Thermal image processing for defect analysis and detection

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Abstract. Infrared thermography is a thermal measurement process that produces images in which each pixel contains a temperature measurement. This technique is very popular in many industries and fields such as preventive and/or predictive maintenance and non-destructive testing, to detect problems more efficiently and safely, but is not currently used effectively. [1]

Techniques and technical applications are developed, for the detection and analysis of a certain defect on electronic circuits and electrical equipment. Current thermographic processing software has some limitations, mainly because it is developed for general applications and does not identify a region of interest. The identification of a region of interest with a particular anatomical shape. These shapes are limited when they do not correspond to the complex geometric shape of the area to be characterized, either by exclusion or inclusion of irrelevant data in the evaluation of thermal images. This restriction is observed regardless of the accuracy of the region of interest. This paper presents an image processing technic for localization of MOSFET faults based on thermal, hence the use of segmentation algorithms increases the accuracy of the thermal image analysis.

Keywords: Image processing, thermography, fault location.

1 Introduction

Thermographic inspection uses an infrared camera to capture and analyze the thermal profile of the equipment being inspected. The analysis of the temperature distribution profile of the target equipment can be done qualitatively or quantitatively. Qualitative measurement is based solely on image processing where the abnormal region is detected by comparative evaluation between the reference temperature and the hot spot temperature of the target equipment.

But IR inspection in an uncovered environment can be strongly influenced by various environmental parameters such as ambient temperature, reflected or background temperature, wind speed, relative humidity of the object and precipitation, etc. For these reasons, the accurate assessment of the health of the equipment can be interrupted, which can lead to an erroneous conclusion of the inspection. For these reasons, the accurate assessment of the health status of the equipment may be interrupted, which may lead the inspection to a wrong conclusion. [3]

The technique of inspection and control by thermography touches several fields and sectors, namely:

- Medical sector to locate various tumors
- Industrial sector to check electrical equipment
- Aeronautical sector to check the correct functioning of the reactor.
- Renewable energy sector to check the blades of wind turbines and solar panels.
- Building sector to see construction errors.

In the present work we are interested in the analysis and localization of faults on a MOSFET. The basic idea is to supply the component (component to be tested) with a direct or alternating voltage according to the manual of each component, after a well-defined time, which ensures the heating of our case plus the distribution of the temperature on the total surface of the component.

Then, with the help of a thermal camera, which measures and records the various heat waves, infrared radiation, emitted by the component [4]. It reproduces an image representing the intensity of the radiation, which makes it possible to evaluate the temperature.

This paper is organized as follows: in section 2 discusses the proposed technological solution, before results and conclusions in sections 4 and 5, a case study of a MOSFET with a HOT SPOT.

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1.1 literature review

The most modern image segmentation methods are based primarily on visible spectrum images. Thermal images can be captured in the dark and deployed at any time of day and weather. However, research on semantic segmentation of thermal images remains underutilized, due to the lack of segmentation data for thermal images of the night driving scene.

On the other hand, existing methods do not properly capture the context between linked pixels and edge details in thermal images. The authors, are oriented to the semantic segmentation of thermal images of night driving scene, being an effective solution [20].

The authors describe in [18] the case of arthritis (subclinical inflammation) when rheumatologists are uncertain about the presence of inflammation. The application of thermal imaging in the detection of subclinical inflammation has been based on the segmentation of the area to which the inflamed region of the knee of the thermal image.

In [16], the authors establish a proposed HSV color model (saturation and value) based on image segmentation to detect and correctly identify defects in the induction motor, as these motors are widely used in many industrial applications, based on five image segmentation methods, namely SOBEL, PREWITT, ROBERTS, CANNY, and OTSU, were used for segmentation. OTSU was used to segment the hue region, as it represents the hottest area of the thermal image.

The several segmentation algorithms and a comparison of unprocessed and optimized ROIs (region of interest) in the medical field, as current commercial software generally uses regular prismatic shapes for the definition of these regions, such as rectangles, squares, circles and/or ellipses that poorly define complex geometric regions [17]. These shapes have limitations when they do not match the complex geometric shape of the area to be characterized.

We can see that the segmentation algorithm is very effective for the processing of thermal images, for the localization of a problem or anomaly in any sector or area, so the interest of our work is to apply this technique on a MOSFET transistor to detect and locate a HOT SPOT and subsequently the failure analysis.

