Microelectronics Reliability xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Microelectronics Reliability

journal homepage: www.elsevier.com/locate/microrel

Pattern image enhancement by automatic focus correction

A. Boscaro [a,b,*], S. Jacquir [a], K. Sanchez [b], P. Perdu [b,c], S. Binczak [a]

[a] Le2i, FRE CNRS 2005, Arts et Métiers, Univ. Bourgogne Franche-Comté, Dijon, France
[b] Centre National d'Etudes Spatiales (CNES), Toulouse, France
[c] Temasek Laboratories, Nanyang Technological University, 50 Nanyang Drive, Singapore

ARTICLE INFO

Article history:
Received 18 May 2017
Accepted 3 July 2017
Available online xxxx

Keywords:
Focus correction
Failure analysis
Discrete Cosine Transform
Thresholding
Radon transform
Image processing

ABSTRACT

Optical analysis techniques are key tools for the failure analysis and defect localization in integrated circuits. Using a confocal laser microscope, it is possible to extract different pieces of information such as spatial distribution of signals or voltage waveforms. Blur is getting a more and critical issue as technology pitch is getting smaller, very close to resolution limits. Find the correct focus, is a recurrent problem to solve in optical microscopy. The expert has to correct the blur disrupting the image, by manually searching the good focus. By consequences, this step may take a long time to identify regions of interest in the circuit. With this purpose in mind, the aim of this paper, is to propose an automatic process estimating the out-of-focus blur parameters characterized by specific attributes. Proposed technique takes advantage of extracted features in the Discrete Cosine Transform (DCT) of blurred images. The blur information is identified and allows to recover the blur's kernel. Finally, the accuracy and the robustness of the suggested process is demonstrated on real blurred images.

1. Introduction

Confocal microscopy is an elementary tool used in failure analysis for the defect localization in the integrated circuits. Its principle, is to supply images by scanning point by point the circuit with specific light. This kind of wavelength must be intensive and focused. That is the reason why, the confocal laser microscopy is the most widely used in our context of research. Use a 1064 nm or 1360 nm laser allows to both pass through the silicon and provide an optical image of the pattern. Furthermore, this kind of observation, provides a significant improvements about resolution, compared to conventional microscopy [1]. Nonetheless, it is challenged by the progress of scaling in microelectronics. Finding areas of interest linked to a defect is more and more complex due to resolution issue. On the other hand, this kind of microscopy is also challenged by the out-of-focus blur. The experts have to find manually the good focus giving the best observation. Whether it is for laser or light emission technique, the observation of the device under test (DUT) with this tool, is a key step to identify clearly the defect [2]. For example, if the laser beam is not well focussed, it will cover a lager region and gives the illusion that the signal originates from the source. The problem is similar for light emission spots, which can overlay more and more gates, if the focus is not adapted. Difficulty arises when there are optical aberrations in the system (spherical, astigmatism, etc.). Blur is getting a more and critical issue as technology pitch is getting smaller, very close to resolution limits.

In the last two decades, image deblurring has become a challenging task in image processing, and has seen its interest grow over time [3]. Generic image restoration techniques, mostly use the Point Spread Function (PSF) kernel to restore image. To know the kernel, improves the restoration's quality and the algorithm computation time. This paper aims to study the benefit of point spread function estimation and deconvolution to enhance images acquired with confocal laser scanning microscope. The state of the art, provides several techniques to estimate the PSF kernel. It would be presumptuous to cite all of them however few examples can be cited, such as circle of confusion estimation [4], spectrum or gradient properties [5,6] and sparse models [7]. Among all the cited approaches, some of them have proved their accuracy in term of parameter estimation but a prevalent difficulty is their running times. This study is focused on providing an automatic, fast and robust parametric out-of-focus blur estimation, which can be easily integrated in real time. With this purpose in mind, this paper reports an automated method based on DCT combined with edge detection and Radon transform to estimate the PSF kernel.

