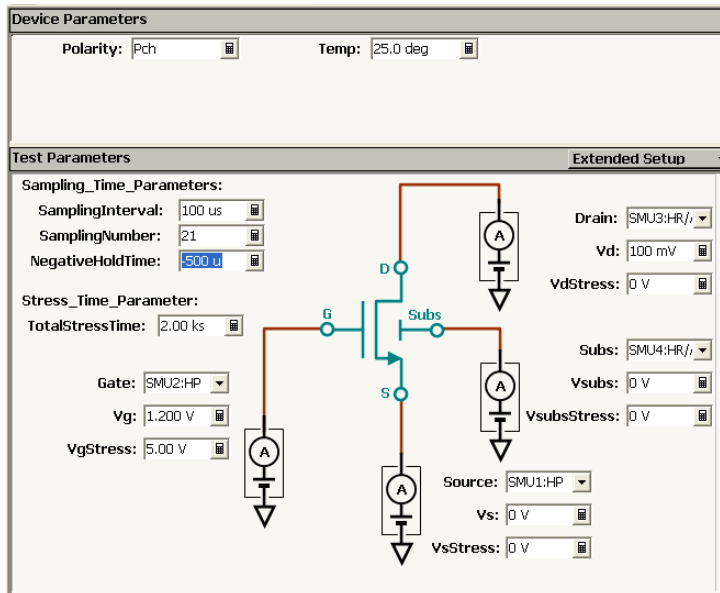

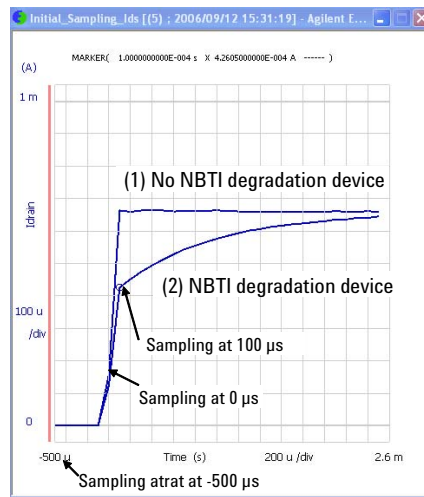Fig. 4 B1500A Timing-on-the-fly NBTI sample library

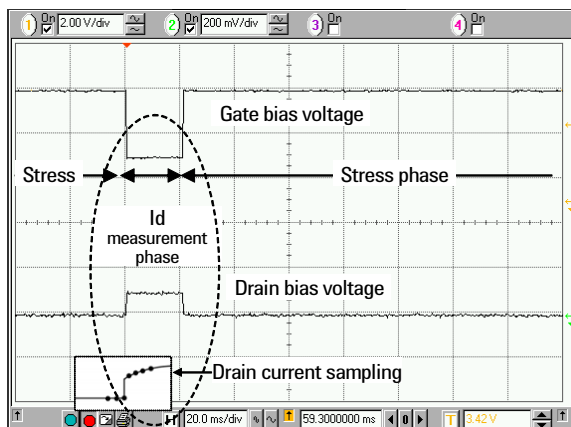Fig. 5 Timing-on-the-fly Id sampling data

Fig. 6 Waveform of B1500A EasyEXPERT software's timing-on-the-fly NBTI test
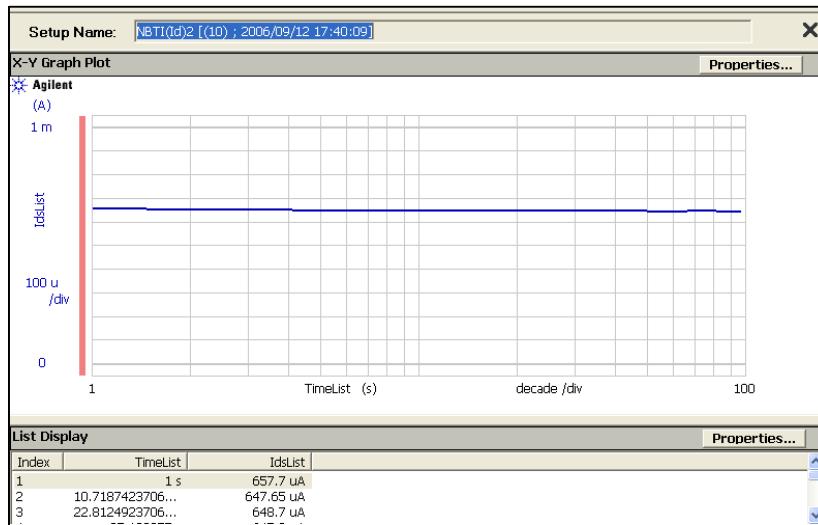
Fig. 7 NBTI degradation output

The final output is plotted as Id versus log stress time, as shown in Figure 7. Maximum stress time in the sample library can be set to 10,000 seconds.

Conclusion

The timing-on-the-fly NBTI test library for the Agilent B1500A EasyEXPERT software solves many issues related to recent NBTI characterization. The benefits of the timing-on-the-fly NBTI method are:

1. There is no dip to ground in the transition between the stress and the measure phases. This eliminates the errors coming from an uncontrolled dynamic recovery in the NBTI test, and provides more accurate and stable NBTI lifetime test results.

2. 100 µs sampling intervals with 20,000 counts full-scale current readout assures accurate NBTI test results. Fixing of the NBTI characterization point in the dynamic recovery transient provides stable and repeatable data.

3. Timing-on-the-fly continuous sampling with 100 µs sampling intervals which can start while in the stress status captures the dynamic recovery behavior with precision. This capability is especially useful for understanding the NBTI degradation mechanism.

The sample application test definition, timing-on-the-fly NBTI, introduced in this application note can be downloaded from the Agilent B1500A web site at www.agilent.com/see/B1500A.

*1: This library can be used on the Agilent B1500A EasyEXPERT software revision A.02.10 or later.

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