Photoluminescence imaging of solar grade mc-Si wafers and solar cells as a tool for efficiency qualification

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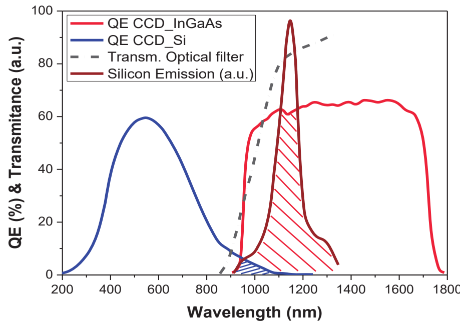
INTRODUCTION

- The photovoltaic industry is, nowadays, dominated by silicon technology. In the case of multi-crystalline Si (mc-Si) the efficiency losses are mainly caused by the structural defects inherent to the growth, e.g. grain boundaries (GBs), dislocations, and incorporation of impurities
- PL imaging (PLi) technique is a promising experimental tool for a fast qualification of mc-Si wafers because permits acquiring in a short time a panoramic view of full wafers. PLi gives information about the presence and distribution of carrier traps, which negatively affect the efficiency
- In this work, we analyze the PLi of several solar cells of known efficiencies, observing fear correlation between the colour lookup table (LUT) extracted from the PL images and the solar cell efficiencies. Both, a Si CCD and an InGaAs CCD detectors were used. The images were processed with "Image J" software
- The final goal of this approach is to provide a tool allowing a robust prediction of solar cell efficiency from the PL images of mc-Si wafers

CHARACTERIZATION: Photoluminescence measuring equipment (Silicon CCD Camera / InGaAs CCD Camera)

PCO 1300 solar (Silicon CCD camera) vs. Hamamatsu C12741-03 (InGaAs CCD camera)



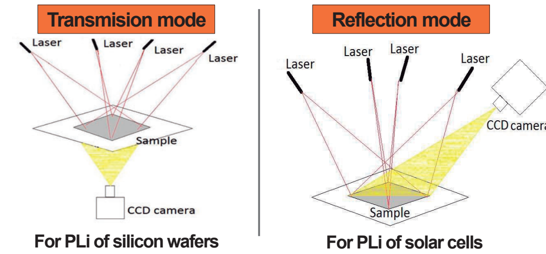
	Silicon CCD	InGaAs CCD
Maximun resolution	1392 x 1040 pixel	640 x 512 pixel
Máximum quantum efficiency	11% @ 900 nm	50% @ 1500 nm
Dynamic range	12 bit	14 bit
Exposure times	5 µs to 3600 s	17 ms to 1 s

InGaAs CCD has better quantum efficiency at silicon band emission

PLi equipment

λ_{exc}= 808 nm (4 x 20 W optical power)

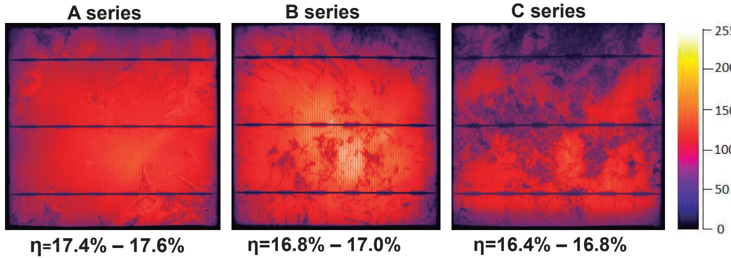
12.5 mm focal length optical objective



RESULTS AND DISCUSSION

PL imaging as a tool for solar cell characterization

Different solar cells analyzed (Silicon CCD camera images)

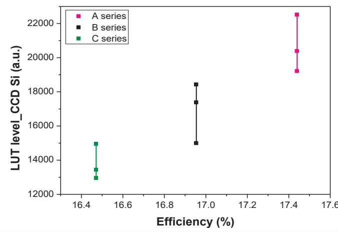


LUT level vs. efficiency

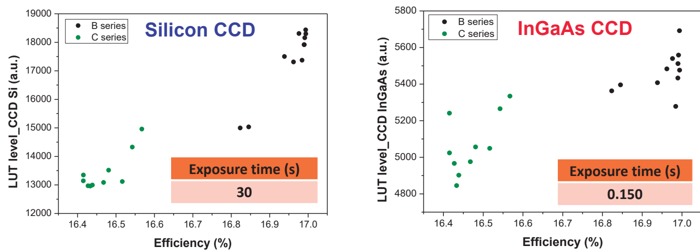
LUT level reflects the luminescence level of the solar cells

