Automated Wafer Testing

Michael Volo
Microelectronic Engineering
Rochester Institute of Technology
Rochester, NY 14534

Abstract - **A test system was installed at RIT that can automatically test every die on a wafer without any operator interruption. The system integrates a Rucker & Kolls 681A wafer probe station, an HP4145 parameter analyzer, an HP Apollo work station, and a Keithley switch matrix. IC-CAP software was used for system control and data extraction. The system was designed to be flexible so additional tests can be added. Any process and any test that an HP4145 can complete manually can be tested using the automated system. Only a few variables regarding die size, device location, data extraction methods, and HP4145 test parameters, need to be changed. For demonstration of the system, the RIT PMOS process was used, and threshold voltage was measured, extracted and stored.**

I. INTRODUCTION

There are several advantages to using an automated system for testing. First, the amount of data available increases. Instead of selecting a few die per wafer, a single device can be tested on every die of the wafer. Also, data extraction is consistently measured using a computer. The automated storage and display of that data then enables patterns to become more visible and analysis methods more available. An automated system, with less operator interaction, has potential for less problems.

Although, many automated systems have the potential to offer many advantages, they are sometimes never used. There are many reasons for this. One reason is because a system has not been designed to be attractive to users. An automated system has a good return on investment only when the amount of resources required to learn about the system is less than the amount of resources that are saved by using the system. Another way of saying this, is that the system must be designed with users in mind as the first priority.

The main goal while designing this system, is that it is attractive to use. The advantages must be easily realized and it must be an obvious decision by the user to use the automated system. This leads into the inherent problem with automation. The biggest challenge of designing an automated system is how to minimize operator interaction while maximizing flexibility.

II. DESIGN

One goal of the design, was to integrate all aspects of the data collection process. This included wafer movement, switch matrix control, HP4145 setup, and data extraction, storage, and display. The other goal was to make the system flexible enough so that it could be changed for different processes and tests.

The design of the automated test system is shown as an interaction diagram in figure 1. The interaction diagram shows what part of the system has control during any given time. It also shows the flow of events that are triggered by one object sending a message to another. The interaction diagram shows how the operator only needs to interact 3 times with the equipment. IC-CAP has taken many of the responsibilities that the operator would have done manually. Manually, an operator would have to interact 9 times with the system. Besides that, the operator no longer needs to know all the details of the equipment setup.