2 Definition of the proposed technological solution

This paper aims to show how a MOSFET can detect and locate defects that have occurred with a thermal image, obtained with a thermal camera, and how to interpret the results obtained.

Among the defects that require thermal inspection is the strength of the wire, as it is very difficult to judge that all wires have the same strength, and all this is used to locate and interpret the defect.

We have summarized our technical solution in a thermal analysis process model [Fig.1], which describes how the defect can be located thermally, step by step.

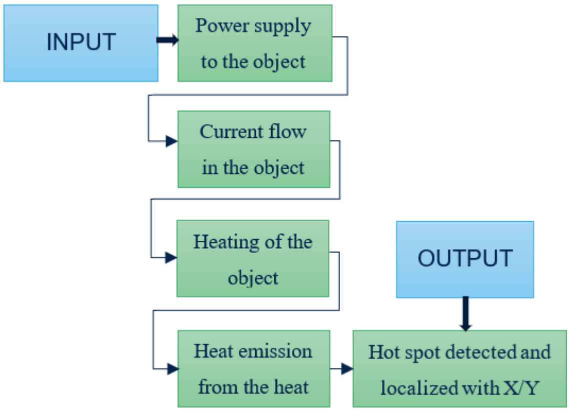

Fig. 1. The process of thermal analysis

3 Material and method

3.1 Definition of a thermal imaging camera and its compositions

A digital camera captures the light reflected from the object, while a thermal camera captures the heat emitted by the object being inspected or monitored.

The principle of a thermal camera [Fig.2] is based on the measurement and recording of the different heat waves emitted by a body or object. It reproduces an image that represents the intensity of the radiation and allows the temperature to be estimated. The hotter the body or object, the greater the radiation.

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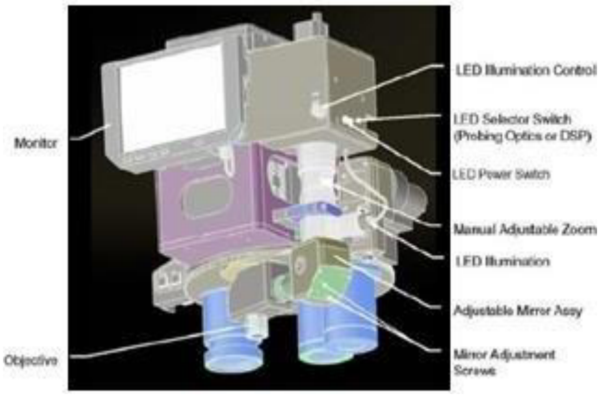

Fig. 2. Thermal camera

It is this data that enables thermal imaging cameras to produce a spatial temperature map, known as a thermograph.

It can detect both hot and cold bodies and applies a color to each temperature and indicates it in degrees Celsius or degrees Fahrenheit. In general, cold temperatures are in shades of blue, and hot temperatures in shades of red.

Thermal cameras have many features and functions, the most important of which are:

- The field of view.
- The total resolution of the image.
- The thermal sensitivity that a thermal camera can have.
- The temperature ranges.
- The focus influences the sharpness of the image, the quality of the measurement, and therefore the accuracy of the result.

The characteristics of the camera used:

- The camera offers a FOV (large field of view), 160mm by 200mm. The distance reduction reduces this FOV to 24mm by 20mm
- It has 04 thermal lenses (Wide Angle, 1x, 5x and 10x).
- Manual zoom (5x to 70x).
- Total image resolution: For full frame mode, the camera can have a resolution of 13 bits.
- High-speed, low-noise infrared detectors capable of detecting infrared light up to approximately 3.5 µm.
- A thermal sensitivity of 20mK.
- Temperature range: Absolute temperature mapping up to 180°C.

3.2 Definition of a thermal image

The thermal image is divided into two images:

- Amplitude image [Fig.3]: allows the location of the defect.

