

Use of Labview Software for Measuring the Change of Surface Potential of Thin Dielectric Layers

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Summary

Monitoring and control of measurement processes in many devices require transmission of information and interaction with the physical process in object. One of the methods for contactless measurement of surface potential of thin dielectric layers during their charging as well as during spontaneous discharge is fast mechanical movement of the layer from the ion generator to the gauge electrode. For this purpose a process control system was designed and developed. Presented is a computing-measuring device consisting of the electro-mechanical measuring block, of the converter “analog-digital and digital-analog”, and of the control program using LabView software. The paper presents the results of the development of specific hardware and software to monitor the measurement process.

Key words:

LabView, Real Time Monitoring and Control, Method of Dosed Charging.

1. Introduction

The measurement of surface potential of the layer, as well as its behavior over time, is one of the fundamental characteristics of thin dielectric layers.

The testing process of dielectric layer consists of two stages: transfer of charge to the layer by placing it in an electric field (electrostatic induction), and the spontaneous change in charge after removal of the electric field, or forced discharge. Based on these data the usefulness of these layers to the appropriate application is determined [2, 3], e.g. the use in electrical engineering, microelectronics, and especially during testing and production of photoreceptors for use in laser printers. It is important to stress, that to obtain these parameters the measurement process itself should be contactless (non-destructive measurements) [1, 4, 6, 7]. During the charging the layer should be placed in the field of electrical charge produced by a strong electric field of $10^{(3-4)}$ V/cm (corona discharge), and when measuring the resulting surface potential the strength of the electric field reaches $10^{-(3-4)}$ V/cm (electrostatic induction). Therefore, the intensity of the electric fields during these two processes differs by 6–8 orders. With this difference in field strength it is impossible to measure the potential of layer surface during the charging of the layer. A compromise solution in this case is the separation of these two processes in time. The

separation is done using a rotating disk with an embedded test layer [5]. Proper computer program performs functions of processing, reading, formation and saving the data in a file. As the measurement is multifunctional, the speed and the accuracy of basic functions largely depend on the algorithm of the used program.

This article describes a device which is used with LabView software and purposely developed application. This application controls the measurement process and serves as the user interface which collects, creates and stores measurement data files. Measurements data include: time of measurement period, value of the charge transferred to the layer, value of the surface potential of the layer obtained from the transferred charge, and value of the calibration potential. This gives the possibility to measure the change of surface potential of the layer depending on the charge transmitted to the surface, the surface potential changes as a result of spontaneous or forced discharge of the layer and the value of the residual potential [1–5].

2. Measurement of Electrical Parameters using the Method of Dosed Charging

The block diagram of the device for measuring the surface potential of the layer during its charging and spontaneous discharge is shown in Fig. 1 B1 – electro-mechanical part, B2 – electronic part, NI – module NI USB-6221 BNC 16-Bit, 250 kS/s and PC.

The structure diagram of the device for measuring the surface potential of the layer is shown in Fig. 2 [5].

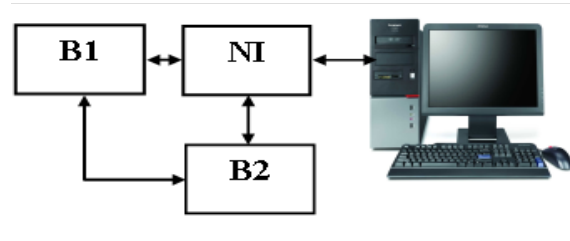


Fig 1 Block diagram of the measurement device. B1 – electro-mechanical part, B2 – electronic part, NI – module NI USB-6221 BNC 16-Bit, 250 kS/s and PC.

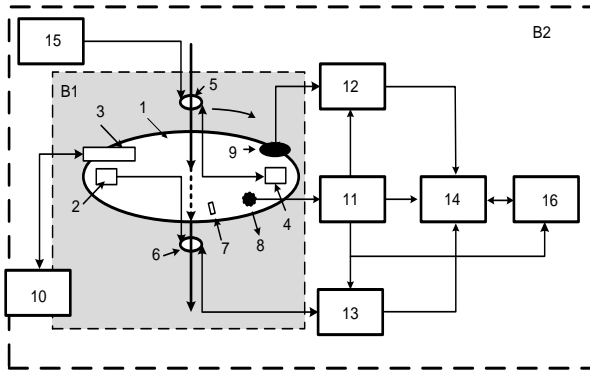


Fig. 2 The structure diagram of the device for measuring the surface potential of the layer.