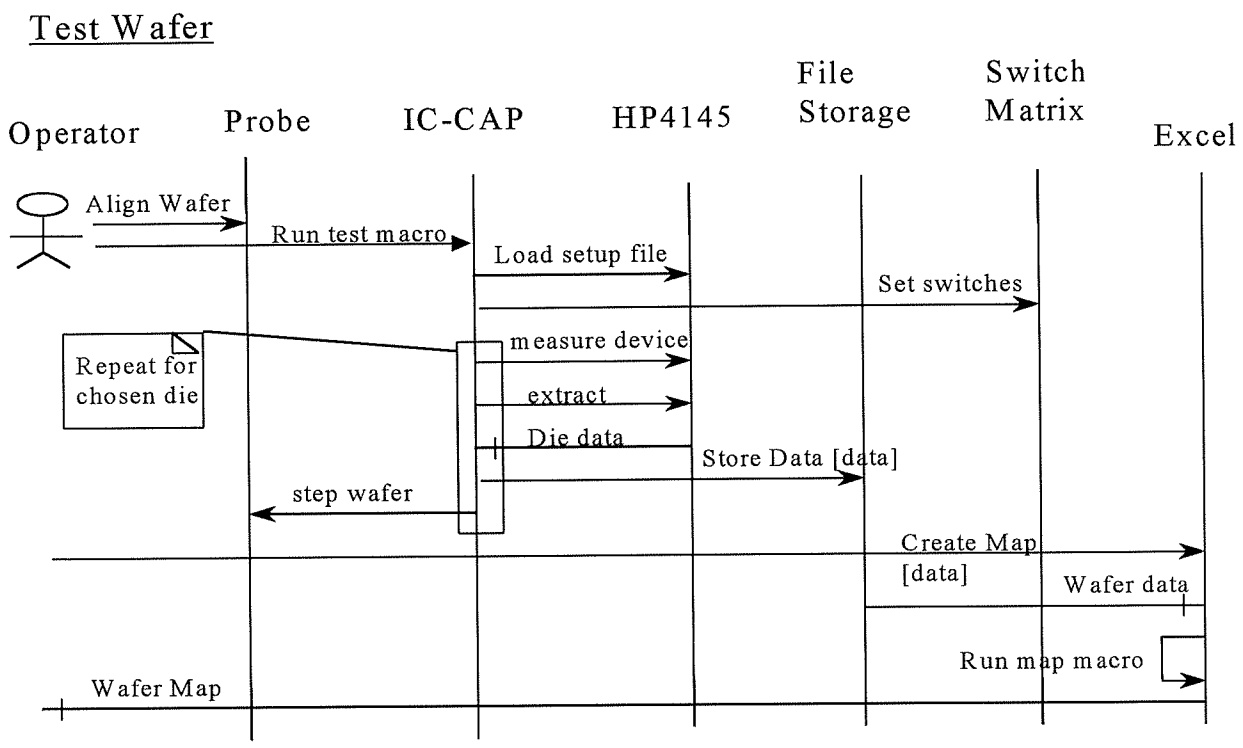

Figure 1 : Interaction Diagram

III. DOCUMENTATION

Two manuals were created that go along with this automated test setup. The "Automated Test Operators Manual" explains in detail how to obtain wafer map data using the automated test system. The manual entitled "Creation of New Automated Tests" contains all the information needed for someone to change an automated test or create a new one. Those manuals contain more detailed information than what is in this report.

IV. SYSTEM COMPONENTS

HPIB

All components of the automated test system are connected by hpib bus connections. In order for that connection to work properly, each tool had to be set with a different bus address. Table 1 shows the address numbers used.

Tool	Address
Probe Station	6
Switch Matrix	7
HP4145 Analyzer	17
LCR Meter	18
Plotter	31

Table 1 : HPIB address numbers

HP Apollo Workstation

The HP workstation needed to be configured so that there were several different levels of security. The first username was called "operator". This username only has read access to the required system and IC-CAP files necessary to run the automated test program. It also has the ability to write in a directory called "data". This is where IC-CAP stored the data after measurement. The next username was "iccap" This username allows someone to change or create new IC-CAP macros. Those macros are what are used to control the system during automatic operation. Information, such as die size, SMU connections, or data extraction routines can be changed so that new processes and test can be added with the "iccap" username The "root" username has complete access to the entire HP Apollo system.

Wafer Probe station

In order to send single commands, a function from IC-CAP was used called "HPIB_write()". In the () of that function, ASCII characters can be sent to any

specified bus address. Automated control of the probe station was accomplished by using this command and programming an IC-CAP macro.

The first command sent to the probe station at the start of the macro must be a "Z". This command initializes the prober for ASCII data transfer. After that, X and Y control was sent to the prober using the command "Ixnnnnn,ynnnnn,". Where nnnnn is an integer telling the prober how far to move.

Unfortunately, there was one feature of the prober that was not taken account for in the automated system. After the first command is sent to the prober from IC-CAP, the prober is placed in remote control. No way could be found to send control back to the prober, so that an operator can control it manually. The only way to put the prober back in local control was to turn it off, then back on.

Plotter

There is currently no known method for plotting IC-CAP plots or HP4145 plots that were created by the automated system. The plotter does not operate properly when the HP computer is plugged into the HPIB bus. A single test can be plotted by unplugging the HP computer from the system, then testing a device, while the HP4145 in manual mode.

IC-CAP Software

Before any automated program could be written, basic control commands first had to be learned. This was accomplished using a menu window in IC-CAP called "Hardware Setup" After choosing an address number, There was one pull down menu that allows the user to send one command at a time to an address.

An automated threshold voltage test for PMOS transistors was used to demonstrate the capabilities of the automated system. SMU connections settings were made through IC-CAP's SETUP-DUT window environment. There was one model file (with extension ".mdl" made for each process. The model files installed on the system were titled "CV_test.mdl", "CMOS.mdl", "old_PMOS.mdl", and "new_PMOS.mdl". Two PMOS model files were created to allow for two stepper jobs used at RIT. The only difference between them is the amount and location of the dies on the wafer to be tested.

Threshold voltage was extracted using an extraction function called "Program". This is how IC-CAP allows for user defined extraction functions. After the measurement for one die is done, the id vs. Vg data is stored in arrays called id and Vg. Threshold Voltage was found by finding the maximum slope of the Vg vs. id curve. When that point was known, an equation in the form of y = mx + b was stored in an array variable in the IC-CAP system, named "extr_VT". That array was then plotted along with the Vg vs. id plot, and is displayed each time a device is tested. The x-intercept of that line is calculated and stored as VT.