The maximum, minimum and mean LUT levels of each series are represented on the graph

LUT levels increase with efficiency



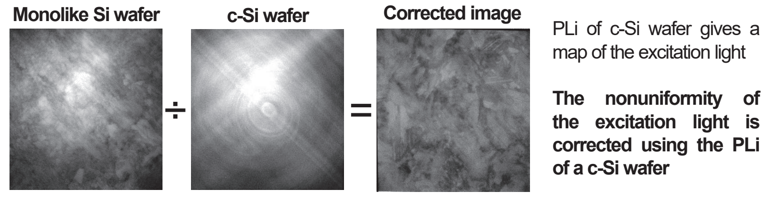
Particular PL analisys of B and C series with InGaAs CCD and Silicon CCD



InGaAs CCD and Silicon CCD yield similar results in solar cell's PLi. However, InGaAs CCD gives better results in a short time

PL imaging as a tool for Silicon wafers characterization

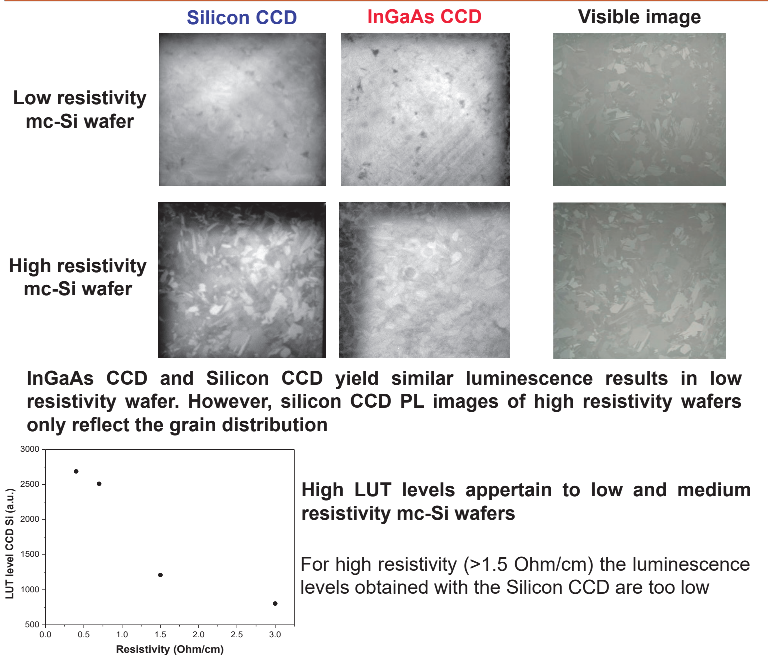
PLi treatment. InGaAs CCD (c-Si wafer used for flat field correction)



PLi of c-Si wafer gives a map of the excitation light

The nonuniformity of the excitation light is corrected using the PLi of a c-Si wafer

Analisisy of mc-Si wafers with different resistivities



InGaAs CCD and Silicon CCD yield similar luminescence results in low resistivity wafer. However, silicon CCD PL images of high resistivity wafers only reflect the grain distribution

High LUT levels appertain to low and medium resistivity mc-Si wafers

For high resistivity (>1.5 Ohm/cm) the luminescence levels obtained with the Silicon CCD are too low

CONCLUSIONS

- ❑ Fine agreement between LUT levels and cell efficiency for the three series of samples analyzed (efficiencies ranging from 16.4% to 17.6%)
- ❑ InGaAs CCD detector permits a substantial reduction of the acquisition time without loss of contrast. In the case of high resistivity wafers, it highlights the non radiative recombination pattern
- ❑ PLi is a fast tool allowing to catch information about the presence and distribution of carrier capture centers in both silicon wafers and solar cells
- ❑ The PLi technique can be implemented as an in-line tool for fast qualification of wafers and cells

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