1 – rotating disk, 2 – test layer, 3 – ion generator, 4 – conductive substrate (equivalent the layer), 5 – collector of equivalent layer, 6 – collector of test layer, 7 – sensor pointer, 8 – sensor of synchronizing device, 9 – measuring electrode of electrometer, 10 – high-voltage source, 11 – synchronizing device, 12 – electrometer, 13 – gauge of transmitted charge, 14 – external controlled converter NI USB-6221 BNC 15 – calibrated voltage source, 16 – PC.

A key part of the device is a rotating disk, on which a test layer 2 and the equivalent of test layer 4 are placed. The equivalent of test layer is made in the form of a conductive plate that is connected with the collector 5 to the voltage source 15. Disc 1 with the test layer 2 and with the equivalent of test layer 4 periodically moves under the ion generator 3, and the measuring electrode 9 of electrometer 12. On the disk a moving part of the sensor 7 is placed, which moves under the fixed part of the sensor 8. The conductive substrate of the plate 2 through the collector 6 is connected to the charge gauge 13. On the stationary part of the block B2 the following elements are placed: a source of high voltage 10 that powers the ion generator 3, synchronizing device 11, gauge of the transmitted charge 13, the external controlled converter NI USB-6221 BNC 14, and the source of calibrated voltage 15, PC 16.

The disk rotates in the indicated direction and the test layer 2 periodically moves under the ion generator 3, charging accordingly, and then under the measuring electrode 9 which is connected to the controlled electrometer 12 [3, 5]. The sequence of operations performed during the measurement using device 2 is shown in Figure 3 as the time diagram of the periodic charging of the dielectric layer, measurement of the deposited charge Q_s on the surface, the measurement of the resulting surface potential U_s from the deposited charge Q_s and calibration potential U_s .

As shown in the time diagram of the measurement process, the whole device is synchronized by sync pulses S_i (Fig. 3) of sensors 7 and 8 (Fig. 2). Simultaneously the time of spinning period of disk 1 is measured in seconds. The

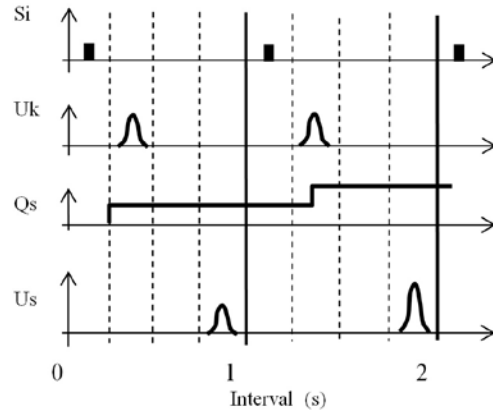


Fig. 3 The time diagram of the periodic charging, measurements of deposited charge and the resulting surface potential of dielectric layer.

S_i – sequence of synchronizing impulse, U_k – calibration voltage; Q_s – charge deposited on the layer surface; U_s – surface potential of the layer.

conductive substrate 4 with a known potential (equivalent to a surface potential of the test layer) periodically moving under the measuring electrode produces the sequence of bell-shaped calibration impulses U_k at the output of the electrometer 12. The computer program determines the maximal surface potential in relative units and specifies the amount of charge transferred to the surface layer, also in relative units. The equivalent of measuring layer is necessary for scaling the measurements of the potential and for determining the value of the potential in absolute units.

3. Process Control Program – an Application for Real Time Monitoring and Control

Before the measurement the test layer 2 (Fig. 2) is placed on the spinning disk 1 in the measuring block B1 (Fig. 2) and the conditions of the testing of layer are settled. The following parameters are set: supply voltage of ion generator, disk rotation velocity, sensitivity of electrometer and sensitivity of charge gauge 13 (Fig. 2). Then the disk starts to rotate and the period of rotation is settled. After the desired rotation velocity is reached, the whole process of measurement is started by clicking the “START” button on the operator interface (Fig. 4).

