# Detection of surface defects on Dielectrics Materials

**CORTEZ ITALO J.[1], CALDERA MIGUEL J.[2], RAMÍREZ POPO JESÚS A.[2] CORTEZ LILIANA[3]**
**Noninvasive Methods Laboratory for Stomatologic Diagnosis**
**Faculty of Stomatology, Benemérita Universidad Autónoma de Puebla**
**31 poniente 1304, Col. Volcanes, Puebla, Pue.**
**Tel. : (01)(222) 229-55-00 Ext. 6405, Fax: (222) 229-55-27**
**[1] Faculty of Stomatology, [2] Faculty of Computer Science, [3] Faculty of Electronics**
**MÉXICO**

*Abstract:* The present work shows a methodology for detection of defects on mica, which is based on the reflectometry method. This prototype is made up of: a tracto transmitter and receiver (T-R), placed on an automatic mechanism to make a surface sweeping and in this way to acquire the data in a computer by an acquisition data card based on the microcontroller PIC 16F877. The data acquired is stored in a matrix form, to which a processing to make the conversion of an RGB image to a scale of grays is applied. Starting from this data a representation in three dimensions is done using topological metrics to do a third dimension reconstruction of the material ruggedness, with which the defects found on the ruggedness of the dielectric material and its characteristics of initial position, final position, may be observed.

*Key Words*: Reflectometry, Topological Metrics, Interpolation, Detection of Defects, Dielectrics.

## 1. INTRODUCTION

Dielectric materials such as: ceramics, wax, mica, etc., are used as insulators, specially in the industry [1]. These materials, even tough they seem to be smooth, they may have defects or impurities that cannot be detected at first sight, therefore it is necessary to know if the dielectric material has some defect [2]. Under defectoscopy, there is not an adequate development in diversity of solutions for materials so the defect analysis on dielectrics is done using methods such as X rays, ultrasound, etc.[3].
In this work a detection methodology for defects on the surface of the mica is shown.

## 2. DEVELOPMENT

The ruggedness analysis on the surface of dielectric materials is based on the reflectometry method. The system developed consists of an automatic mechanism which makes a sweeping on the surface and to the acquired data a processing is applied to make the conversion to an RGB image in a scale of grays. To this image a treatment of digital images is applied to eliminate outlier data or data with noise, to this new data a reconstruction processing in three dimensions is applied to generate an image of the material topology in order to detect the defects.

### 2.1 Data Acquisition.

The analysis is performed using the reflectometry method, which consists on making a light ray to fall on the surface and through a receiver the light reflected is taken. In figure 1 the method of geometric distribution is shown, where the angles for the transmitter and receiver as well as the distance between the tracto transmitter receiver and the surface are calculated.

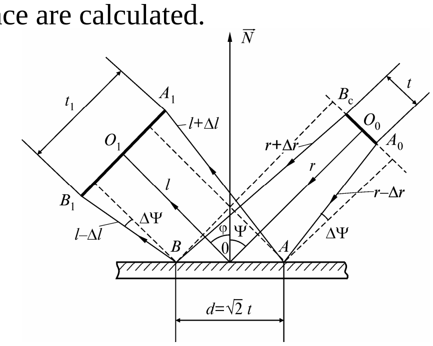

Figure 1. Geometric distribution of the device

Starting from figure 1 you get the luminosity equation of the answer that is given by (1):

$$E = \frac{I_0 \cos\psi}{r^2} \qquad (1)$$

where:

$I_0$ Intensity of the light ray fall.

$r^2$ Distance from the transmitter to the surface.

$\psi$ Transmitter inclination angle regarding the surface.

You also get the intensity equation of luminosity reflection (2) [4]

$$\Phi = \bar{\rho} I_0 S \frac{2(r+l)C}{2r + d\cos\psi}\left[1 - \pi^2 h^2 \cos\psi \left(\frac{1}{\lambda_2^2} - \frac{1}{\lambda_1^2}\right)\right] \tag{2}$$

where:

$\lambda_1$ $\lambda_2$ Border values of the falling beam spectrum.

