As semiconductor devices become smaller and more complex, the need for advanced analytical tools becomes critical. In a cooperative development project, feedback between the device developer and user resulted in a multi-laser scanning microscope capable of performing several valuable techniques for the analysis of semiconductor devices.

The tool incorporates two different near-IR lasers. A 1064-nm neodymium-doped yttrium aluminum garnet/vanadate (Nd:YAG/YVO₄) laser is used to inject a photoelectric current into a semiconductor device. This allows the tool to perform such device-analysis techniques as light-induced voltage alteration and the single-contact optical-beam induced current (SCOBIC) method by monitoring the current and voltage changes of a device.

A second 1340-nm Nd:YVO₄ laser acts as a high-resolution thermal source. This allows the system to perform techniques such as thermal-induced voltage alteration (TIVA) and resistive interconnect localization (RIL). These techniques take advantage of the change in resistance caused by the heating action of the laser.

Both lasers allow the devices under test to be imaged from the backside of a device through the silicon substrate by detecting the reflected signal intensity using a photodiode. The laser wavelengths result in minimal absorption by the substrate. Through the use of these and other techniques, device-analysis engineers can find assorted defects, including transistor gate leakage, interconnect shorts, and soft failures such as those sensitive to voltage, frequency, and temperature. SEMICAPS Inc. (Singapore) designed the original tool prototype, and engineers at Advanced Micro Devices (AMD; Austin, TX) then provided a wish list of features and modifications that were implemented in the hardware and software.

the design

The basic instrument is based on an optical microscope with five objectives housed in a light-tight enclosure supported by an anti-vibration table, with a motorized three-axis stage for holding the device under test (DUT). This allows for navigation around the device and imaging under several levels of magnification. The actual lasers are separated from the microscope enclosure and coupled to the scanning module by a safety-shielded optical fiber.

The module that houses the lasers underwent several design changes during the development process. In the initial design, the output from the 1064-nm laser was fed straight through to an optical-fiber coupler, while the beam path of the 1340-nm laser was bent in order to impinge on the same coupler. A user-controlled shutter system determined which laser was directed at the coupler. Neutral density filters could be moved into each path to allow for 10% of the available power to reach the DUT.

The first major change featured a rearranged optical path that was optimized for the 1340-nm laser, rather than the 1064-nm laser. This change enhanced the sensitivity of the TIVA and RIL techniques. Secondly, we switched out the neutral density filter for a multi-element filter wheel that offered varying optical densities for customized levels of attenuation. A computer-controlled stepper motor allowed the user to select from 31 filters. The wide range of control was necessary due to the fact that as higher magnifications were used, more laser power was delivered to a smaller area, and devices were being permanently damaged.

In addition to adjustable laser power, we needed control of the actual laser raster. The enhanced design allows the user to set laser dwell time per pixel and synchronize the dwell time with the system being used to electrically stimulate the device. The addition of an optical chopper adds the capability to pulse the beam. The SCOBIC technique relies on a transient capacitive effect that disappears under steady state. The chopping of the beam allows this small current effect to be visualized as a varying grayscale contrast level.

Most of the changes to the tool design were the direct result of communication between AMD and SEMICAPS. They were determined during actual use of the tool and represent the type of information that suppliers don't often have access to during their development process. The resulting instrument is more user-friendly for the purchaser and a more functional product for the manufacturer than either side could have developed independently.

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