# Electroluminescence (EL) analysis
## for a qualitative evaluation of photovoltaic modules

S. Ambrosius, J. Wittfoth, Centrosolar Sonnenstromfabrik GmbH (April 2011)

**Application Note**

### Introduction
Due to an increased demand of photovoltaic modules in the last 10 years, the photovoltaic industry experienced a big growth including a steady development and optimization of the photovoltaic technology. With regard to a reduction of costs of solar cells and photovoltaic modules, the electroluminescence analysis is used for a qualitative evaluation of the photovoltaic modules. In this process direct current in forward direction is send through the solar cell. The faultless areas of the photovoltaic cell are starting to exhibit luminescence, because of a plus of minority charge carriers which are inducing a radiant recombination. On the other hand the damaged areas are lasting dark.

### Measuring station
The measuring setup is realized in a relatively simple way. In a totally darkened room current is send through a solar cell or photovoltaic module. The emitted luminescence is captured by a digital camera and can then be evaluated via a computer.

The luminescence of silicon can be located in the near infrared range with a wavelength of about 1000 to 1300 nm, which is not visible for the human eye. For these measurements the Luca$^{EM}$ R 604 from Andor Technology is used. At a wavelength of 1000 nm the relative sensibility of the Luca$^{EM}$ R 604 amounts to only 8%, but this is absolutely sufficient for a good picture quality for the solar cell evaluation. Heart of the camera is the 8x8 mm$^2$ big and monochromatic silicon EMCCD-sensor from Texas Instruments. This EMCCD-sensor is an advancement of a standard CCD, whose screening register is coupled with an amplifier stage with electron multiplication. Before the A/D conversion, the amplifier stage offers a signal gain to a factor of 200. This enables a noiseless exposition even of a minimal luminescence respectively an exposure time far below one second.

Because the A/D conversion inclines to a so called read out noise, it is necessary to gain weak signals before the conversion to increase the picture quality. This is done with the integrated EM-Gain Register of the Luca$^{EM}$ R 604. Besides the read out noise, the dark current noise of the sensor has also a negative effect on the picture quality. The Luca$^{EM}$ R 604 reduces the dark current noise by cooling the sensor electrically to -20 °C using a Peltier Element. The signal gain and the system cooling are reducing the system noise (read out- and dark current noise) to a minimum. So noise values less than one electron per pixel and second can be reached.

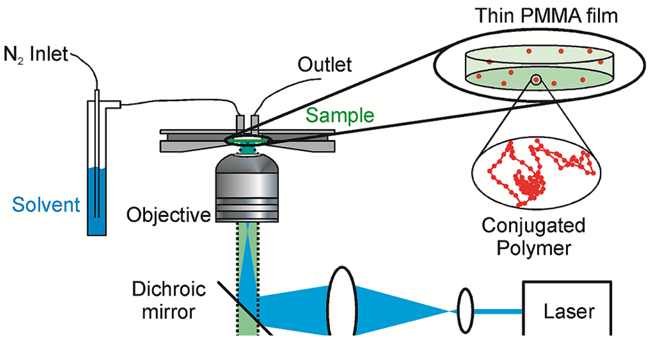


Fig. 1: Electroluminescence picture of two polycrystalline silicon solar cells at 5 A

### Measurement results
Following damages can be detected during the production of photovoltaic modules using the electroluminescence analysis:

- cracks
- breaks
- short circuits
- grid finger interruptions
- contact forming errors

The damages mentioned above are shown in the following figures (Fig. 2-6). They are showing how highly defined the Luca$^{EM}$ R 604 is displaying the solar cell surface, and so enables a highly accurate analysis of photovoltaic modules regarding to damages.

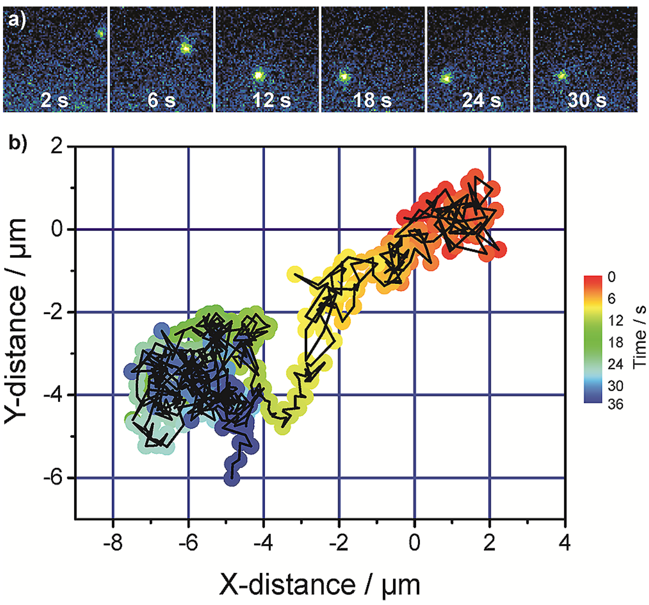


Fig. 2: Micro crack revealing as a fine continuous line

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Fig. 3: Break with total loss of power

