

# AUTOMATIC RECOGNITION DEFECTS IN LBIC IMAGE IN THE SOLAR CELLS

**Aleš Veselý**

Doctoral Degree Programme (3), FEEC BUT

E-mail: xvesel29@stud.feec.vutbr.cz

Supervised by: Jiří Vaněk

E-mail: vanekji@feec.vutbr.cz

**Abstract:** This paper deals with automatic computer analyze of LBIC image. The output data of defect detection method like LBIC or electroluminescence image contains lots of information about contacts structure and about the defects in the area of solar cell. This data can be analyzed by operator in image form or can be analyzed by computer system in row form.

**Keywords:** Computer analyze automatic, photovoltaic, solar cell, swirl defect, metallization defect

## 1. INTRODUCTION

### 1.1. LBIC

Light Beam Induced Current (LBIC) works on principle of exposure very small area of a solar cell, usually by laser beam focused directly on the solar cell surface. This point light source moves over measured solar cell in direction of both X and Y axis. Thanks to local current response the XY current distribution in investigated solar cell can be measured. Acquainted data are then arranged in form of a current map and the behaviour of all solar cell single parts is thus visible. In such current map is therefore possible to determine majority of local defects. Sometimes there is necessary (automatically or by hand) to extend steps of grey on displayed areas for good picture of particular defects.

An accuracy of this method depends on actual size of the light point and on the step of the laser pen movement. By longer step the accuracy of the method is lower, but whole measurement process accelerates because of reduced number of the measured points. On the contrary in the case that the step matches the sizes of the light point the measurement will be highly accurate but also very slow. On this account there is very important to choice the optimum ratio step to light point size.

It is obvious that the accuracy of LBIC measurement depends firstly on the light point size. Laser diodes are therefore used because of well mastered technology of focalization of laser beam. Next advantage of the laser diodes is very high light beam intensity. The method LBIC is indeed lengthy and is advisable to use it only at small quantity of solar cells.[1]

### 1.2. AUTOMATIC COMPUTER ANALYSES

Presumption of automatic computer analyse of LBIC image is knowledge of defects of silicon solar cells. That's why we take advantage of Dr. K. Jandova's research which created catalogue of solar cells defects.

Next necessary step is choosing right image processing method which convert raster image to the numeric values.

Whole processing of LBIC image has a following four steps:

- scanning and digitalizing

- pre-processing
- segmentation
- classification

### **Pre-processing**

Purpose of pre-processing is noise reduction and image distortion. In the pre-processing we can highlight characteristics of image which we can use for further process e.g. edge detection.

Segmentation image by edge detection is coming-out from the fact when many objects or area of image is characterized by constant reflecting or absorption of surface. Than is possible to use determination of brightness constants of edge to the separating object from the background. Edge detection is transformation input image  $f$  to the output binary image  $g$  according to equation

$$g(i, j) = \begin{cases} 1 & \text{for } f(i, j) \geq T, \\ 0 & \text{for } f(i, j) < T \end{cases} \quad (1)$$

Where  $T$  is in advance determined constant called edge,  $g(i,j) = 1$  for object and  $g(i,j) = 0$  for background. Value of edge it is possible define interactive or with the help some methods of automatic edge detection.

### **Edge detection methods**

The simplest situation occurs if character  $r$  is defined in advance that the image has after segmentation. The edge we assign so that we are accomplished this character by segmentation. More complex method is based on analyses shapes of histogram.

### **Canny edge detector**

Canny edge detector is algorithm take in few steps for the best extracting objects from two dimensional discrete images. First step is elimination noise using Gauss filter. Second step is application of Sobel operator for finding size and orientation of gradient. Next step is selection of local maximums of founded gradients where principle consist in that point of the edge is marked only that point which neighbouring points in the vicinage normal to the direction of gradient has less value of gradient. Direction of gradient returns Sobel detector. Finally edge detection has hysteresis. Objective is remove edges which could be caused by noise and therefore has distinctively lower gradient value then right founded edges.

Algorithm is designed so that was completed basic requirements:

- minimum fault
- accuracy
- definiteness

To accomplished this requirements it is necessary right set up input parameters  $T_1$  and  $T_2$ . Founded gradient values are compared with these edge parameters.

### **Hough transform**

Hough transform is a method for finding parametric description objects in the image. For this method is necessary to know analytic description of finding objects shapes. That why this method can be used only for simply shapes. Main advantage of this method is passivity against discontinuous finding shape.

As a line model we used equation:

$$x \cdot \cos \theta + y \cdot \sin \theta = r \quad (2)$$

Where  $r$  is length of the normal line between bisector and coordinate origin,  $\theta$  is the angle between normal line and X axis.

As a circle model we used equation:

$$(x - a)^2 + (y - b)^2 = r^2 \quad (3)$$

Where  $a$ ,  $b$  and  $r$  are finding parameters. With finding circles distinctively increase computing difficult of algorithm.

### **Segmentation image by comparing with model**

With this function we can find areas in the image that contains given shape and which has image character. Beside object finding and area this method can use for stereoscopic determining objects features if we have two image same scene scanning from the different places. From single image we are detach searched objects and help to suitable organized searching is finding same objects in rest of images.

