CHARACTERIZATION OF SOLAR CELLS

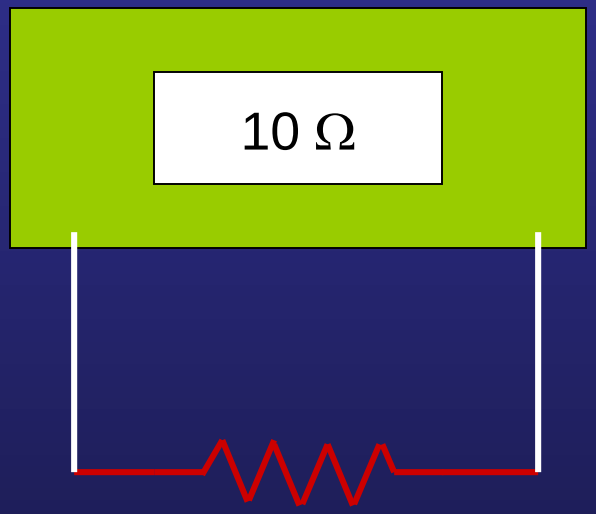
Resistivity

Material characterization

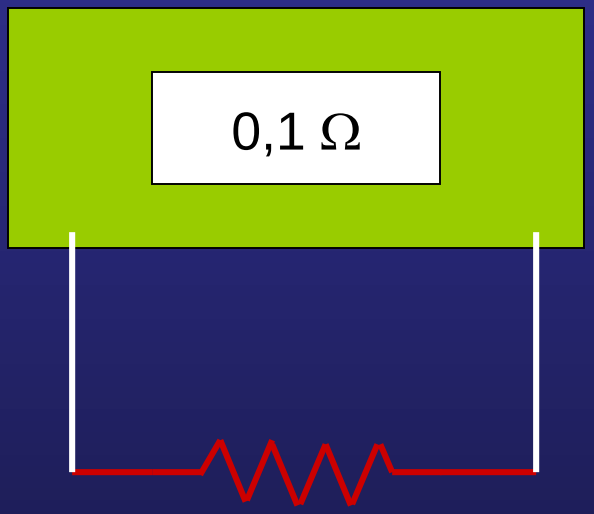
Solar cell characterization

CHARACTERIZATION OF SOLAR CELLS

Resistivity



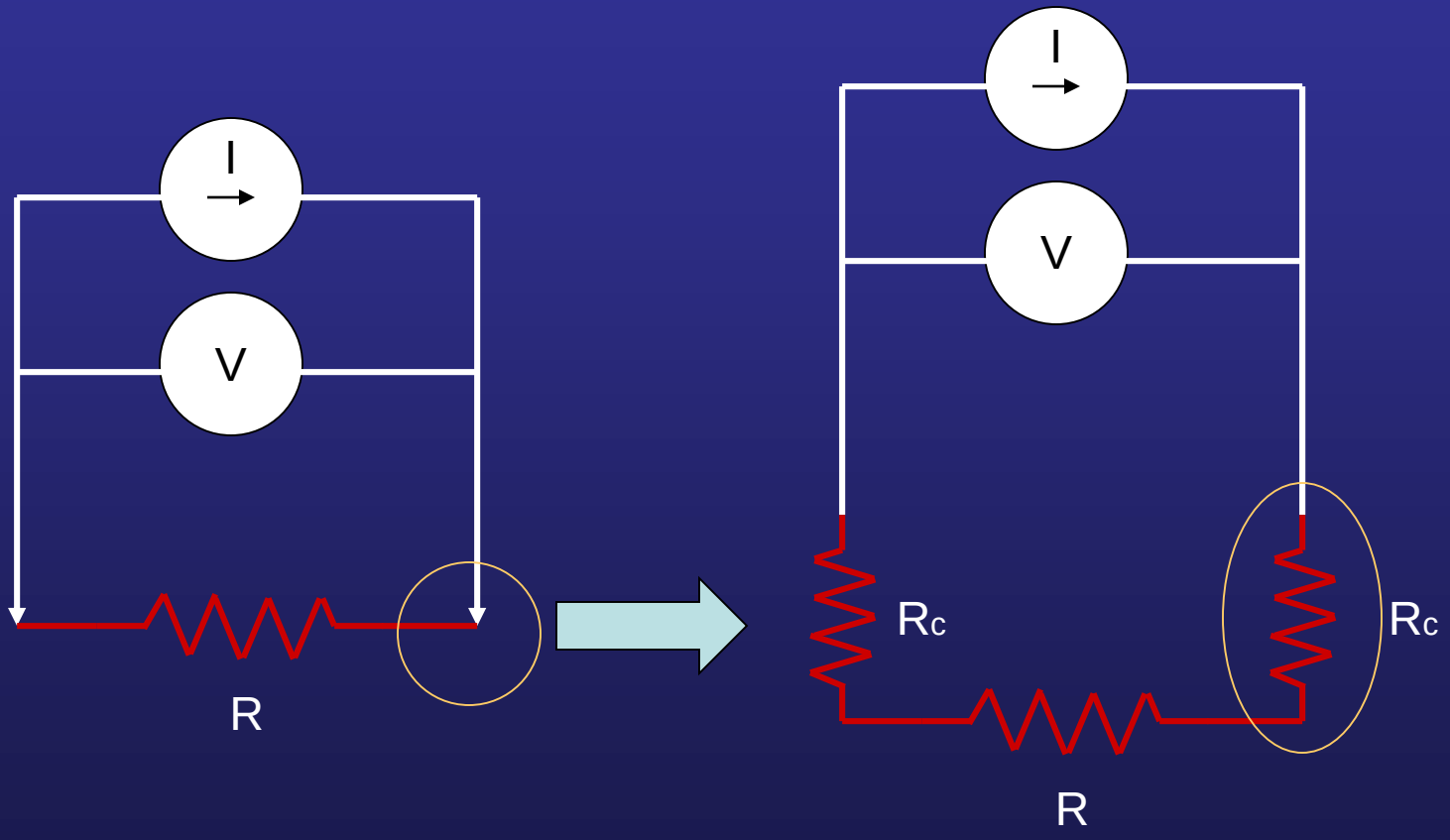
R=10 Ω



R=0,05 Ω

CHARACTERIZATION OF SOLAR CELLS

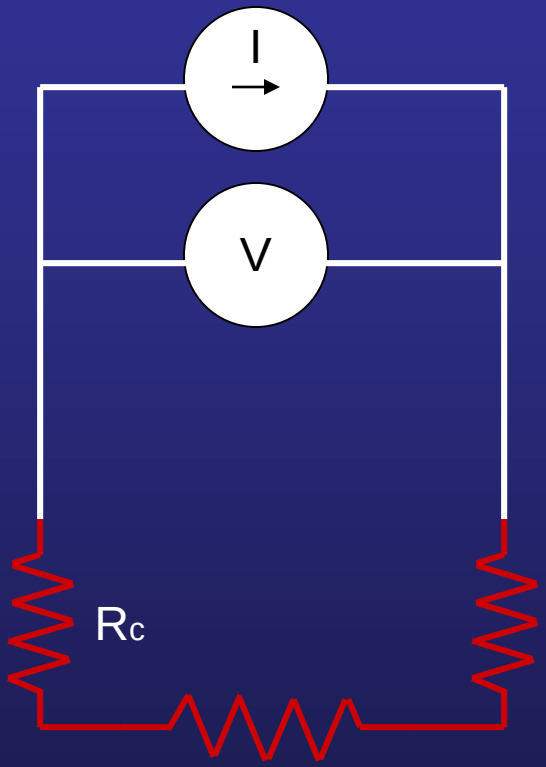
Medida da resistividade



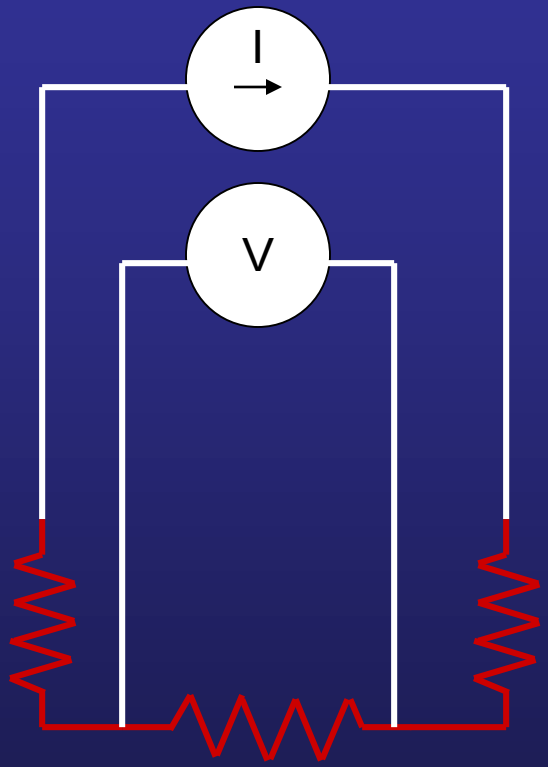
