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Automatic Operation of a Bias Temperature Stress (BTS) Test

Introduction

Semiconductor research and production facilities routinely measure the amount of sodium contamination in the oxide of their wafers. With modern systems, the concentration of this mobile ion is easy to measure. After identifying the source of the contamination (typically from handling or a contaminated furnace), action can be taken to eliminate the problem.

This Lab Note describes a relatively simple software program called "STRESS." This program, along with a temperature controlled chuck and the Keithley Model 82 Simultaneous C-V Measuring System, allows measurement of the mobile ion concentration in the oxide layer of a wafer.

Measuring Mobile Ion Concentration

The C-V method is one of the more common ways to measure mobile ion concentration. The first step is to measure a high-frequency C-V curve on a MOS capacitor fabricated on the sample wafer. After this measurement, a bias voltage is applied to the MOS capacitor, and the wafer is heated to increase the mobility of the mobile ions. In typical tests, the bias voltage is selected to cause a 10^6 V/cm field in the oxide with a temperature between 200°–300° C. The wafer is held at these voltage and temperature conditions for a few minutes.

After the sample is returned to 23° C (to "freeze" the ionic charges in place), the bias voltage is removed, and another C-V measurement is taken. By comparing the flatband voltage before and after the stress, the mobile ion concentration can be calculated.

Automating the Bias Temperature Stress (BTS) Test

The Keithley Model 82 is an automatic High Frequency/Quasistatic C-V Measuring System. The Keithley system can perform the necessary C-V measurements on the MOS capacitor and calculate the flatband voltage and other parameters needed for mobile ion measurements. With a relatively simple additional program (called STRESS) and a temperature controlled chuck, the system can also perform the BTS test.

The software included with this note is designed to run in conjunction with the Keithley Model 82 to perform the BTS test. It is designed for users who must occasionally measure mobile ion concentration. Since this program is a separate program and is not integrated with the Model 82 software, the user must exit one program before running the other.

Instrument Setup

In addition to the complete Model 82 System, a Temptronic thermochuck and one extra IEEE-488 cable are needed. The required equipment is listed in Table 1.

Table 1. Required Equipment

Equipment Summary
Keithley Model 82 C-V System
Temptronic TP0315B Thermochuck with optional IEEE-488 interface
Keithley Model 7007-2 Shielded IEEE-488 cable