### **Image registration**

Image registration is a process which align two or more images same scene to the one. One image is called model and the others refer to the model. Purpose of the image registration is transfer input image to the basic image by helping of geometric transformation. By this method can be happen deference between input and output image. These differences can be evoked by differences of the used sensors.

### **Mapping**

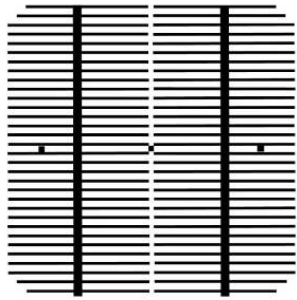
Mapping is used for identification and selection points (objects) in the image which are shared in all images and currently form indispensable part of the image.

## **2. EXPERIMENTAL PART**

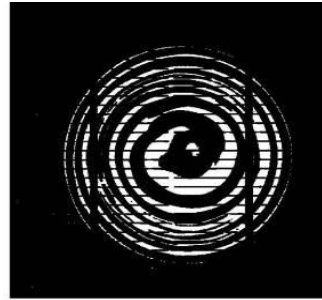
Analysis routine is writing in the Matlab R2007a. This program is useful for image analyzes and display result component.

### **2.1. REFERENCE IMAGE**

Reference image was created from the defect less solar cell image. This reference image was created by thresholding by the help histogram. Images are consisting of logical values matrix. Pixels, which are lower value then set up edge, are rate as logical null (black). Beside pixel, which are higher value, are rate as logical one. This method should be taken off all defects in the image evoked by nonideal scanning. Next steps are correlation (finding crosses), evaluation by the mask. Final reference image is on the figure Fig.1.



**Fig. 1:** Created mask of the reference image



**Fig. 2:** Input image after thresholding and subtracting

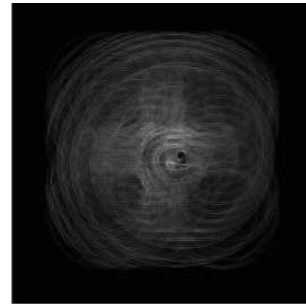
## 2.2. DETECTION OF THE SWIRL DEFECTS

After loading image to the program is implemented correlation which fit image to the predefined points. Next is necessary modifying image so that was surpassing finding defect. At first is an image converting to the grayscale after that is an image thresholding. After that is subtract mask of the reference image from the modified input image. A result of this operation is on the next figure Fig. 2.

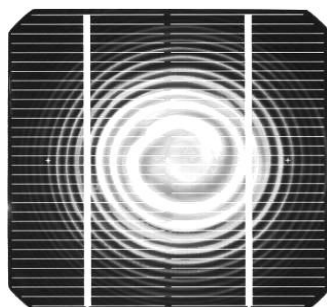
On like this modified image is applied Canny edge detector and Hough transformation which create final output image.



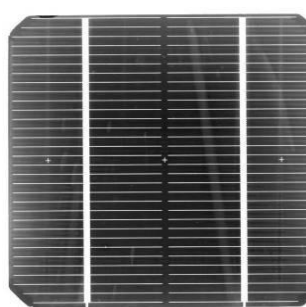
**Fig. 3:** Swirl defect after application of the Canny edge detector



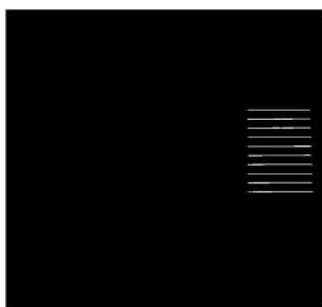
**Fig. 4:** Hough space of the swirl defect



**Fig. 5:** Output image with swirl defect



**Fig. 6:** Input image with metallization defect



**Fig. 7:** Founded area with metallization defect

### **2.3. DETECTION OF METALLIZATION DEFECT AND COVERING CONTACTS**

Metallization defect is caused by nonfinalization of silkscreen process. Covering contacts defect may be caused with scanning solar cell when some part of the scanning equipment shade solar cell. On the input image is again implementing same procedure as in previous case. But in this case is finding discontinuity of the metallization and contacts.

### **3. CONCLUSION**

The computer data analyses of LBIC image were done. There is possible to detect many defects than we are presented in this paper like missing contacts, scratches and dust traces. For more defects detection is important to make large catalog of defect shapes and characters to be able detect.

### **REFERENCES**

- [1] K. Kubickova, J. Bousek, M. Janda, T. Fort, R. Barinka. Fast LBIC scanning of solar cells, Proceedings of The Seventh European Photovoltaic Solar Energy Conference and Exhibition, Dresden 2006.
- [2] V. Hlavac, M. Sonka. Pocitacove videni. Prague: Grada, 1992. 272 s., ISBN 80-85424-67-3, Czech Republic
- [3] The MathWorks Accelerating the pace of engineering and science [cit.2009-01-20] <http://www.mathworks.com/access/helpdesk/help/toolbox/images/index.html?/access/helpdesk/help/toolbox/images/imrotate>
- [4] M. Dobes. Zpracovani obrazu a algoritmy v C#. 1. vyd., Prague BEN, 2008, 143 s., ISBN 978-80-7300-233-6, Czech Republic