$V = (Rc+R+Rc)*I$

CHARACTERIZATION OF SOLAR CELLS

Técnica dos 4 pontos



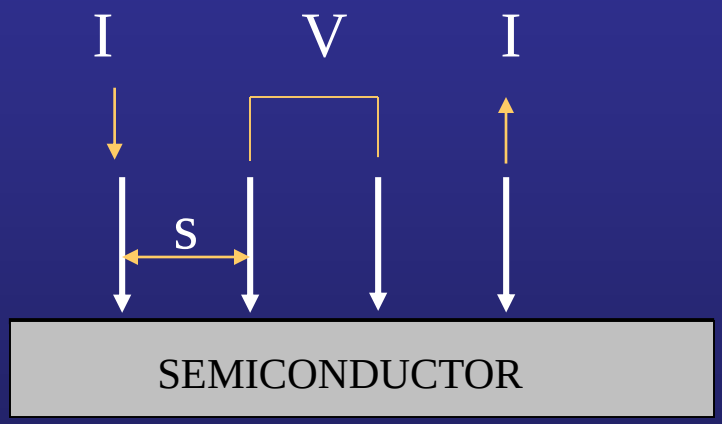
$V = (R_c + R + R_c) * I$



$V = R * I$

CHARACTERIZATION OF SOLAR CELLS

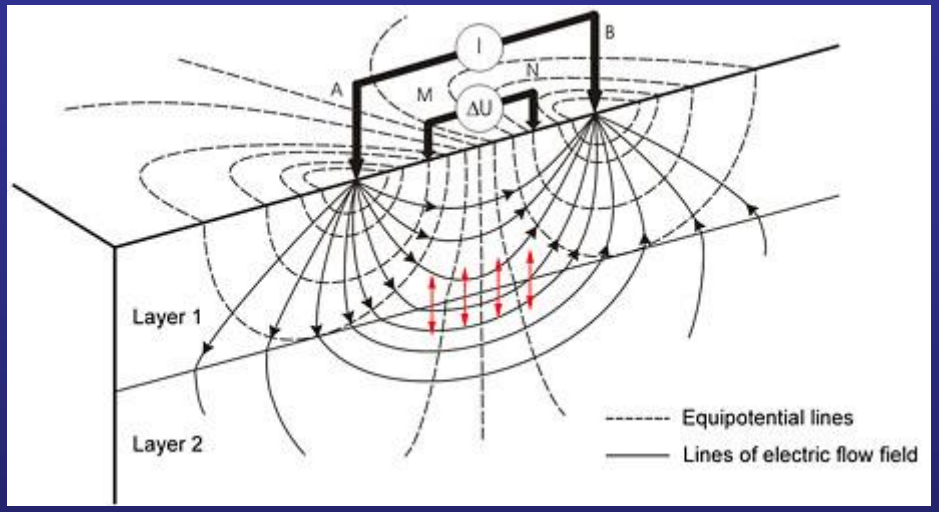
Técnica dos 4 pontos



$$\rho = 2\pi s F (V/I)$$

CHARACTERIZATION OF SOLAR CELLS

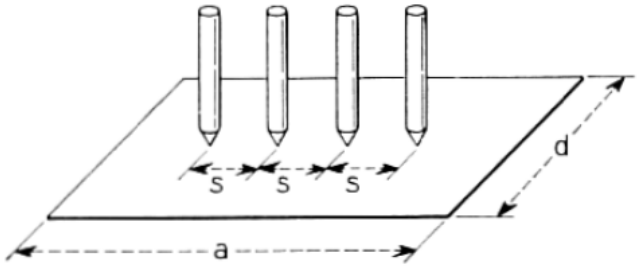
Técnica dos 4 pontos