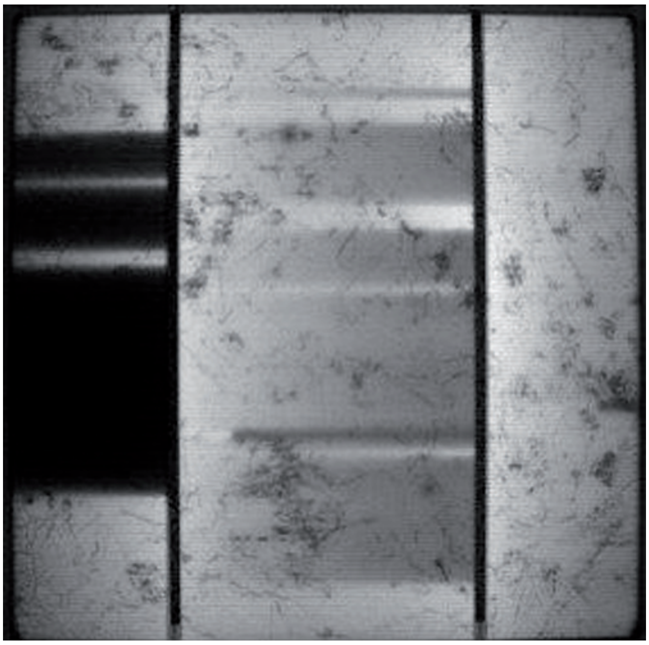

Fig. 5: Grid finger interruptions:
at the left of the busbar with a total loss of power
in the middle without a measurable loss of power

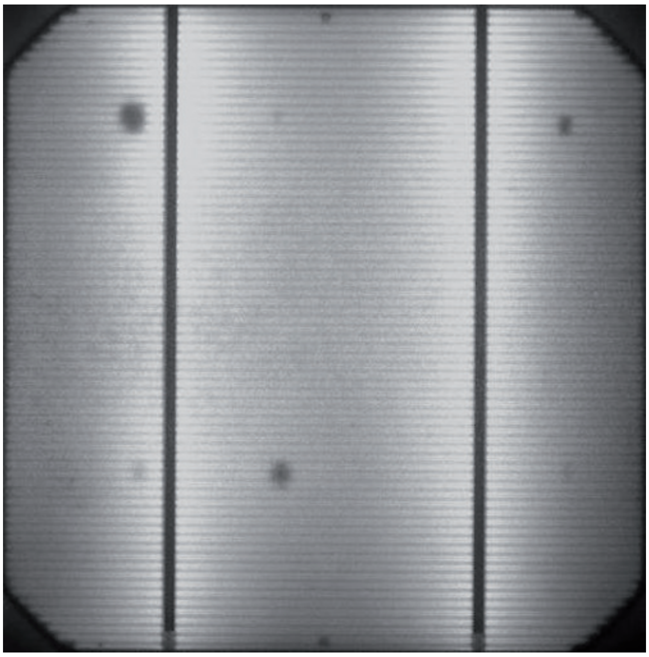

Fig. 4: Three short circuits of a monocrystalline silicon solar cell

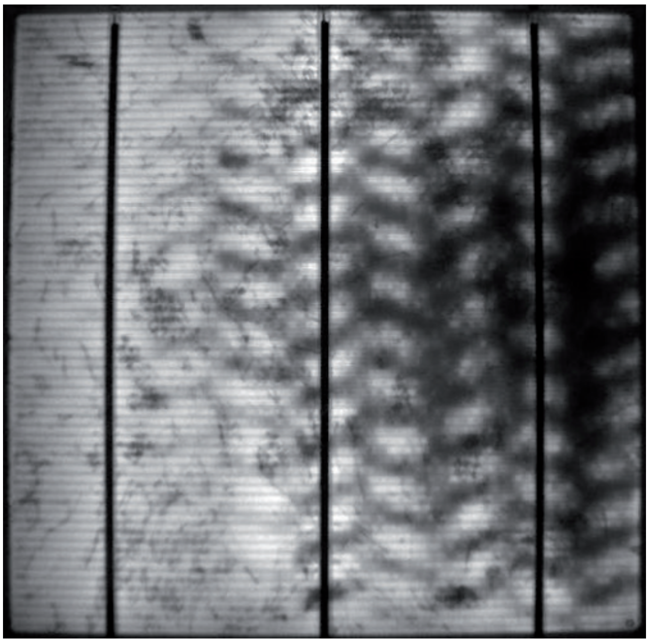

Fig. 6: Contact forming errors from an inhomogene temperature distribution at firing process

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