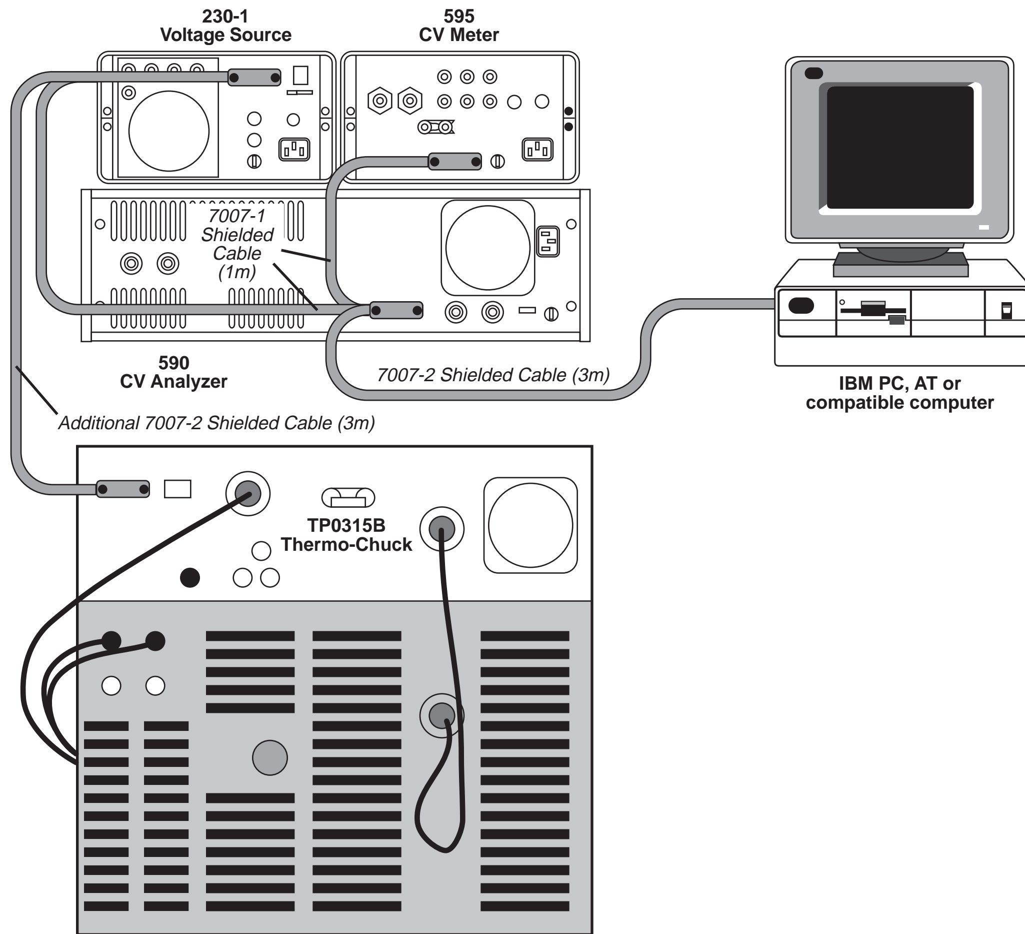
Note: The Temptronic TP0314A, TP0314B, and the TP0315A are also compatible units. Optional IEEE-488 interface must be included. The computer requirements are the same as for the Model 82 System.

NOTE

If your equipment setup is different than described, refer to *Modifying STRESS.EXE* later in this lab note.

Connect the Model 82 instruments together, and set up the software as described in Section 2 of the Model 82 Instruction Manual. After the Model 82 is completely set up, add the Temptronic TP0315B to the system by connecting the IEEE-488 interface cable between the temperature controlled chuck and the other instruments in the system (refer to **Figure 1**). Attach the chuck to your probe station to complete the hardware setup.

Figure 1 IEEE-488 connections



Finally, make sure the Temptronic TP0315B primary address is set to 9, its factory default address.

Software Installation

The software supplied with this note was written and compiled in Microsoft QuickBASIC 4.0. It is provided on the diskette as both source code and as a stand-alone executable file.

To install the software, simply copy the file STRESS.EXE to your hard disk drive. If you wish to print a listing or modify the source code, copy the file STRESS.BAS to your disk. The program is not copy protected and may be copied using the DOS COPY or DISKCOPY commands.

Software Startup

To run the program, type STRESS at the DOS prompt. The display shows the command menu. To select one of the commands, type the letter of the command, and press <Enter>. The lower portion of the computer display prompts for the other parameters. For example, if you select R for read temperature, the lower portion of the display shows the actual temperature of the chuck.

NOTE

The program sets the chuck temperature to 23°C after startup. This value is used as the starting temperature for the test. To change this start temperature you must modify a variable in the source code. After startup, the program also sets the bias voltage to 0V.

WARNING

It is possible to apply a hazardous bias voltage and a high temperature to your sample. These conditions may continue even after the program has been halted. Do not touch the sample or chuck until the chuck temperature has returned to a safe temperature, the voltage source is set to 0V, and the probes are clear of the sample.

Software Command Overview

B — Perform Bias Temperature Stress

Select this command for the full BTS test. The display prompts for the bias voltage in volts, the test temperature in degrees Celsius, the temperature window in degrees Celsius, and the delay time in minutes. The computer then programs the Model 230 Voltage Source, programs the Model TP0315B Thermochuck, and waits for the chuck to stabilize to within the temperature window.