$$\rho = 2\pi s F (V/I)$$

CHARACTERIZATION OF SOLAR CELLS

Técnica dos 4 pontos

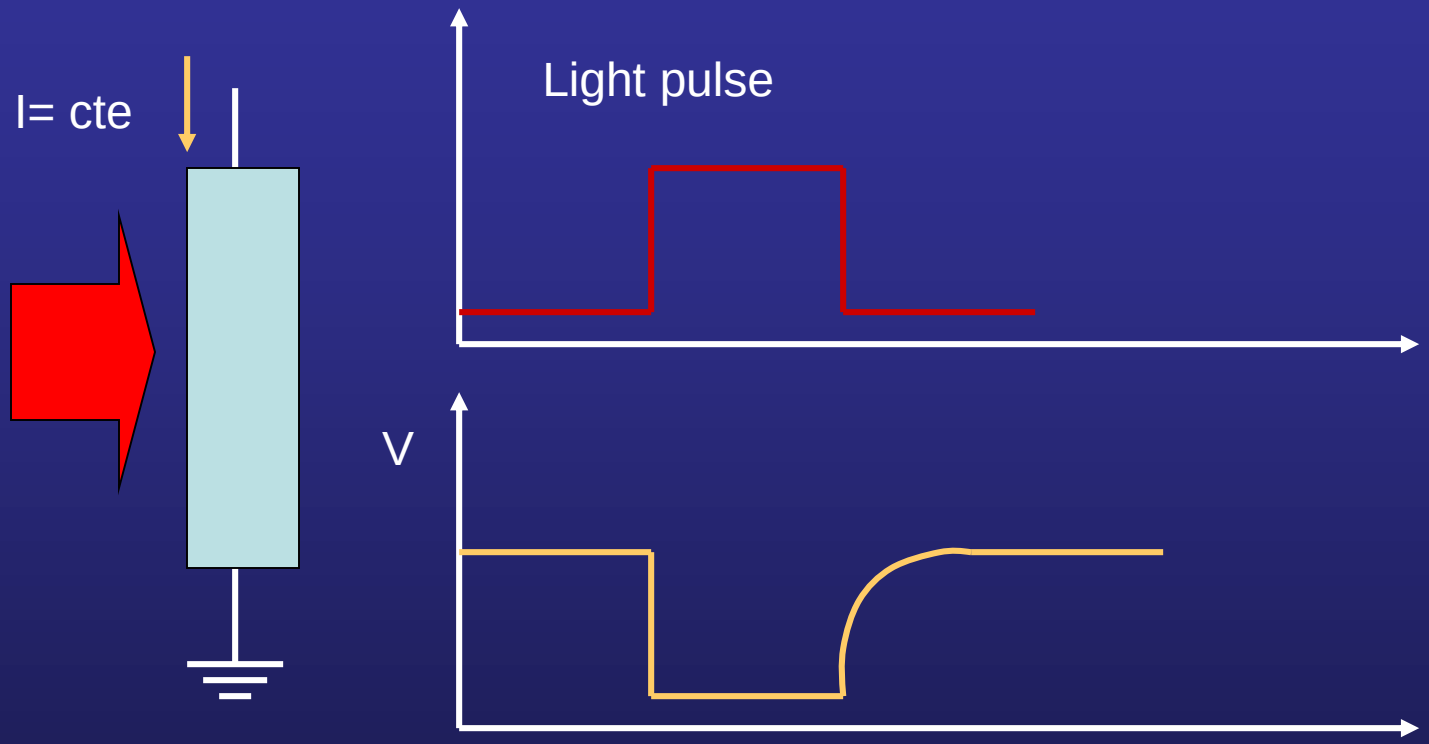


$$\rho_s = \frac{V}{I}\,\frac{d}{s}\,C'$$

d/s	$a/d = 1$	$a/d = 2$	$a/d = 3$	$a/d \geqq 4$
1.0			0.9988	0.9994
1.25			0.9973	0.9974
1.5		0.9859	0.9929	0.9929
1.75		0.9826	0.9850	0.9850
2.0		0.9727	0.9737	0.9737
2.5		0.9413	0.9416	0.9416
3.0	0.8192	0.9000	0.9002	0.9002
4.0	0.7784	0.8061	0.8062	0.8062