A LabView 8.5 programming package was used for registration and visualization of measurement results [8]. Using this package a program for data logging and displaying was designed. This program records all the measurements, processes and displays them, and at the end of the registration stores them in a data file for further processing.

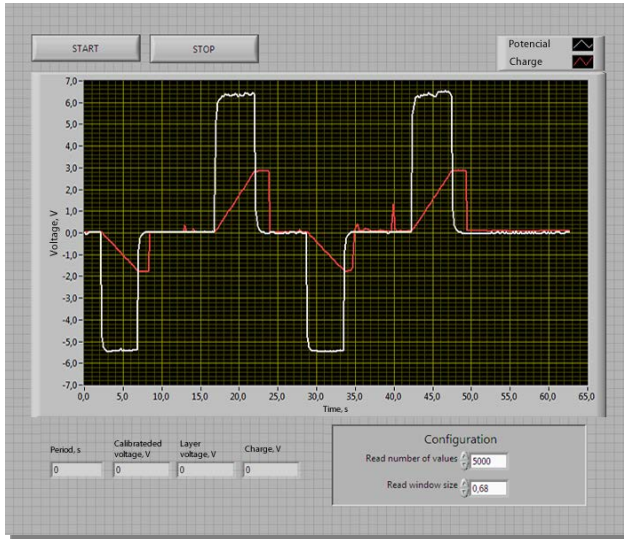


Fig. 4 Program window (Operator's interface).

The program window is shown in Fig. 4. The program allows the user to start and to stop the measurement by clicking "START" and "STOP" buttons accordingly. After the completion of the measurement, the user is offered to save measurement data in a separate file for further processing. Program represents data of each measurement in real-time both graphically and numerically. Graphic display of measurement data allows to see decay (potential and deposited charge), and the numbers – the precise values of the last measurement data (period, calibration and surface potential, and deposited charge). The program allows user to set two operating parameters: 1 – number of values to read; 2 – part of the period, in which program reads values (Read window size). Both of these parameters directly affect the speed of the program, because after each measurement period the program has to calculate the measurement results. With increasing the number of read

values, more computer resources are needed for the calculation, but greater measurement accuracy can be achieved. The second parameter is required in order that the program takes the time to calculate the results and prepare a digital-analog converter for the next measurement. If the data is recorded in the whole period, then the next period will be skipped, because the analog-digital converter will be not ready to read new data.

After the user presses the measurement beginning's button "START", the measurement program starts to act according to the algorithm in Figure 5.

The first step is "Measuring of the measurement period". Program measures the measurement period, which is used for setting the data read rate. This value and the read values number entered by user are transmitted to the analog-digital converter that it can complete the measurement in the right time, when the disk fully rotates. Disk rotation (measurement) period is calculated by a synchronization signal received from the sensor.

In the second step, "Initialization of the measuring parameters" the program initializes arrays needed for the measurement, and sets the parameters of the digital-analog converter. Four arrays are initialized, in which all the values collected during the measurement will be stored: time S_i , charge Q_s , surface potential U_s and calibration potential U_k , in relative units. Next the parameters of the measurement equipment, namely the digital-analog converter, are set. Two converter channels are used for the measurement, one for measuring of potentials U_s and U_k , second for measuring of charge Q_s . A finite number of values is used for the measurement, therefore we define that number (read values number) and the speed of measurement (data read rate), so that the measurement would last exactly one period. Values are not recorded in the whole period; otherwise there would be no time for value calculation and for preparation of the converter for the next measurement. The parameter "Read Window Size"