Keithley Switch Matrix Control

The Switch Matrix is also controlled by the IC-CAP macro. Commands can be sent to the switch matrix using the IC-CAP function "HPIB_write", and specifying the correct address. The two commands of most concern are ":CLOS (@1!1!2)" and "OPEN ALL", where the 1!1!2 can be changed to whatever connections you want to make.

Data Storage

An ASCII text file is created each time a wafer is tested. The file name is "[lot_id].[wafer_id]", where lot_id and wafer_id are entered by the operator at the beginning of each test. The IC-CAP "pthreshold" macro prompts the user for these two names. The file is opened for storage by the IC-CAP macro, and the UNIX system date is stored in the first line. There are three items stored on each line of the file. The row number, column number, and threshold voltage are separated by spaces and are labeled in the file. For an example, one line of a file could look like this "Row = 1 Column = 4 VT = -2.3"

Wafer Maps

A software package called "Wafer Mapper", created by Third Coast Software was copied onto the HP computer, but unsuccessfully installed. RIT has not purchased the rights to use that software.

An alternative way to create maps was used. The first step is to transfer the data from the HP hard drive to a dos formatted floppy. The following command can be entered at the HP UNIX prompt to accomplish this: "doscp [filename] /dev/floppy/c0t0d0:" For this command to work successfully, the file must be in the current directory. To find out what directory is current, enter the command "pwd". To list all the files in a directory, enter "ls"

After the data is copied to a PC formatted floppy disk, EXCEL can be used to create wafer maps. Figure 2 shows an example of the data output that was created from this method. Excel was used to import the ASCII file and create the 3D graph. Where there are no die on the corners of the wafer, an averaging technique was used. This averaging causes the corner

spreadsheet cells with no data, to store data similar to the cells around them. This was necessary, because Excel does not produce circular graphs that are not a square matrix.

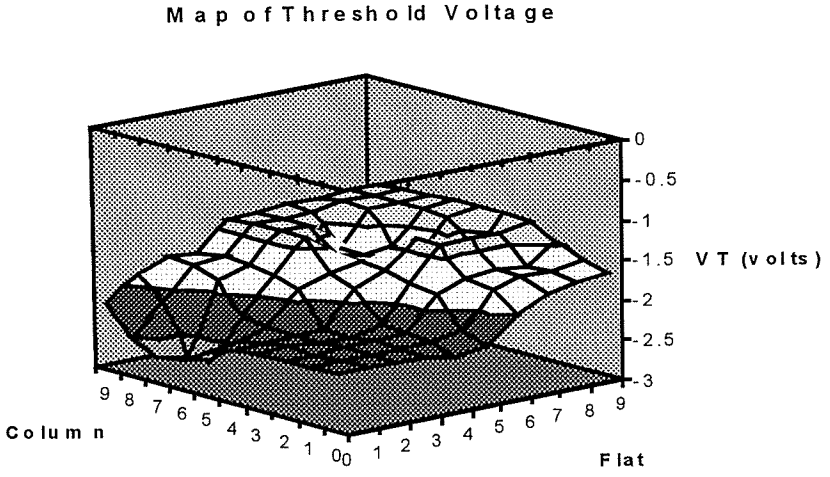

Figure 2: Wafer map of threshold voltage

CV tests

IC-CAP software can also be used with the LCR meter to perform CV tests. This test can not be run automated with the current setup. However, a test setup model file was created called "CV_test.mdl" that can be used to test single device structures.

V. RESULTS AND CONCLUSIONS

The automated wafer testing system integrates several aspects of wafer testing into an easy to use system. The automated features include:

1. Wafer movement
2. Parameter extraction
3. Switch Matrix control
4. HP4145 analyzer setup
5. Data storage
6. Data display on screen

Directions to obtain a wafer map of threshold voltage were described in detail in the operator's manual. A brief outline is given here:

1. An operator aligns a wafer on the probe.
2. The operator selects a process and test from ICCAP menus.
3. The entire wafer is tested and data is stored on the HP in an ASCII format.
4. The operator can then create a wafer map using EXCEL.

Normally, device testing would involve the knowledge of many different hardware controls. An hour worth of work might have been enough to obtain 20 different die on a wafer. With the automated system, it takes 15 minutes to learn the system and setup the test. Then, it takes only 25 minutes to test and store data for an entire 4" wafer, with 76 die.