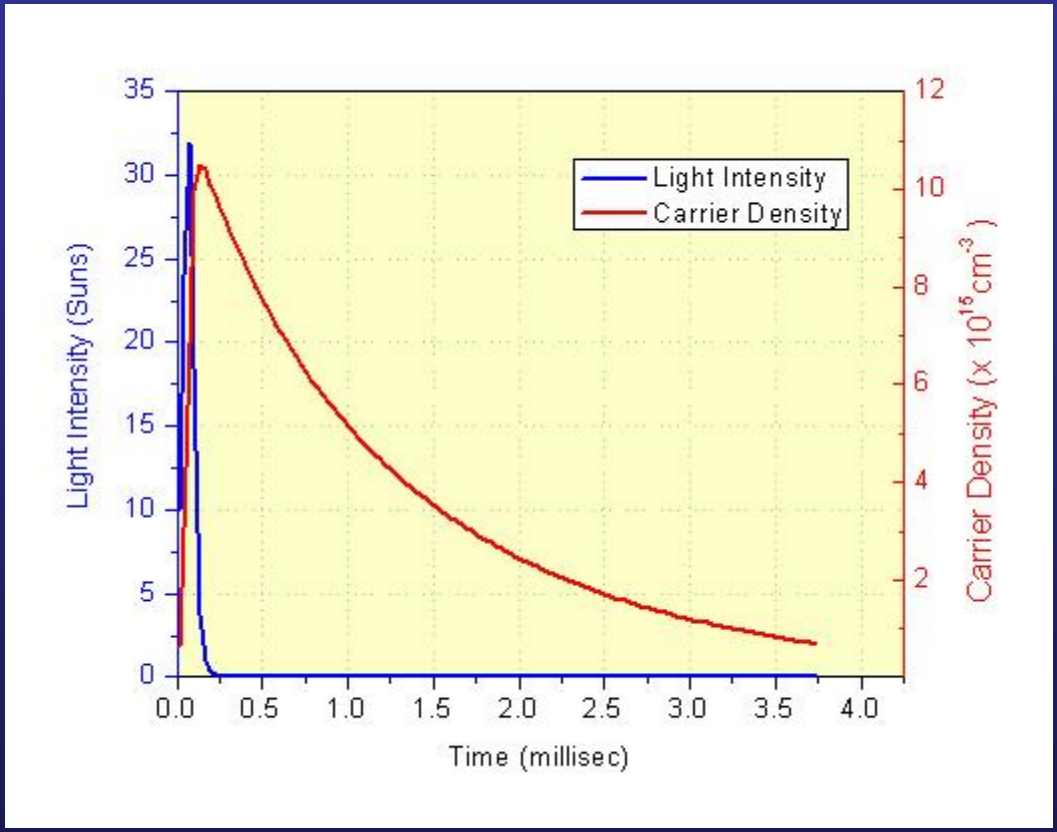
CHARACTERIZATION OF SOLAR CELLS

Carrier Lifetime



CHARACTERIZATION OF SOLAR CELLS

Carrier Lifetime

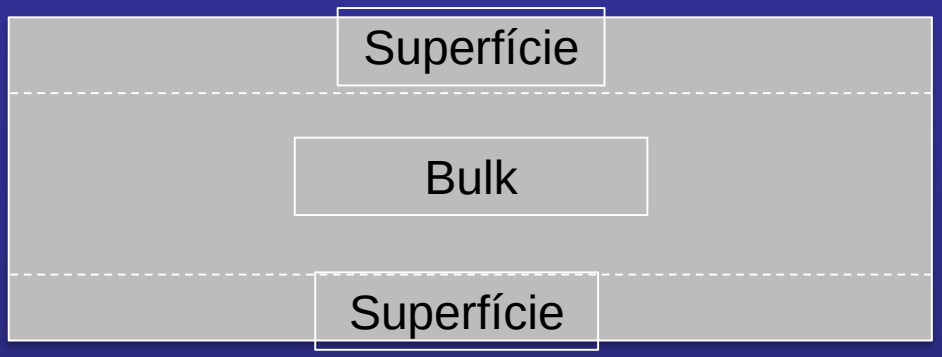


$$L = \sqrt{D\tau}$$

Excess minority carriers decay because of recombination.

CHARACTERIZATION OF SOLAR CELLS

Carrier Lifetime



$$\frac{1}{\tau_{eff}} = \frac{1}{\tau_b} + \frac{1}{\tau_s}$$

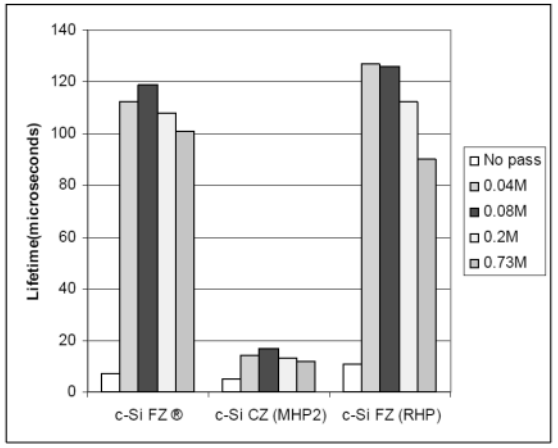


Figure 1: The figure shows the measured lifetime (microseconds) for different wafers (Czochralski –CZ; Float Zone-FZ) against the iodine concentration solution. The white bar refers to measured lifetime for the same samples without passivation.

Excess minority carriers decay because of recombination.

CHARACTERIZATION

Spectral Response

Gives us access to internal parameters of the solar cell

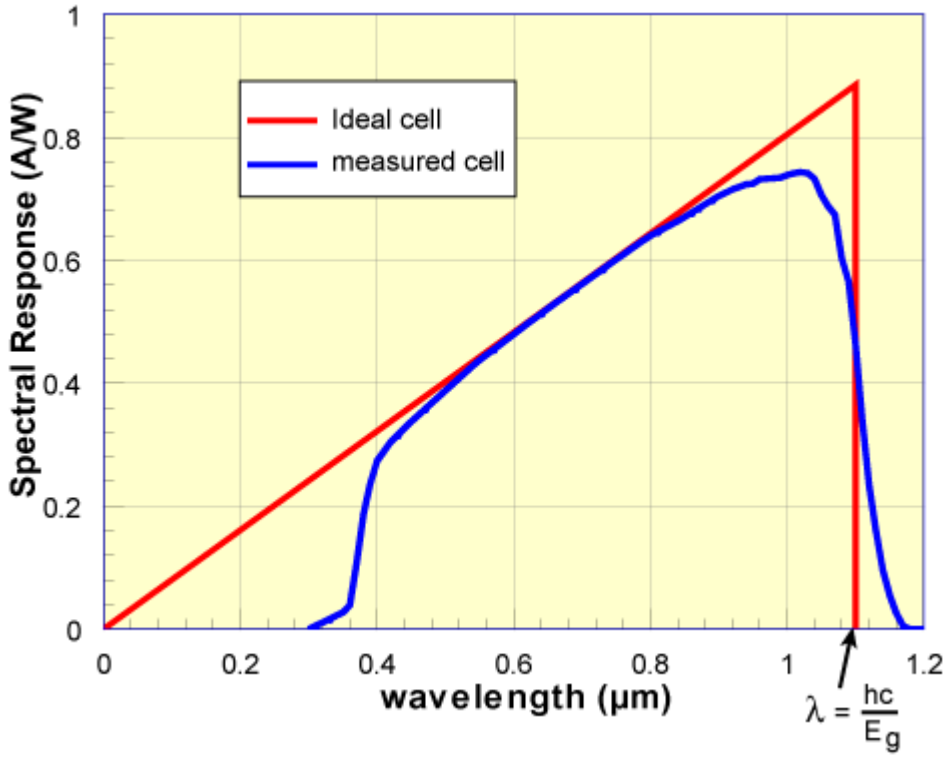
I-V Curve

Gives us access to the most important external parameter of a solar cell: Conversion efficiency

CHARACTERIZATION

Solar cell/modules characterization

Spectral response



CHARACTERIZATION

Spectral response (SR) is the short circuit current produced by the cell when illuminated by a given power

External quantum efficiency (EQE) is the probability of a incident photon contributing to one electron to the short circuit current