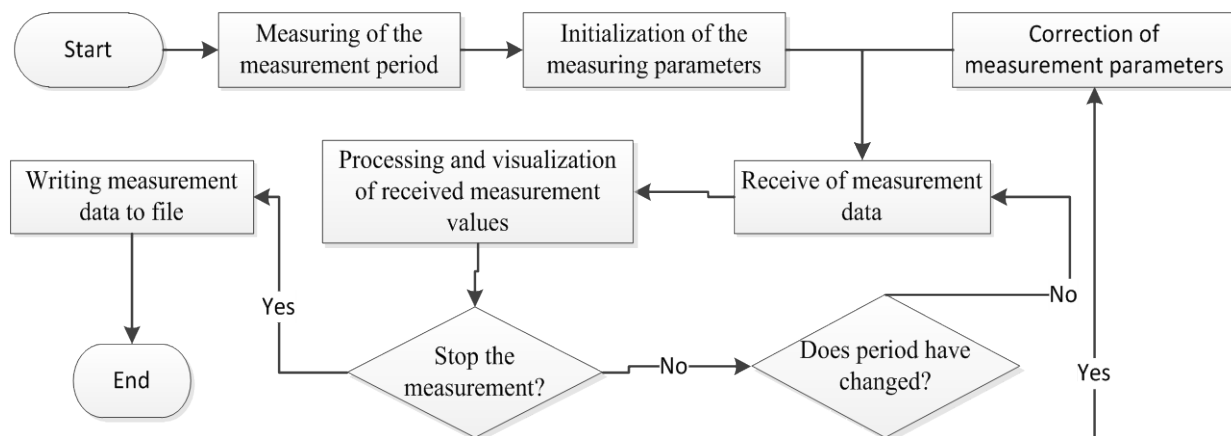


Fig. 5 Algorithm of the measurement program.

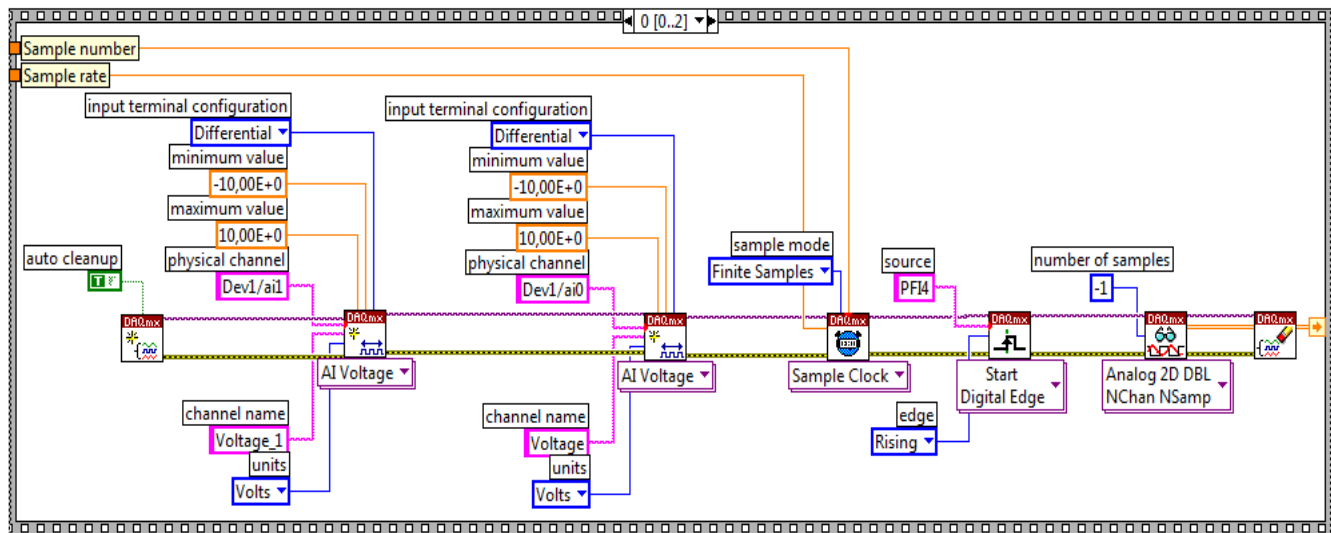


Fig. 6 Initialization of measurement, and receive measurement data.

determines what part of the period is registered.

Typically, this value is set at 0.68, because the key measurement values are obtained at the beginning of the period. Read values number influences the speed of further calculations, so it must be chosen carefully. Of course, the higher it is, the higher measurement accuracy can be expected. Using these values the program calculates the required data recording speed and forwards it to the converter, that it would be ready, as soon as a synchronization signal indicating a need to start the measurement is received. Then the third step “Receive of

measurement data” is executed (Fig. 6).