When the chuck has stabilized, the delay time counts down. After the time has expired, the temperature controlled chuck is reprogrammed to the start temperature (23°C). The bias voltage resets to 0V when the chuck temperature has stabilized at 23°C.

Figure 2 shows a temperature versus time graph of the full BTS test.

R — Read Temperature

Select this command to read the current chuck temperature and display it at the bottom of the computer screen. Press <Enter> to clear the display and return to the command menu.

S — Set Temperature

Select this command to set the temperature of the temperature controlled chuck. The computer will prompt for the temperature in degrees Celsius and the temperature window.

The temperature window is used to determine when the temperature controlled chuck has stabilized. For example, if the chuck is set to 50°C, and the window is set to 1°C, the temperature controlled chuck will give an at temperature indication when it is between 49°C and 51°C. In most cases, a 1°C window is adequate.

V — Set Voltage

This command sets the Model 230 voltage source to the desired voltage (-100V to +100V). Use this command to apply a bias voltage or (with the Set Temperature command) to run a BTS test manually.

Q — Quit

Select this command to quit the program. It resets the wafer test conditions to 0V and 23°C and exits the program.

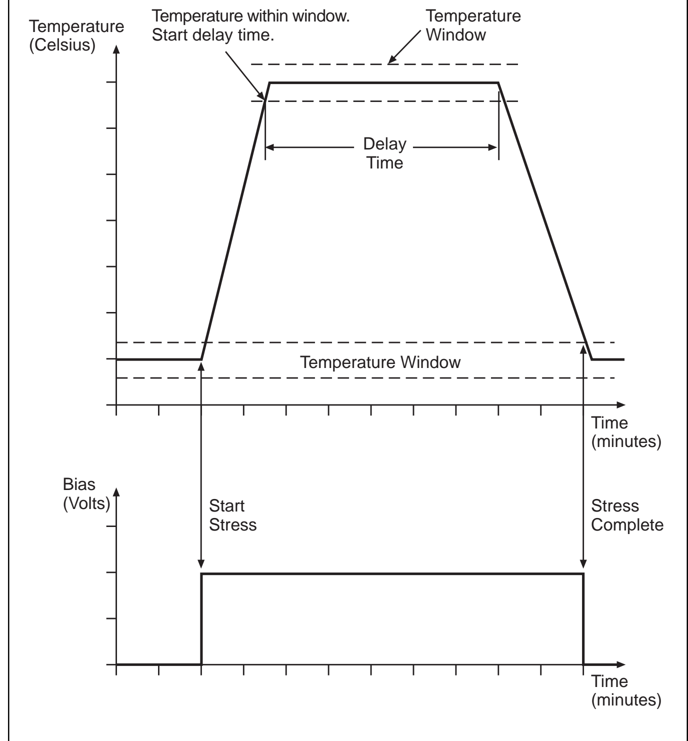
Example Operation

The following example uses the Model 82 and the STRESS program to perform a mobile ion measurement on a sample MOS capacitor.

NOTE

Model 82 operation is covered in the Model 82 Instruction Manual. Only a summary of Model 82 functions are covered here.

Figure 2 Temperature vs. time operation of BTS test



1. Start up the Model 82 software, and make sure the measuring system is calibrated and operating properly. Manually program the temperature controlled chuck for 23°C.
2. Place the sample on the chuck, and perform tests to determine oxide area (A) or oxide thickness (t_{ox}), oxide capacitance (C_{ox}), and equilibrium delay time.
3. Using the Model 82 software, set the measurement parameters as needed (range, sweep voltage, frequency, etc.), and run a C-V sweep. Using the analysis menu, record the gate area (A) and flatband voltage (V_{fb}). Both of these parameters are displayed on screen in the analysis section. Refer to this first flatband voltage as V_{fb} (0) for 0V applied bias.
4. Exit the Model 82 software, and type STRESS to run the stress test program. Select B from the command menu to perform the bias temperature stress test. In this example, assume t_{ox} is 150nm, a 1MV/cm field in the oxide, and a temperature of 200°C. (Since the requirements of samples may vary, select values appropriate to your needs.)