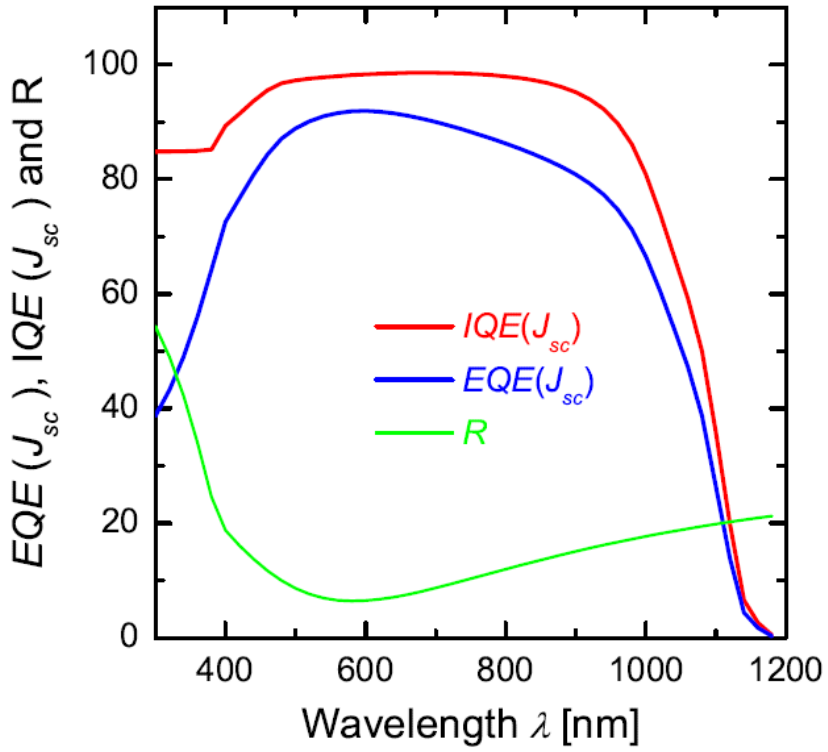
Internal quantum efficiency (IQE) is the probability of a absorbed photon contributing to one electron to the short circuit current

$$SR(\lambda) = \frac{I_{sc}}{P_{opt}} \qquad SR(\lambda) = \frac{q\lambda}{hc} EQE \qquad IQE = \frac{EQE}{1 - R(\lambda)}$$