$\bar{\rho}$ Polarization degree.

Then it is determined the equation (3) in order to convert to voltage

$$U = k\bar{\rho} I_0 S (C_1 - C_* h^2) \tag{3}$$

where:

$$C_1 = \frac{2(r+l)C}{2r + d\cos\psi} \quad C_* = C_1 \pi^2 \cos^2\psi \left(\frac{1}{\lambda_2^2} - \frac{1}{\lambda_1^2}\right)$$

$k$ Transfer coefficient of the converter.

$h^2$ Ruggedness.

With (1), (2) and (3) a software to obtain the optimum angles of the transmitter and receiver was developed, and also the distance between the tracto T-R and the sample. As a result the software produced 20º for the transmitter and 20º for the receiver and a distance of 2mm regarding the sample.

The sample was placed on an automatic mechanism which makes a sweeping on X, Y axis, the receiver is connected to a data acquisition card that is based on the microcontroller PIC 16F877. This one is connected to a computer to store the data generated by the optoelectronic system. The data storage is made under a matrix form, which is binarized and represents the ruggedness image of the material. This matrix is converted into an RGB matrix up to 256 colors in a scale of grays.

### 2.2.1 Noise Elimination or Outlier Data

To the digital image obtained in a scale of grays, a transformation filter was applied in the frequency domain. This filter is the Fourier Transform which was modified for the image since a sequence of $x(n_{1,} n_2)$, results in (4).

$$X(k_1, k2) = \begin{cases} \sum_{n1=0}^{N1-1}\sum_{n2=0}^{N2-1} x(n_1, n_2) e^{-j(2k/N_1)k_1 n_1} e^{-j(2\pi/N_2)K_2 n_2} & 0 \le n_1 \le N_1 - 1,\ 0 \le n_2 \le N_2 - 1 \\ 0, enotrocaso \end{cases} \tag{4}$$

Next a transformation of columns and rows into a series of frequencies is made [4].

This image is cleaned of outlier data, if they could exist later an inverse Fourier Transform is applied in order to generate a new modified image as shown (5).

$$x(n_{1,} n_2) = \begin{cases} \frac{1}{N_1 N_2} \sum_{K_1=0}^{N_1-1}\sum_{K_2=0}^{N_2-1} X(k_1, k_2) e^{j(2\pi/N_1)K_1, n_1} e^{j(2\pi/N_2)k_2 n_2} & 0 \le n_1 \le N_1 - 1, 0 \le n_2 \le N_2 - 1 \\ 0, enotrocaso \end{cases} \tag{5}$$

To the image obtained the Butterworth filter of level 2 is applied to eliminate the noise.

### 2.2.2 Interpolation

To generate the ruggedness topology of the dielectric material an interpolation is done by topological metrics that is why the following is done:

1) Discard all vectors to which the attributes are missing, this is only viable when the number of vectors with absence of data is small compared with the total of vectors.

2) For the i-esima component find the medium value with all vectors available and substitute this value in vectors where this component is missing.

3) For all component pairs $x_i$, *and* $y_i$ *of vectors* $\boldsymbol{x}$ and $\boldsymbol{y}$ define $b_i$ as,

$$b_i = \begin{cases} 0, \text{as much } x_i \text{ as } y_i \text{ there is no similiraty} \\ 1, \text{in case contrary} \end{cases}$$

Then, the proximity between $\boldsymbol{x}$ and $\boldsymbol{y}$ is defined as (6):

$$\varphi(x, y) = \frac{l}{l - \sum_{i=1}^{l} b_i} \sum_{\forall i: b_1 = 0} \phi(x_i, y_i) \tag{6}$$

where: $\phi(x_i, y_i)$ indicates the proximity between the two scales $x_i$ and $y_i$. $\phi(x_i, y_i) = |x_i - y_i|$ [5].

