Low Light Imaging Benefits IC Testing

Low light level imaging is used for a wide range of applications from biomedical research through astronomy. In spite of their diversity, these applications often have similar demanding requirements from their electronic imaging systems in terms of linear response, high dynamic range and software flexibility. In this article, we examine how high performance CCD cameras facilitate a novel, low light imaging method for studying device failure and characterizing reliability in integrated circuits.

For developers and manufacturers of integrated circuit chips, understanding reasons for device failure and statistical analysis of failed devices are critical to improving manufacturing yields. In recent years emission microscopy has become an increasing popular tool used for this purpose.

The principles of this method are very simple. When current leakage or inappropriate voltage occurs in a semiconductor junction, such as within a transistor, a weak emission of photons may occur. This is due to the motion of hot electrons relative to silicon atoms, and is known as Braking Radiation or Bremstrahllung.

Failure test labs use electroluminescence to locate sub-standard or failed microcomponents within an IC. The decapsulated silicon IC, or unpackaged wafer, is placed under a variable magnification microscope equipped with a cooled CCD camera. This camera captures a low magnification image of the silicon surface under conventional (lamp) illumination. The IC is then powered-up and a second image taken in the absence of any ambient light. By overlaying the two images the location of the weak emission sites are found. The microscope's magnification is then increased to zoom in for exact location, again relying on the overlay of conventional and emissive images. In the simplest test, the chip is supplied a standard voltage and ground. In more sophisticated tests, a series of voltage vectors are applied to "exercise" the part.

Within the past few years a team at Advanced Micro Devices (AMD) led by Victoria Bruce, Senior Engineer, Device Analysis, has been working to extend the utility of this technique. Bruce states that "Commercially available emission microscopy systems did not have the resolution or sensitivity needed to accurately study the weak emissions in state-of-the-art submicron geometrics. In addition, the inflexible software made it difficult to optimize these systems for a broad spectrum of uses; from research through routine operation by failure lab technicians."

Bruce's group therefore set out to build an instrument that not only overcame these limitations, but would allow them to perform *energy resolved emission microscopy (EREM)*. This involves resolving the emission from the failure sites into discrete wavelength windows using a carousel of optical bandpass filters (40nm bandwidth) in front of the camera. According to Bruce, "Taking images at multiple wavelengths can not only locate the defect site but also provide the energy distribution of emitting carriers. This information helps us characterize the nature of the failure. By building a statistical data base, we can also correlate this information to device lifetimes."

Bruce's instrument uses Zeiss microscope optics and a back-thinned TK 512 chip in a liquid nitrogen cooled Photometrics camera (model CH260). Typical integration times are from 30 to 300 seconds. Positional stability over this long exposure time is maintained by integrating the entire test on a vibration isolation platform. This system not only costs less than commercial systems, but thanks to the cooled back-thinned CCD, it yields an order of magnitude gain in detection capability.

Another important aspect is system software - both to enhance performance and allow the system to be used by a broad range of end users. The AMD instrument uses a Macintosh computer and IPLab-SU2 software from Signal Analytics. States Bruce, "This software is excellent for creation of custom macros, which allow push button operation of complex operations by non-technical users." The three main macros they have created are for (a) sharpening edges within an image, (b) an image overlay routine that also contains a filter to eliminate cosmic events and local "sparkle" artifacts, and (c) an optical flat fielding routine to correct the spectral sensitivity of the entire apparatus at each of the selected wavelengths. She adds, "The architecture of the IPLAB-SU2 software enables experienced users to bypass these macros and customize both the acquisition and the overlay procedure to their particular needs.

The two aspects of a cooled CCD camera that are critical to the work described here are the ability to acquire low noise images from extremely low intensity sources, and the CCD's linear response in the intensity domain. These benefits apply to many other imaging applications including chemiluminescence, fluorescence detection of *in situ* hybridization, and astronomy.

Reprinted from the Photometrics CCD newsbrief, Fall, 1993.

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