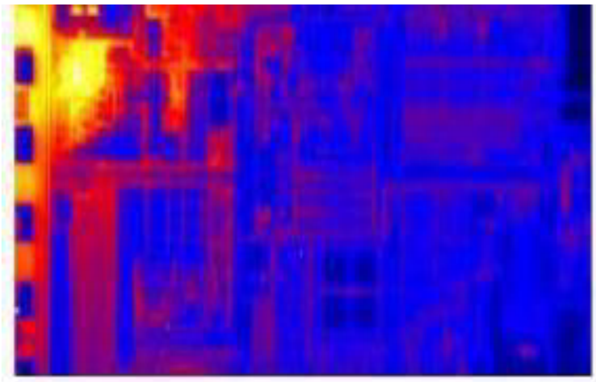

Fig. 3. Amplitude image

- Phase image [Fig.4]: to measure the depth of the defect

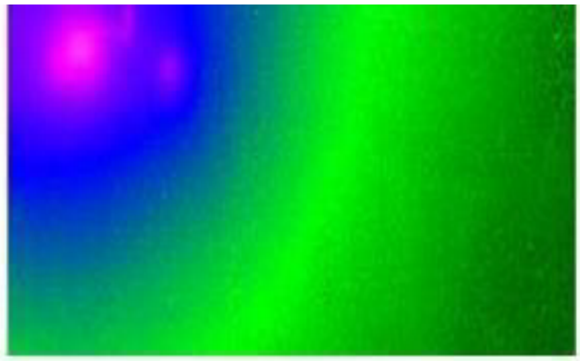

Fig. 4. Phase image

3.3 Algorithm used

Segmentation is the process of delineating an object in an image using the properties of the object. These properties can be edges, texture, intensity variation of pixels within the object, shape, size, and orientation [16].

Segmentation has two purposes, the first is to break down an image into regions for further analysis and the second is to effect a change in the representation of an image for faster analysis. Depending on the application, one or a combination of segmentation techniques can be applied to effectively solve the problem [17].

There are three types of segmentation techniques:

- Segmentation by thresholding.
- Edge detection segmentation.
- Segmentation by region.

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3.3.1 Segmentation by thresholding

Thresholding segmentation algorithms define the boundaries of images that contain solid objects on a contrasting background. This technique gives a binary output from a grey scale image. This segmentation method applies a single, fixed criterion to all pixels in the image simultaneously.

The method consists of selecting a suitable threshold value T, which is a binary image converted from a greyscale image. The advantage of obtaining a binary image is that it simplifies both the data complexity and the recognition and classification process [20].

3.3.2 Edge detection segmentation

This type of segmentation is based on the abstract level of edges and attempts to capture objects by their closed outline in the image. This technique detects both edges and boundaries between objects and the image background. Edges are seen as a sign of a lack of continuity and closure. As a result of this transformation, the edge image is obtained without changing the physical qualities of the main image.

There are several types of edge detection techniques, the most traditional and widely used are those of SOBEL, ROBERTS, PREWITT, the Gaussian Laplacian, and CANNY [**18**].

By implementing this type of segmentation on FPGA circuits, we can make our embedded solution [**21**].

3.3.3 Segmentation by region

In our case we must use region-based segmentation (watershed algorithm) on thermal images. Region-based segmentation treats an image as a composition of a finite number of regions and performs regional statistics that are used for segmentation. The watershed transform is a widely used technique for image segmentation. The intuitive idea behind this method comes from geography. The topographic surface will be slowly flooded, from the lowest regions to the top of whatever is in the watershed. When the waters meet, they build dams. These dividing lines resulting from these multiple floods are the watersheds. The watersheds separate the homogeneous regions, giving the desired segmentation result [**17**].

This technique allows us to locate hot spots in an exact way where there is more useful data to process.

4 Result and discussion

To locate the fault thermally, the heating of the enclosure must be progressive. The setting must be precise and with very small intervals to maintain the initial fault, and not distort the fault location.

Our test was performed on a MOSFET. The device was heated until a hot spot appeared, [**Fig.5**] shows the location of the fault and [**Fig.6**] shows the depth of the fault.