## 2.2 Data treatment

The RGB image represents only the data under tones in the scale of grays in two dimensions, to observe the edges, the structure form of the sample and the ruggedness tones.

$\phi(x_i, y_i)$ of the scales $x_i$ and $y_i$. $\phi(x_i, y_i) = |x_i - y_i|$ [5].

### 2.2.3. Ruggedness Reconstruction

Reconstruction was made using topological metrics. This method consists in getting the distance of the chess board, $D_8(p,q) = Mqx\{|x-s|,|y-t|\}$, the maximum metric of the 8 neighbors, this value is added up to get the maximum value and it is subtracted to get the minimum value of point (x,y) rank. This value is compared with the distances of the 8 neighbors, and if it is inside of the maximum and minimum rank a vertex is traced. All of this is done for each matrix value of the linealized data (6, 7).

## 3. EXPERIMENTS AND RESULTS

The experiment was performed with a piece of mica of 3 x 2 x 2 cm.. It was started sweeping on the defectless sample with the E-R tract (see fig. 2). Then a sweeping was made on the same sample but now with a defect of 150 microns of thickness (fig. 3). The result was compared under a metallographic microscope through which the ruggedness and the defect could be observed.

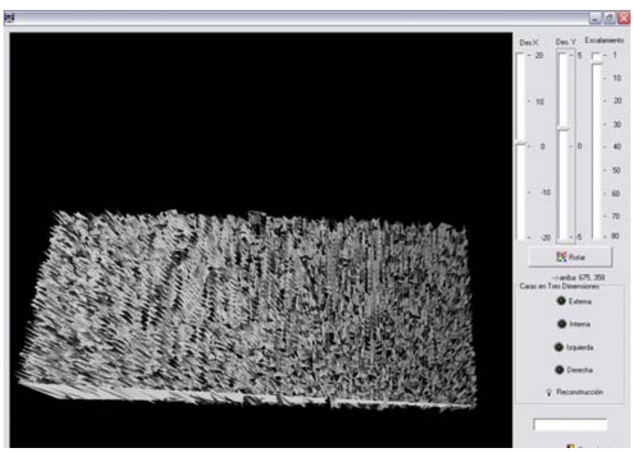

Figure 2. Mica before the defect

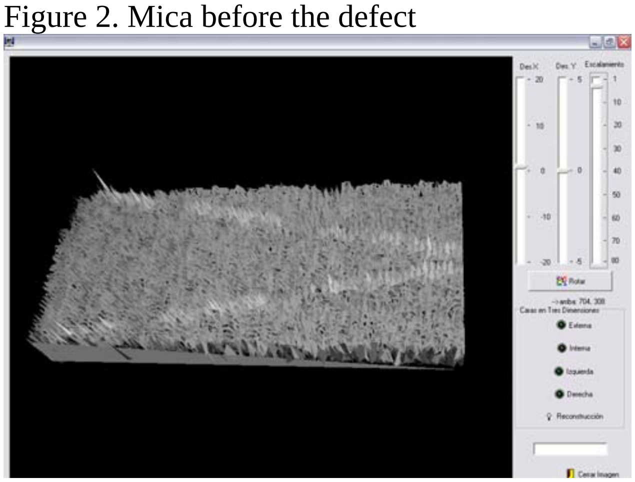

Figure 3. Mica after the defect

## 3 CONCLUSIONS

It was observed that the surface in its natural state it seems smooth but it has a variant ruggedness and after introducing the data to the software with the defects previously made, this could be diagnosed. Therefore, the contribution is the methodology as well as a software that allows matching the defects, also the prototype that is based on the noninvasive and no contact technique.

## 4 ACKNOWLEDGMENTS

This work was made with funding of the Public Education Secretary and the Improvement Program for the Teaching Staff whose support we thank them.

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