   To obtain a field of 1MV/cm, the applied bias voltage must be (150nm/10) = 15V. At the prompts, enter 200°C for temperature, 1°C for temperature window, 10 minutes for delay time, and 15V for bias voltage.

   The program will now run the complete stress test and return to the command menu when done.

NOTE

For best results from this test, a positive bias should be applied first. On a newly formed oxide, most of the mobile ions are at the metal-silicon dioxide interface, which is where the ions enter the oxide during fabrication. The positive bias moves these charges to the silicon-silicon dioxide interface and causes a large change in the flatband voltage. The negative bias (step 6) moves these charges back to the metal-silicon dioxide interface, again causing a large, easy-to-measure change in the flatband voltage.

5. When the stress test is complete, enter Q to quit the program. Start the Model 82 software, manually program the temperature controlled chuck for 23°C, and perform another C-V measurement using the same parameters as the first curve. From the analysis section, record V_{fb}. Refer to this flatband voltage as $V_{fb}(+)$ for the positive bias voltage applied during the stress test.
6. Repeat step 4 (BTS test) using all the same values except for the bias voltage, which should be negative in this case. In this example, set the bias voltage to –15V.
7. Repeat step 5 (C-V measure and analyze), and record $V_{fb}(–)$.
8. Now that the values of A, C_{ox}, $V_{fb}(0)$, $V_{fb}(+)$, and $V_{fb}(–)$ are known, calculate the mobile ion concentration as follows:

   $Q_{mi} = 6.2415 \times 10^6 \times V_{fb} \times C_{ox} / A$

   where: $V_{fb} = V_{fb}(+) - V_{fb}(0)$

   or, $V_{fb} = V_{fb}(-) - V_{fb}(+)$,

   whichever is larger.

Modifying STRESS.EXE

Those who wish to use this program with a different temperature controlled chuck or instrument setup must modify the program and recompile it. The following information is for individuals who are familiar with BASIC programming. It is not a complete guide for modifying STRESS.BAS, and modification details are left to the needs of the individual. While this demonstration program is copyrighted by Keithley Instruments, we give the right to our customers to modify it as they deem necessary for their business use. Refer to the software license agreement for details.

The program STRESS is supplied in both executable (STRESS.EXE) and source (STRESS.BAS) code on the disk. Use Microsoft QuickBASIC 4.0 (or later) versions to modify and recompile the program. The structure of the program is relatively simply, and many comments are included. The main program module sets the program constants and controls the command menu. Each of the other functions (B, R, etc.) is a separate subprogram.

While you are modifying the program, you may run it directly from the QuickBASIC environment, which is the easiest way to debug the altered program. After the modified program is running properly, recompile it using the QuickBASIC “Make EXE File” command under the “RUN” menu.

Make sure the IEEE-488 driver is loaded before trying to run the program. The IOtech Driver488 is supplied with the Model 82 DOS software.

Please feel free to call the Keithley Applications Department if you have any comments or questions.

C-V Utilities Software

Those who are interested in a turnkey BTS software package may purchase the Model 5958 C-V Utilities Software from Keithley Instruments, Inc. In addition to the required temperature and bias voltage control, the Model 5958 also includes provisions for automatically running pulsed or staircase C-V sweeps to determine the device flatband voltage. Mobile ion concentration parameters are automatically calculated by the software.

In addition to BTS tests, the Model 5958 can also perform Zerbst/C-t analysis. These tests are useful for determining minority carrier lifetime and surface generation velocity of the wafer under test.

For more information on the Model 5958, contact the Keithley Applications Department or your Keithley representative.

Trademarks

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Driver 488 is a trademark of IOtech, Incorporated.

References

Nicollian, E.H., and Brews, J.R., *MOS Physics and Technology*. New York: Wiley, pp. 424-435

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