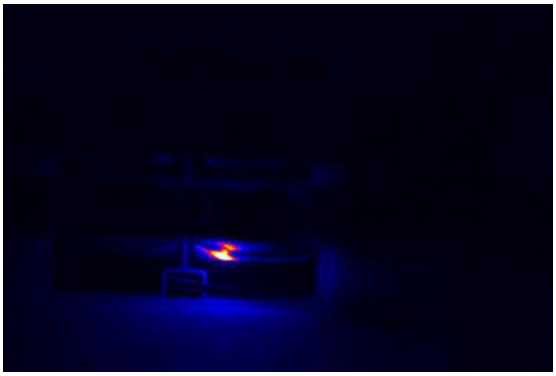

Fig. 5. Amplitude image MOSFET transistorwithout thermal adjustment

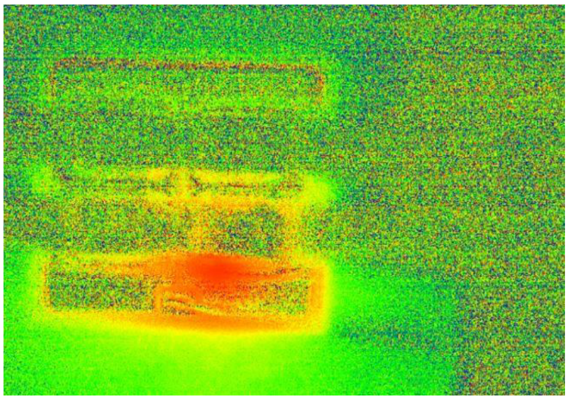

Fig. 6. Phase image MOSFET transistorwithout thermal adjustment

After the acquisition of the two thermal images (amplitude and phase), we found that both images carry significant results, but the analysis of a defect requires thermal images well-adjusted thermally, this explains why we adjusted the intensity of the thermal images [**Fig.5**] and [**Fig.6**] to obtain [**Fig.7**] and [**Fig.8**]

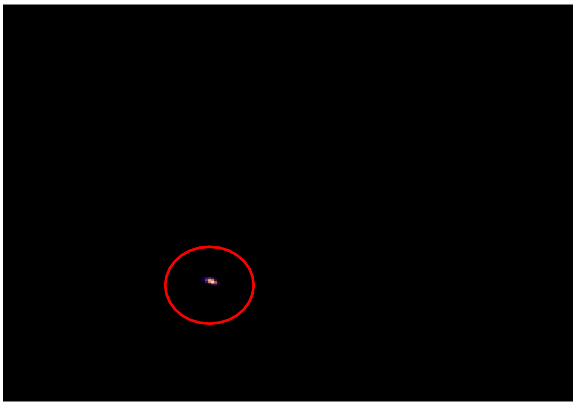

Fig. 7. Amplitude image MOSFET transistorwith thermal adjustment

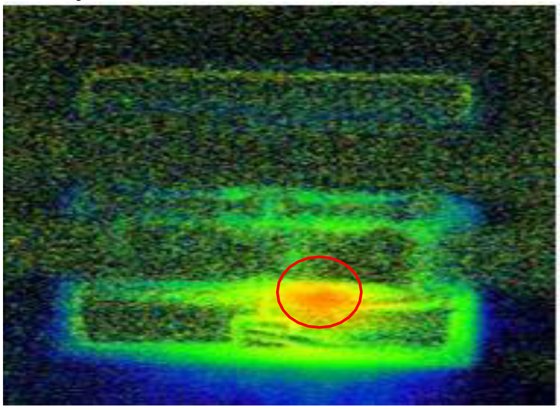

Fig. 8. Phase image MOSFET transistorwith thermal adjustment

After the localization of the defect on the case in question, we find that the heating is low which makes the localization of the defects in a more detailed way is very delicate, this is the reason why we before proceeding to a chemical opening of the part, plus the metallization of the part to be detectable by X-rays, thereafter we take the radiographic image (X-Ray) [Fig.9] of the component, to merge the two images: the image of amplitude and the radiographic image (X-Ray) to localize the defect [Fig.10].