CHARACTERIZATION

Solar cell/modules characterization

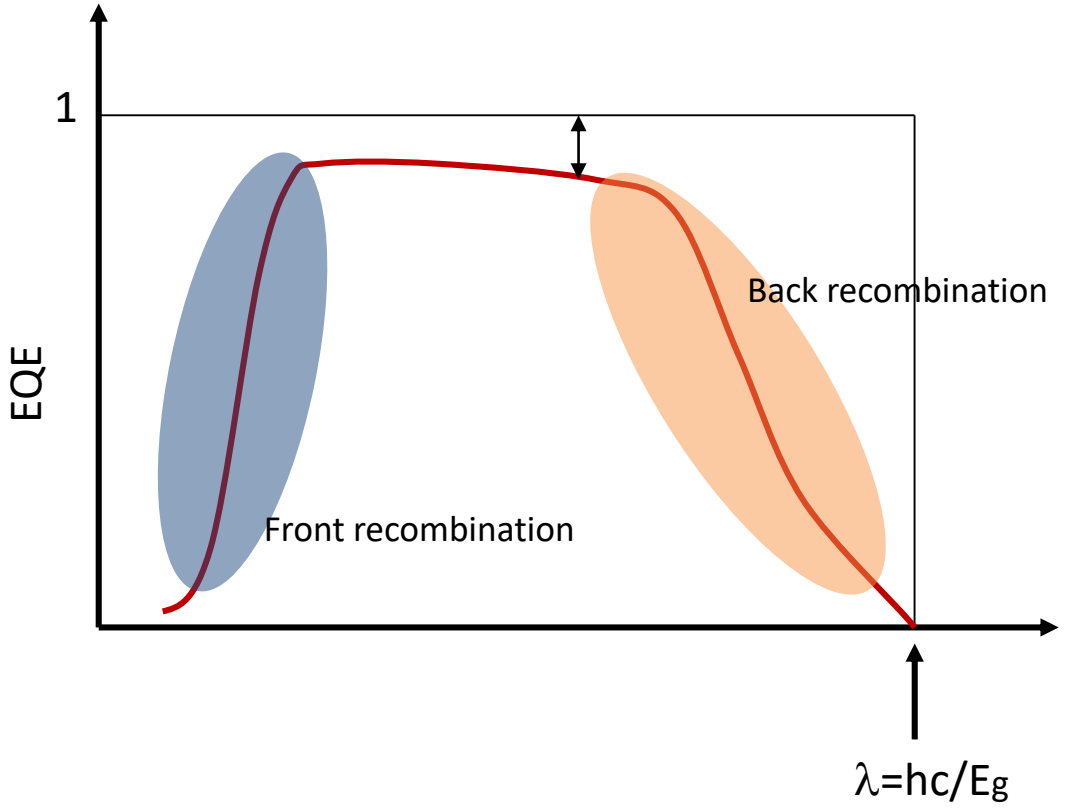
Spectral response



CHARACTERIZATION

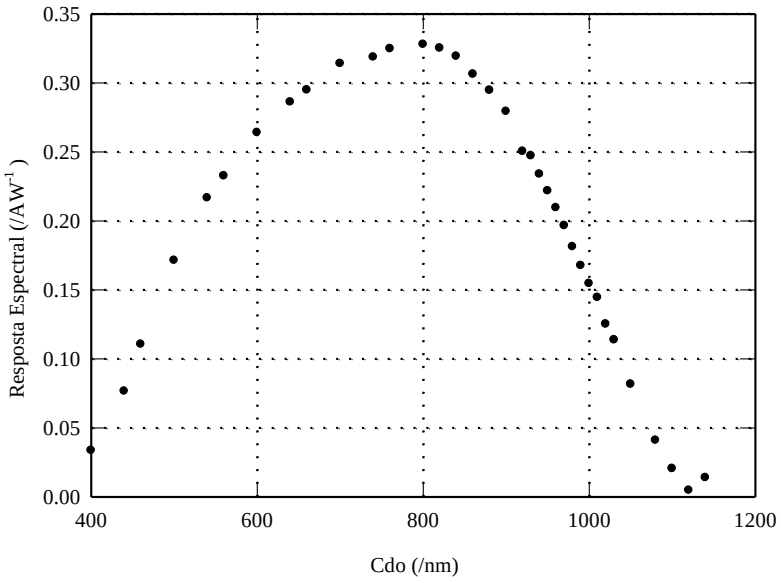
Solar cell/modules characterization

Quantum efficiency

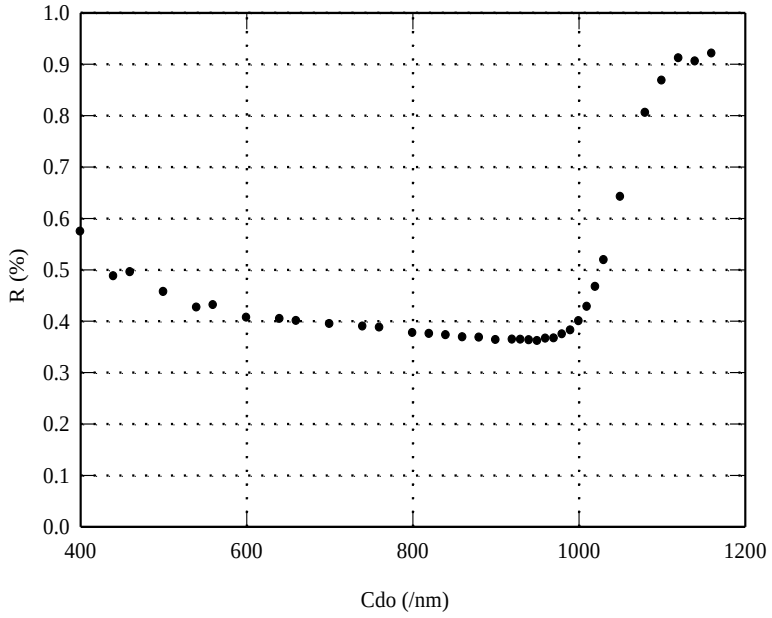


CHARACTERIZATION

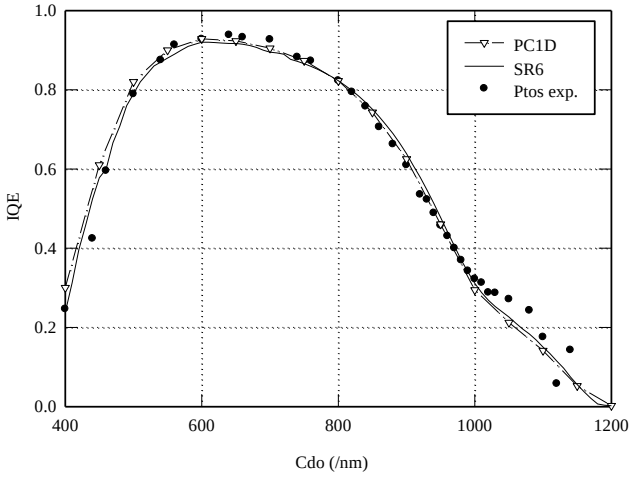
Spectral response



Reflectance



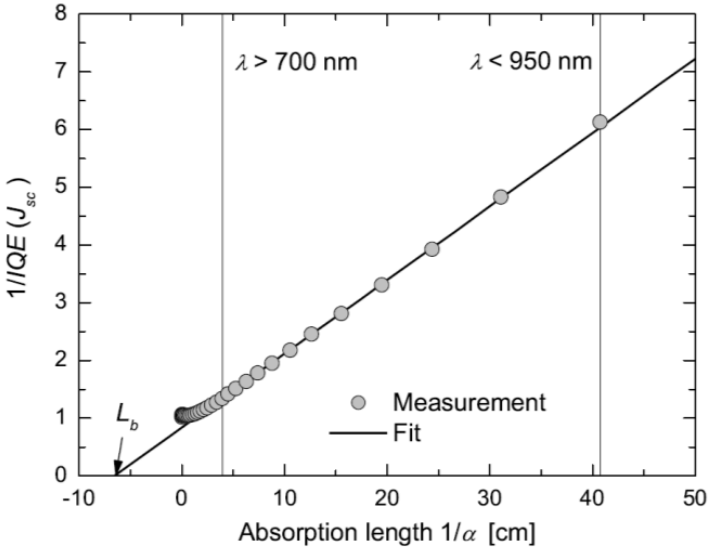
CHARACTERIZATION



Determination of diffusion length:

if $\alpha^{-1} << t$ and $L << t$ then, it can be shown that, for 800-1100nm:

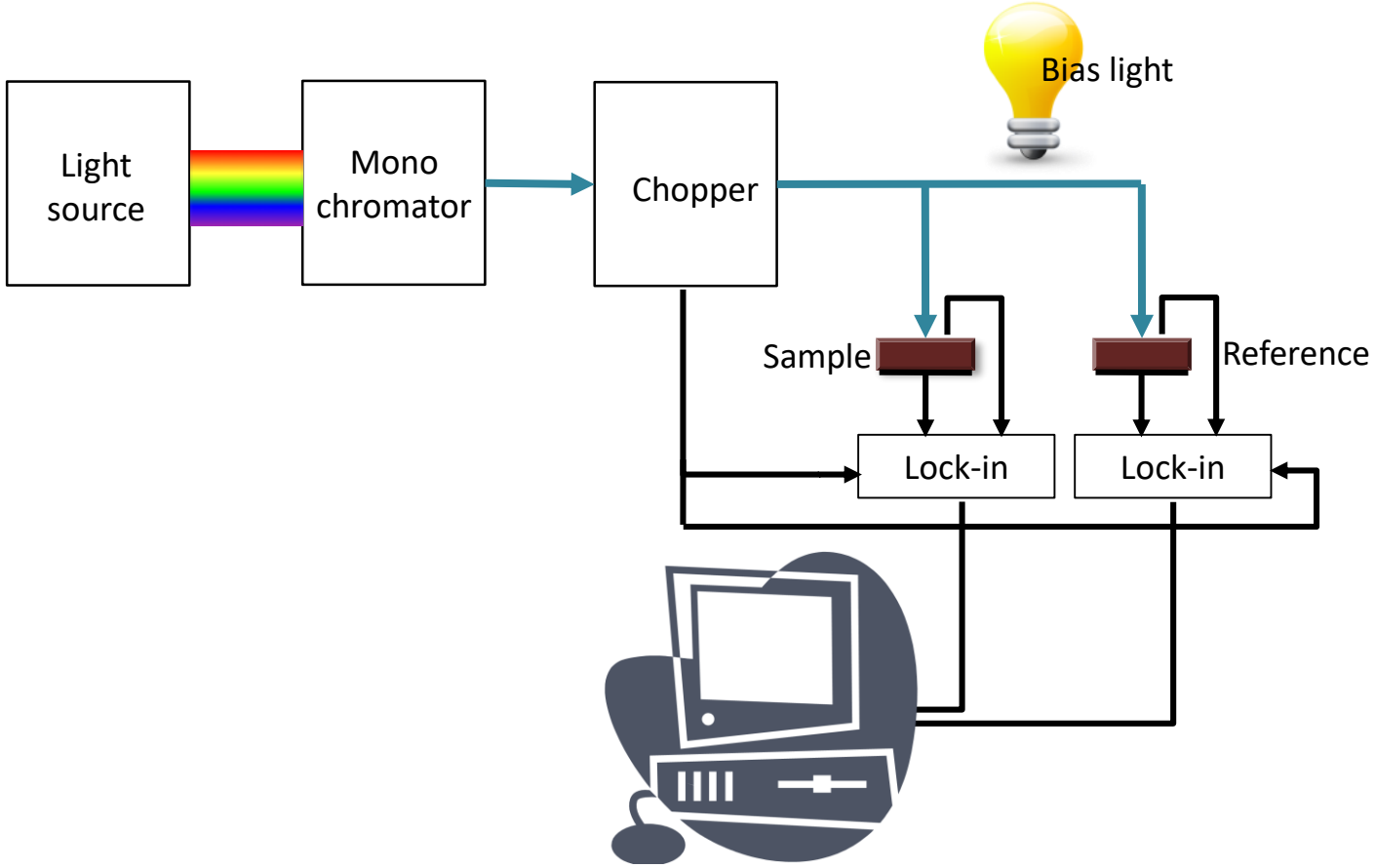
and thus L can be extracted from plot IQE vs α^{-1}



CHARACTERIZATION

Solar cell/modules characterization

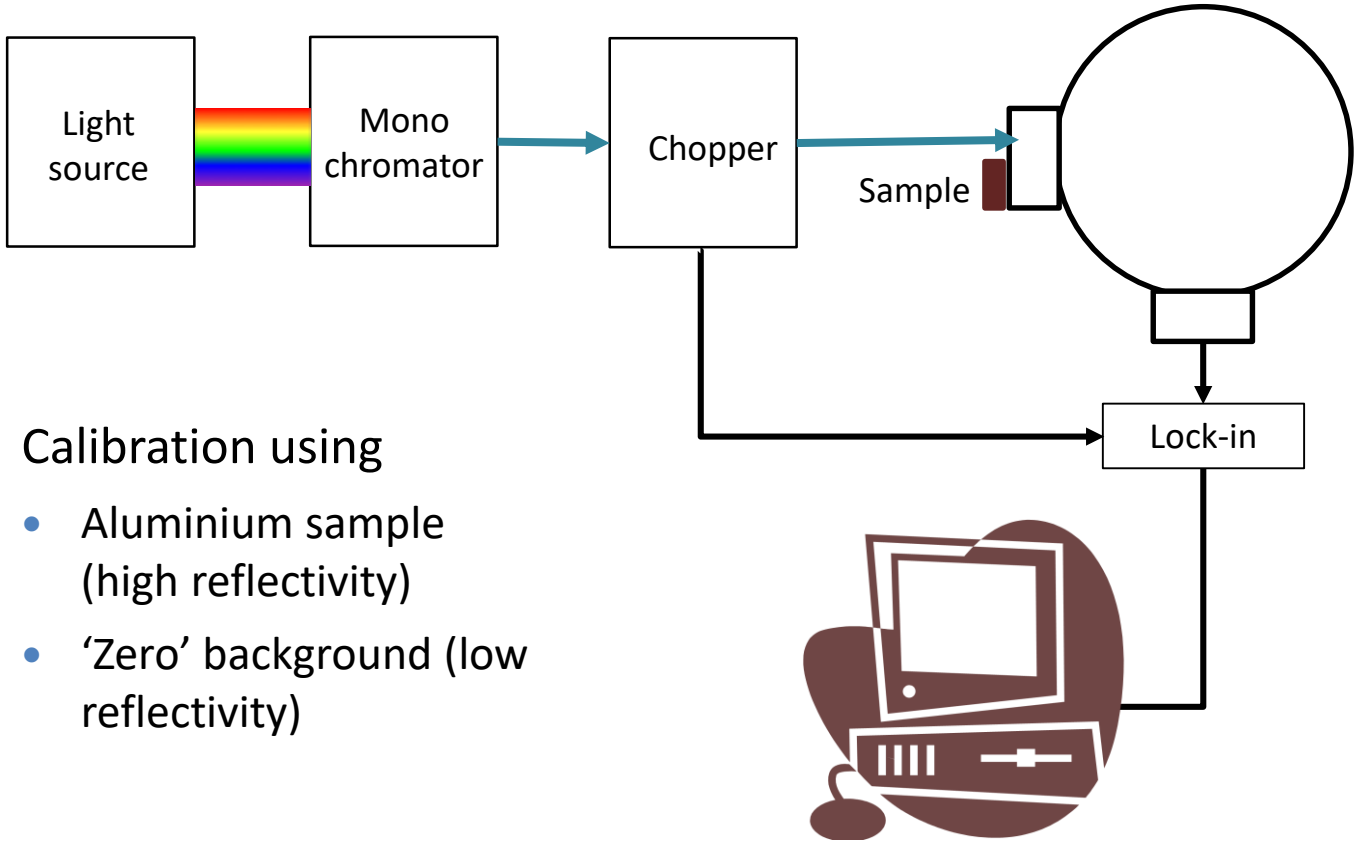
Spectral response: measurement



CHARACTERIZATION

Solar cell/modules characterization

Reflectance



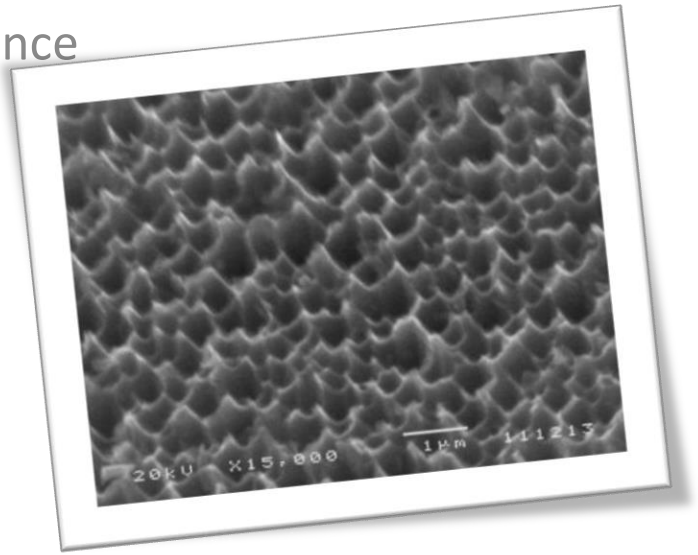
Calibration using

- Aluminium sample (high reflectivity)
- ‘Zero’ background (low reflectivity)