In the fourth step, “Processing and visualization of received measurement values” the program processes the received data. The data from the analog-digital converter are received in a two-dimensional array called “Measurement data”, where different channel values are separated by channel’s index. Therefore, at the beginning the program separates the charge values from the surface potential values. In our case, the charge values are with index “1”, and the surface potential values with “0”. Then the program works with separated charge and surface

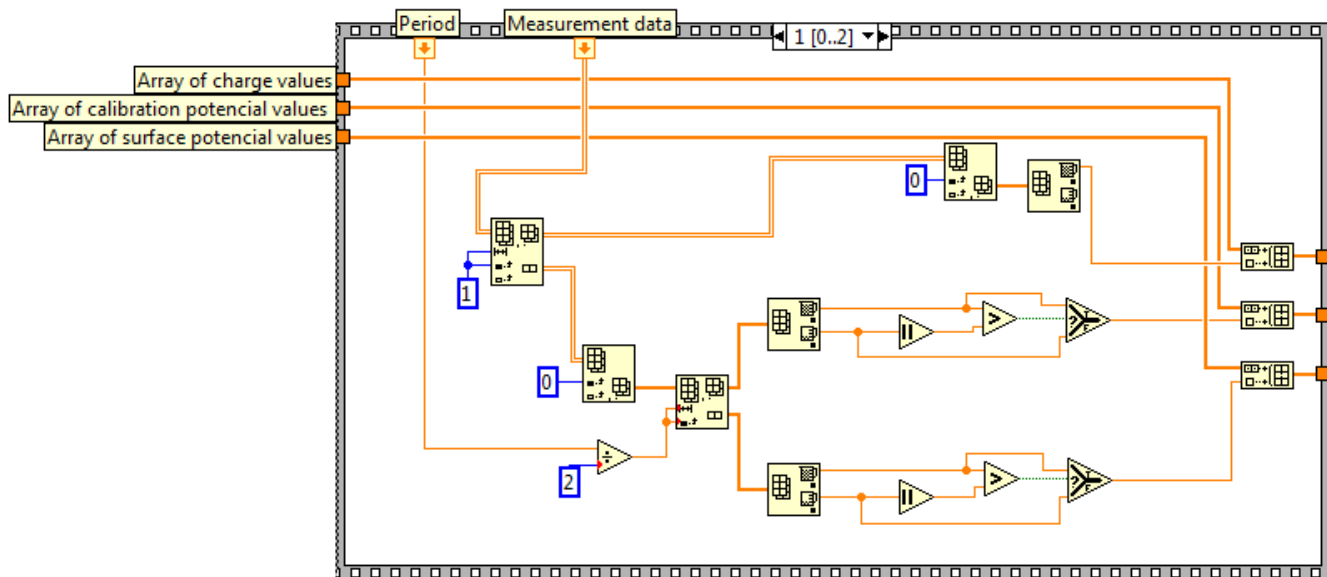


Fig. 7 Processing of array of measurement data.

potential values. From all charge values the program selects the maximal one, which shows what charge was deposited during last period, records it in the array of charge values, and presents on the graph. The program divides the array of potential values into two parts, since in

Table 1: File of formed data of measurement process.

| t s | Us _{r.u.} | Uk _{r.u.} | Qs _{r.u.} |
|-------|--------------------|--------------------|--------------------|
| 0,000 | 0,005 | 2,225 | 0,007 |
| 0,208 | 0,003 | 2,221 | 0,002 |
| 0,416 | 0,001 | 2,202 | 0,001 |
| 0,625 | 0,005 | 2,222 | 0,001 |
| 0,833 | 0,006 | 2,215 | 0,004 |
| 1,041 | 0,123 | 2,210 | 0,014 |
| 1,249 | 2,594 | 2,194 | 0,048 |
| 1,458 | 3,370 | 2,227 | 0,090 |
| 1,666 | 3,593 | 2,229 | 0,131 |
| 1,874 | 3,759 | 2,223 | 0,173 |
| 2,082 | 3,778 | 2,236 | 0,213 |

the first part the values of calibration potential and in the second part values of the surface potentials of the test layer are recorded in relative units. Then the program determines the maximum value for each part separately, and records them into the dependent arrays, and also presents on the graph. All this is represented in Fig. 7.

