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Infrared Solutions

Application note

Application Note: SWIR Microscopy

Key features:

- *Semiconductors: ability to see through silicon (and other III-V semiconductors) in SWIR*
- *Solar cells: EL in SWIR reveals microcracks and indicates efficiency*
- *Photon emission: detect and localize defects in circuits on-wafer*
- *Fiber-optics: inspection of novel photonic integrated circuits*
- *Optical glass (microscope refractive lenses) transmits in SWIR*
- *SWIR photon source: Tungsten light bulb in microscope*

Optical microscopes typically use refractive glass lens systems to examine samples at large magnifications. Unlike infrared camera in MWIR and LWIR, SWIR cameras can operate with standard glass optics and do not require the use of reflective optics. Consequently, SWIR cameras can be used with most existing microscopes.

The ability to see into the silicon material comes from the fact that SWIR photon energy is smaller than the band gap of silicon. Furthermore, the typical tungsten light bulb found on most microscopes serves well as the source of SWIR photons.

Wafer/die inspection

Nowadays, silicon process technology has advanced to the point that very complex devices can be made. A SWIR microscope is a useful tool for in-process verification for pre-bond and pre-hybridization on critical alignment applications in MEMS (micro-electro mechanical systems), wafer bonding and 3D chip stacking. In post-process operations, it can be used for validation and direct measurement of sub-surface features in silicon, GaAs and other SWIR transmissible materials. Fig. 1 shows alignment verification performed with a Xeva 1.7 320 TE1. The highly sensitive SWIR offers superior imaging capability, also for hard to image materials such as doped silicon and silicon with rough surfaces.

Fig. 1 SWIR images of alignment structures in a pair of bonded silicon wafers

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Solar cell microcrack detection and electroluminescence inspection

Electroluminescence (EL) imaging takes advantage of the of the radiative band-to band recombination of excited charge carriers. The emitted photons can be captured with a sensitive camera to obtain an image of the distribution of radiative recombination in the cell. Electroluminescence imaging can be used for:

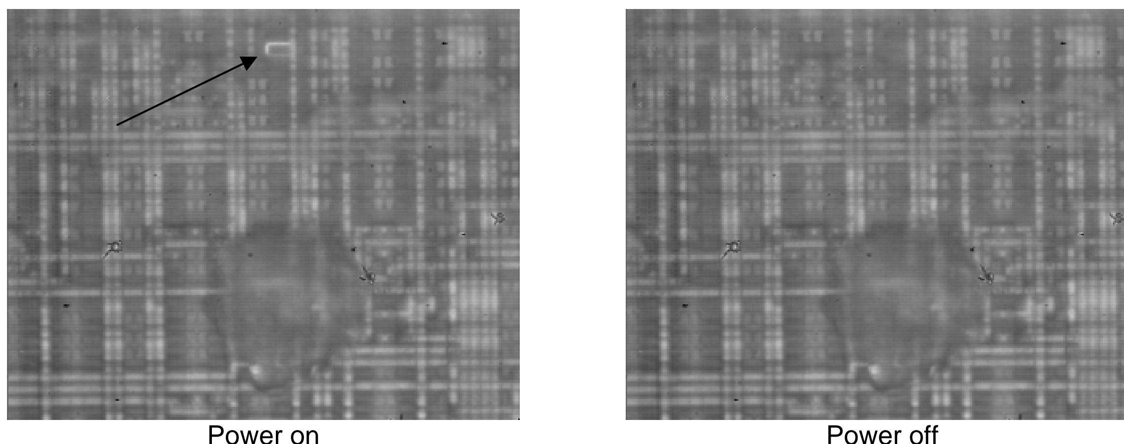
1. detection of cracks, grain boundaries, broken contacts and shunts
2. mapping of series resistance
3. distribution of diffusion length of minority carriers indicating the quality of the material

In solar cell characterization, scientific grade Si CCD cameras are typically used for luminescence imaging applications. These cameras however have to be cooled significantly to reduce noise and dark current. Moreover, Si CCD based cameras, with a cut-off wavelength at 1100 nm, will only detect the short wavelength tail of the band-to-band luminescence from silicon solar cells at room temperature. By using a SWIR InGaAs camera, about an order of magnitude enhancement of the measured photon flux can be achieved. An InGaAs camera is sensitive throughout the entire spectral range in which band-to-band emission from crystalline silicon occurs. Another benefit of using an InGaAs camera is that it is sensitive to an emission band in the spectral range 1400 to 1700 nm. This defect luminescence is linked to the presence of dislocations and is detectable as a broad spectral emission band around 1550 nm at room temperature.

Semiconductor failure analysis: photon emission

Photon emission microscopes detect faint emissions caused by semiconductor device anomalies (generally associated with forward or reverse biased pn junctions, transistors in saturation or dielectric breakdown) to specify the failure location. As lower device voltages lead to longer emission wavelengths, a SWIR InGaAs camera's high sensitivity in the 900 to 1600 nm range, becomes very important. It offers a high level of detection capability in low-drive IC chips and in faint emission analysis (see Fig. 2).

However, the growing number of metallization layers complicates examination from the front. Fortunately, silicon at low doping levels is transparent to SWIR light, and therefore, InGaAs cameras can be used either in a back or a front examination set-up.



Power on Power off

Fig. 2: SWIR photon emission micrograph; taken with Xeva 1.7 320 TE3.

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Photonic integrated circuits

Fiber optic telecommunication networks use SWIR lasers at wavelengths around 1300 and 1550 nm. These signals can easily be seen with InGaAs SWIR cameras. In photonic integrated circuits, signal processing and computing is done in the optical domain. A SWIR microscope is well-suited to verify optical design, check for misalignments or light scattering on such an IC. Fig. 3 for example, shows the light scattered off the top of silicon waveguides on a chip over a length of 0.73 cm. This technique can be used to measure propagation loss in a waveguide on chip.

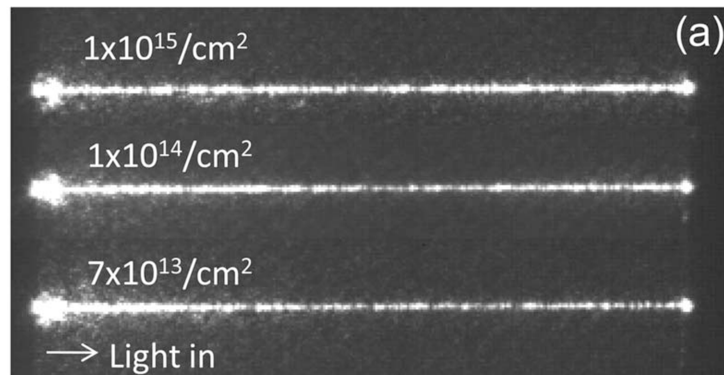

Fig. 3: Light scattering in three waveguides on chip. Top view micrograph taken with a highly-sensitive SWIR InGaAs camera Xeva 1.7 320 TE1. Picture from E.J. Teo; "Fabrication of low-loss silicon-on-oxidized-porous silicon strip waveguide using focused proton-beam irradiation", Optics Letters, Vol. 34, Nr. 5.

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