CHARACTERIZATION

Solar cell/modules characterization

Reflectance



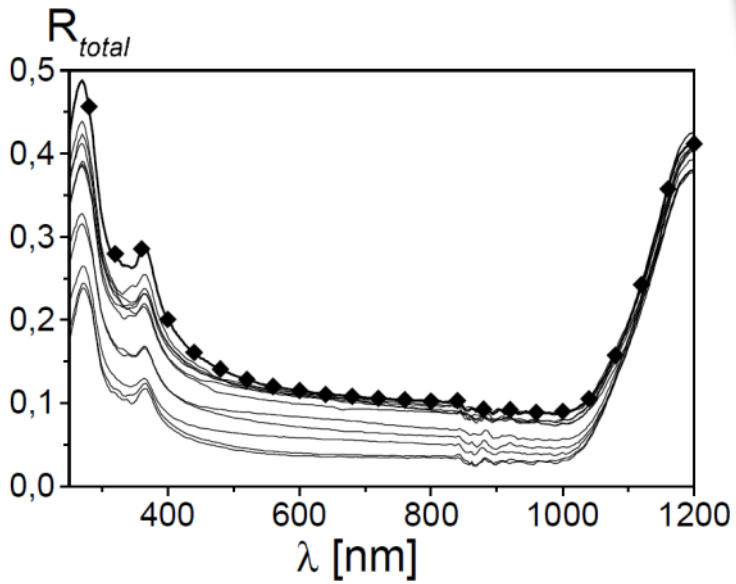
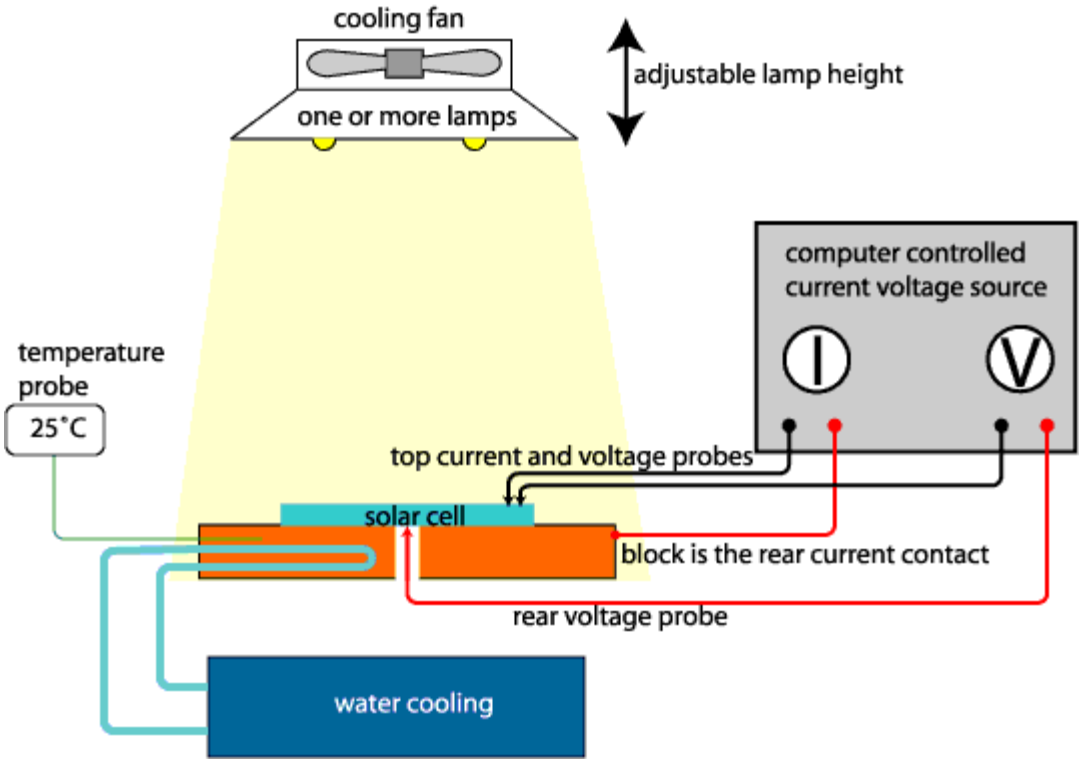


Figure 4: Reflectivity spectra of a macroporous texturised POLIX wafer (straight lines). For comparison the reflectivity curve of NaOH texturised, (100) oriented c-Si is also shown (◆).

CHARACTERIZATION

Solar cell/modules characterization

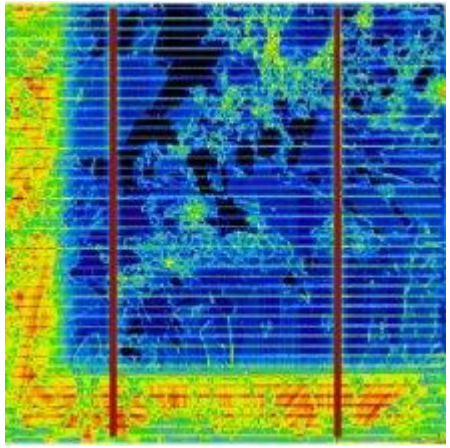
IV curve



CHARACTERIZATION

Spatial resolution techniques

INFRARED IMAGING



Includes
Electroluminescence (EL)
photoluminescence (PL) and
lock-in thermography (LIT).

Allows measurement of
Series or shunt resistance
Junction breakdown
Hot spots
Lifetime