Automated Silicon Wafer Measurement Using IMAQ and LabVIEW

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The Challenge: Developing a nondestructive silicon wafer measurement system capable of controlling a motorized stage and storing infrared images as well as wafer thickness data.

The Solution: Using National Instruments ValueMotion products to control stepper motors, data acquisition (DAQ), and image acquisition (IMAQ) products to acquire voltage and image data, and LabVIEW software to provide a graphical front-end for instrument control and data storage and retrieval.

Introduction
Researchers at the University of Virginia Center for Semicustom Integrated Systems developed a nondestructive method for measuring the thickness of silicon wafers using National Instruments LabVIEW, ValueMotion, IMAQ, and DAQ products. We designed this industrial instrumentation prototype, dubbed the Optical Micrometer System 1 (OMS-1), at the University of Virginia (UVA) for Virginia Semiconductor, Inc. (VSI), of Fredericksburg, Virginia.

VSI is an industry leader in ultrathin silicon wafers for use in integrated circuits and microelectronic machined devices, which range in thickness from 5 to 500 µm. Before the development of the OMS-1, we had to measure these kinds of wafers using hand devices such as mechanical micrometers, which left a dimple on the surface of the wafer.

When VSI realized they needed a more versatile solution than a previously used embedded solution, we selected a PC running Windows NT, along with National Instruments IMAQ, DAQ, and ValueMotion stepper control boards to replace the custom hardware.

Configuration
The wafer sits on a Teflon stage that can be moved in two dimensions by stepper motors. Using an infrared (IR) laser, the camera captures images of the wafer in IR conditions. Using the new LabVIEW interface, none of this hardware needed to change; we simply redid cables and wiring to accommodate connectors to the National Instruments boards.

First, we added a National Instruments AT-MIO-16XE-50 DAQ board to the system. Red and IR light emitter/detector pairs, with detector output voltages ranging from 0 to 10 V, produce an analog voltage based on the thickness of the wafer being measured. These voltages are processed in a fifth-order polynomial equation to yield a thickness value. We used digital inputs on the AT-MIO-16XE-50 board for limit switches. These switches are used for the custom stage movement routines with ValueMotion virtual instruments (VIs) as drivers. Additionally, two limit switches detect the position of the emitter/detector pairs for thickness measurement because they must be moved out of the optical path of the IR camera.

We used IMAQ to acquire IR total thickness variation (TTV) photographs. These images result from the interference pattern of an IR laser reflecting off the surfaces of the silicon wafer. The image produced (see figure on the reverse side of this page) resembles a topographical map, with the dark lines representing 100 nm variations in thickness. A quality assurance technician viewing these images can make a decision on whether a wafer conforms to VSI's standards for “smooth” wafer surfaces based on the concentration of interference fringes in a TTV image.

Finally, we used ValueMotion VIs and the National Instruments PC-Step-40X board to control two stepper motors. Each motor controls one axis of the positioning stage on which the silicon wafer rests. We used a VI to automatically reposition the wafer underneath the thickness measurement detectors or the IR camera. The operator enters the varying sizes of the wafer diameter. We also developed a VI to recenter the stage after a measurement, based on the state of the limit switches polled by the DAQ board.

Although the cost-effectiveness of LabVIEW and its ability to further automate the wafer inspection process were attractive, the most important factor in choosing LabVIEW was the ability to store all the relevant information about a silicon wafer in a PC database.
Because of the versatility of the LabVIEW solution, constant upgrades to the Optical Micrometer System, to meet the needs of a dynamic marketplace are possible.

Developing for the Future with LabVIEW

Because of the versatility of LabVIEW, VSI continually improves their quality assurance process simply by modifying the LabVIEW software. This is made possible by the easy addition of new features and statistical process control.

The Optical Micrometer System has been a very successful project for UVA and VSI. With it, we can measure the absolute thickness of silicon wafers without making physical contact with the wafer surface. Traditional mechanical micrometers can damage the wafer while measuring, whereas the LabVIEW solution is more accurate, achieving an error margin of less than ±2 µm (mechanical micrometers are usually accurate to ±4 µm).

The simple user interface and automatic data recording system have made the Optical Micrometer System easy to use. VSI uses its capabilities daily to inform customers and quality assurance engineers. And finally, because of the versatility of the LabVIEW solution, constant upgrades to the Optical Micrometer System are possible.

The development of the LabVIEW-based Optical Micrometer System took approximately six months—less than half the time it took to develop the original functionally limited and more expensive custom hardware solution. The end result of this project is that UVA researchers have developed a device that not only meets the current testing needs of VSI, but can also adapt to their future requirements.

For more information on the Optical Micrometer System, please contact Arin Sime at tel (804) 924-6086, e-mail asime@ieee.org.

Visit the Center for Semicustom Integrated Systems on the Web at csis.ee.virginia.edu.

This technology has been issued U.S. Patent Number 5,754,294.

B Total Thickness Variation Image. This is an infrared image that the Optical Micrometer System acquires and stores as a bitmap using IMAQ. The lines correspond to 100nm thickness variations in the wafer.