In the next step “Stop the measurement?” the program checks whether the user wants to stop the measurement, by pressing the “STOP” button. If no, the measurement is carried out once more, if yes, then all values stored in arrays are put down to the data file for further processing of the results. In the case of repeated measurement, the program checks whether the disk rotation period has changed, for that the last measurement period is used. In case of change the speed of value registration is set anew. For the control of the measurement process, it is presented graphically on the screen of user's interface. The obtained measurements data are formed in the file. An example of eleven periods of such formed file is shown in Table 1. The measurement can be arbitrarily long, depending on the duration of the process or on the demand. The data file of cited here measurement process contains 112 measurement periods.

On the basis of formed file (Table 1) the time dependence of changes in the surface potential of the layer as a result of a deposited charge during its charging and during its spontaneous discharge is illustrated in Figure 8.

On the Figure 8, based on data from the column Us_{r.u.}, we obtain a graph Us (1) showing increase of the positive surface potential of the layer during its charging by the positive charge Qs (2). Sections 1a – spontaneous discharge and 1b – forced discharge of layer. Graph 4 shows increase in the negative surface potential of the layer – Us during its charging by the negative charge Qs (5). Section 4a – spontaneous discharge and 4b – forced

discharge of layer. Relation 3 – calibration potential Uk. Surface potential of the layer U (2) in absolute units in volts is determined by the formula: $U = U(\text{plate}) / Uk_{r.u.} \times Us_{r.u.}$. The value of U (plate) can be from 10 V to 1 kV. In this example the scaling voltage was 300 V. The absolute

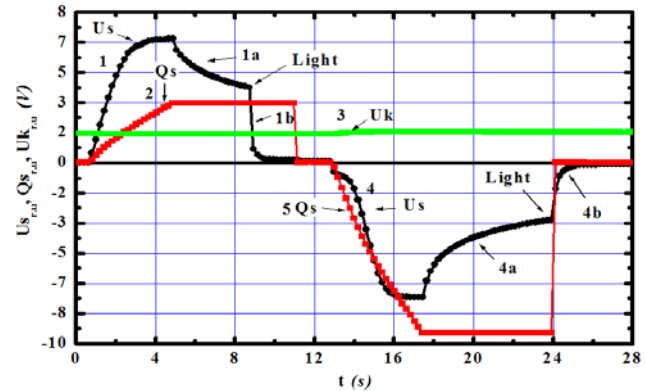


Fig. 8 Time dependence of changes in surface potential of the layer during its charging and during its spontaneous discharge.

1 – dependence of the surface potential Us during charging by positive charge Qs (2) and during spontaneous (1a) and forced (1b) discharge, 4 – the dependence of the surface potential Us during charging by negative charge Qs (5) and during spontaneous (4a) and forced (4b) discharge, Uk – calibration potential.

value of the charge transferred to the layer is defined as the factor of the equivalent load capacity of the meter and the voltage at its output.

Conclusions

Presented computing-measuring device with process controlling LabView software gives wide possibilities of measurements by the proposed algorithm [2]. LabView software is a much more transparent and faster than others [1, 5]. The applied external “analog-digit and digit-analog” converter of type NI USB-6221 BNC 16-Bit, 250 kS/s M Series made by company “National Instrument” is connected to a PC via USB and works well with different types of computers. Such a device is capable up to ten measurements per second. The measurement made in the article has five measurements per second, measured charge ranges from 10^{-8} do 10^{-4} C and the range of surface potential is from 1 V to 3 kV. Based on these data it is possible to specify the capacity, the resistance of the film during its charging as well as during the spontaneous discharge. Based on these data the conclusion can be drawn about the properties of layer and the possibility of its application.

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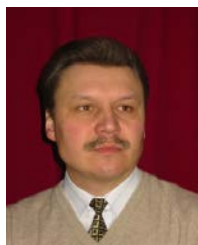
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