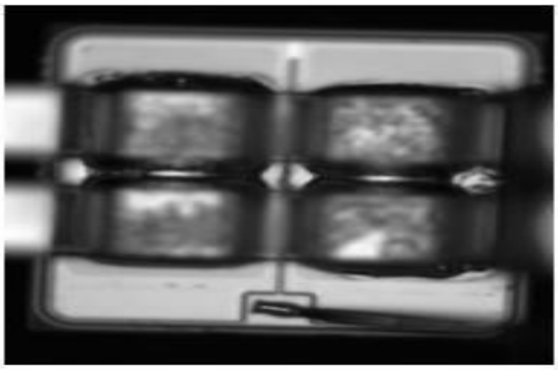

Fig. 9. Image X-Ray Transistor MOSFET

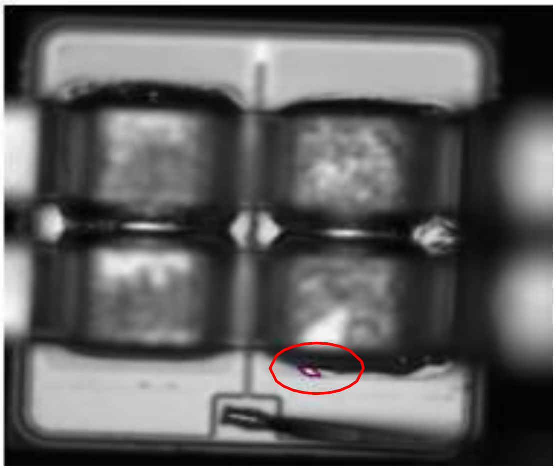

Fig. 10. Image obtained by the merge function The

analysis of the thermal image merged with the X-Ray image in [Fig. 10] allows us to judge the existence of a problem in the DIE, this problem means that the component is highly stressed with physical quantities (voltage, current) that exceed the capabilities of the package on the one hand.

On the other hand, the component can be used in conditions of temperature and humidity higher than the capacities of the case, which generates the birth of a crack DIE, in addition to the beginning of current leakage, and to ensure that we are facing a problem of leakage current we can rely on an equipment curve tracer which traces the graphs (voltage and current).

To go further in the analysis of the defect one can turn to other destructive inspection techniques such as a micro-section of the area where the **HOT SPOT** is located, then take an image based on a Scanning Electron Microscope (**SEM**) [Fig. 11] and Energy Dispersive X-Ray (**EDX**) analysis [Fig. 12] to know the type of alloys to judge if it is oxidation or not.

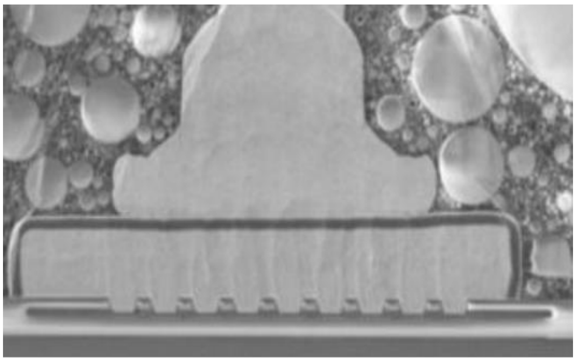

Fig. 11. Image obtained by SEM

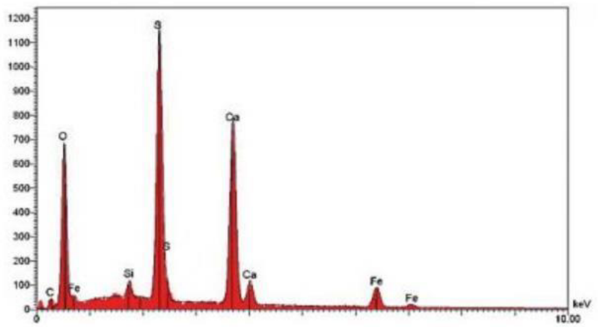

Fig. 12. EDX analysis

5 Conclusion

The objective of this paper is to present an image processing technique for locating one of the defects of a MOSFET transistor that has a HOT SPOT defect, based on thermal images and segmentation algorithms, we have shown the different possible cases of defects that can cause the HOT SPOT.

Recently, cycling sport has experienced another method of doping, but this time we are talking about technical doping based on the integrity of a small lithium battery with a power of 36 watts, which powers an electric motor coupled to the wheel and all these elements are well integrated or even invisible, so that the only way to detect this fraud is via a thermal image plus the use of segmentation algorithms, and to propose a quantity-based intelligent diagnostic system combining image processing and artificial neutral network to improve the analysis of thermal images and the extraction of maximum information from a thermal image in order to help the cycling organizing committee to judge whether the participant adopts this fraud technique or not.

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