The rest of this paper is organized as follows. In Section 2, the general process flowchart and examples on real blurred pattern images

* Corresponding author at: Laboraroire Le2i, FRE CNRS 2005, UFR Sciences et Techniques, Université de Bourgogne Franche-Comté, 9 Avenue Alain Savary, 21000 Dijon, France.
E-mail address: anthony.boscaro@u-bourgogne.fr (A. Boscaro).

http://dx.doi.org/10.1016/j.microrel.2017.07.012
0026-2714/

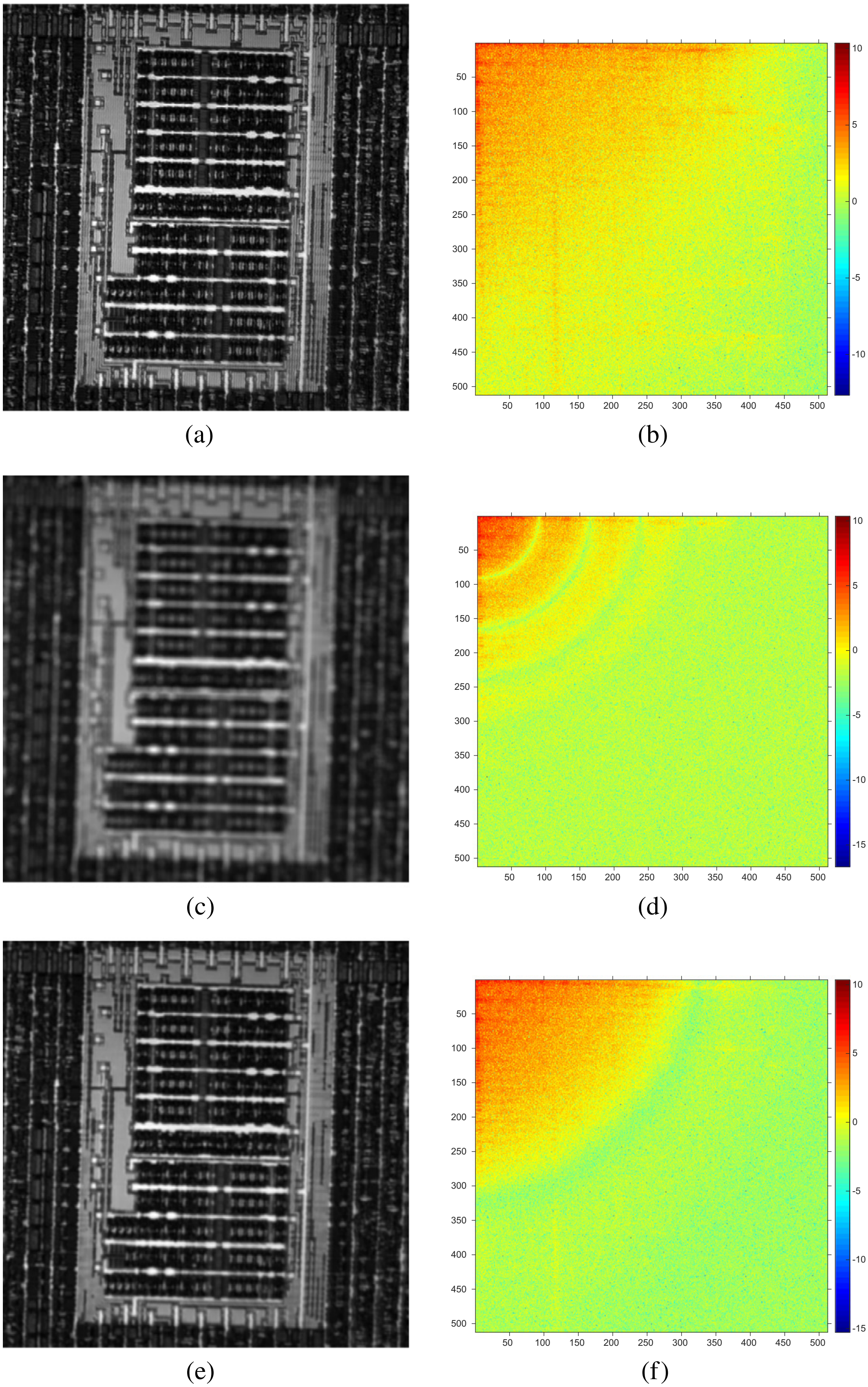

Fig. 1. (a) 512 × 512 original 90 nm microcontroller pattern image, (c) corrupted by a blur whose radius is $R = 7$ pixels and (e) $R = 2$ pixels. (b), (d) and (f) represent respectively the absolute value of the DCT with a logarithm scale for the original image, and the out-of-focus blurred images.

Please cite this article as: A. Boscaro et al., Pattern image enhancement by automatic focus correction, Microelectronics Reliability (2017), http://dx.doi.org/10.1016/j.microrel.2017.07.012