InGaAs is not always the answer

Reasonably-priced CCD and CMOS cameras for solar cell inspection

The visual inspection of solar cells with regard to material and/or contact defects is based on the physical effect of luminescence. Cost-intensive cameras with indium gallium arsenide (InGaAs), EM-CCDs (electron multiplying CCDs) or deep depletion sensors are usually used to detect the long-wave light that is released in the process.

Baumer near-infrared cameras HXC40NIR and TXG14NIR (from left to right)

With two new digital industrial cameras, Baumer offers reasonably-priced alternatives which are based on SONY CCD and CMOSIS CMOS sensors and which have been developed specially for applications in the field of electro and photoluminescence measurement.

The answer is in the detail

Highest quality standards apply in the production of high-class photovoltaic elements. Cracks in semiconductor material can lead to the shattering of individual solar cells during the production process, and thus to expensive machine downtime. Due to the extreme material stress that solar modules are exposed to by thermal fluctuations in the course of their lifetime, even the finest microcracks can lead to the failure of individual cells. A drastic reduction in the efficiency of the entire module would be the consequence. It is therefore important to detect these cracks and microcracks, which are very difficult or even impossible to find at first glance, as early as possible and to remove the solar cells in question from the manufacturing process.

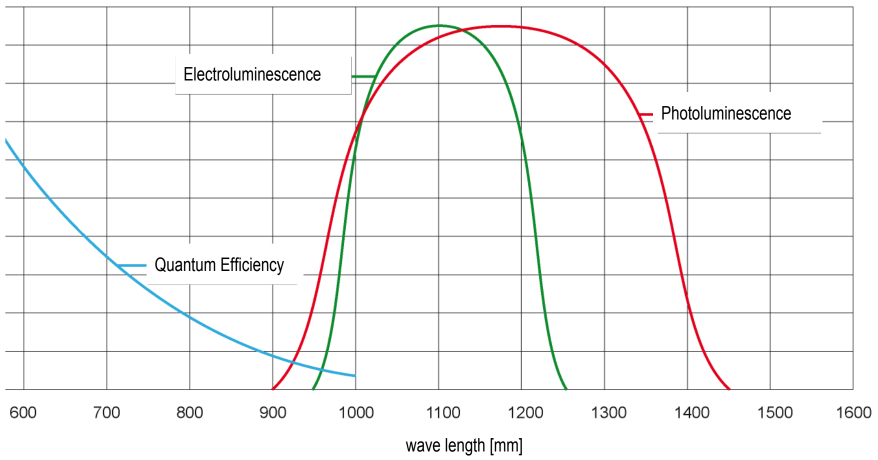
Let there be light

The luminescence effect mentioned above – that is, the emission of light from a semiconductor material in the course of its transition from an excited state to its ground level state – can be provoked by using two different methods, each under the condition of preventing extraneous light. On the one hand, the excitation can be effected by applying a high current, in the range from 3 to 10 ampere. This is described as electroluminescence. The second method, referred to as photoluminescence, is based on the irradiation of the semiconductor with short-wave light and the physical laws of the Stokes shift – meaning the shift between absorption and emission wavelength. In both methods – which, by the way, are suitable for the inspection of monocrys-talline as well as of polycrys-talline cells – light is emitted by silicon in the near-infrared range of the spectrum. Emission wavelengths of approx. 900 to 1450 nm are typical of photoluminescence and approx. 950 to 1250 nm in the case of electroluminescence. Material defects within a cell – like the cracks and microcracks mentioned above – light up more brightly than the material surrounding them. In the inspection of complete panels, cells with defective contacts are characterized by the fact that they do not emit any light.

High demands on the camera

The wavelength of the emitted light is not only outside the visible spectrum for human beings, but is also in a range which the majority of silicon-based CCD and CMOS sensors cannot detect. This is the reason

Baumer TXG14NIR



Emission wavelengths of electro and photoluminescence and quantum efficiency of a silicon-based sensor (diagrams)

for the great popularity of cameras whose sensors are based on indium gallium arsenide, which – compared with silicon-based sensors – have greatly increased sensitivity in the near-infrared and infrared ranges. However, the technological advantage of these InGaAs cameras also goes hand in hand with disadvantages, for example high costs and readout noise, as well as a very limited resolution on account of the pixel size and number.

Slowly but surely

Due to low noise, high resolution and a wide dynamic range, standard sensors such as the SONY ICX285 or CMOSIS CMV4000 E12, for example, offer very high accuracy in the detection of material defects and are thus ideal for critical inspection tasks in the field of photovoltaic manufacturing. However, these positive attributes are balanced out by long integration times, in the region of approx. 3 to 6 seconds. This means that cameras which use these sensors are ideal for offline inspection tasks. The need for long sensor exposure times is due to two facts: On one hand, a basic characteristic from sensors and photodetectors plays an important role: the quantum efficiency. This represents the relation between photons of a defined wavelength, and the number of generated electrons contributing to the photoelectric current. With monochrome sensors, this quantum efficiency falls as the wavelength increases. Since the number of photons arriving at the pixels of the sensor per time unit is constant in a still scene, the number of electrons contributing to the photoelectric current can only be increased through longer integration times. On the other hand – on account of the spectral characteristics of the sensors – only the lower marginal range of the emitted spectrum, i.e. only a fraction of the emitted photons, is detected by the sensor [see sketch].

The new models

With the TXG14NIR and HXC40NIR models, Baumer presents two new cameras that have been developed specially for the inspection of solar cells. The TXG14NIR is based on the reliable and tested SONY CCD sensor ICX285, which has been optimized utilizing an innovative circuitry design with regard to its sensitivity in the near-infrared range. The camera offers a resolution of 1392 x 1040 pixels with a pixel size of 6.45 x 6.45 µm and is equipped with a Gigabit Ethernet interface. The increased near-infrared sensitivity of the HXC40NIR is based on an epitaxial layer which is 7 µm thicker compared to the "standard" CMV4000. The camera offers a resolution of 2048 x 2048 pixels with a pixel size of 5.5 x 5.5 µm and is equipped with a Camera Link® Full Interface.

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