

WEB APPLICATION FOR HIGH ACCURACY MEASUREMENT OF VOLT-AMPERE CHARACTERISTICS

Abstract. Web application is described that allows, by scanning digital images of analog oscillograms of voltage and current pulses, to measure with high accuracy the volt-ampere characteristics of semiconductor materials at high electric currents. The application allows measuring voltage and current with a relative error that does not exceed $\pm 1\%$.

Keywords: web application, digital image, voltage-ampere characteristic, impulse test, analog oscillogram.

Statement of the problem and purpose of research. When pulse tests of semiconductors in the region of strong electric currents, it becomes necessary to measure their volt-ampere characteristic (VAC). For this purpose, it is convenient to use single exponential voltage pulses, which provide change of the voltage over a certain range of values. This makes it possible to test a section of volt-ampere characteristic in a certain current range [1]. As work [2] shows, it is possible to measure with high accuracy the parameters of electrical signals using for this aim the digital images of analog oscillograms obtained by a digital photo camera. It is known, that unlike digital oscilloscopes analog oscilloscopes register oscillograms of electrical signals directly, without performing preliminary digitization of signals using an analog-to-digital converter. In the case of digital images of analog oscillograms, the digitization of visual information is carried out using a digital photo camera. With a high resolution of such camera, it is possible to ensure high accuracy in measuring the parameters of digital image objects, according to the data of scanning their coordinates, since the absolute scanning error is ± 1 pixel. The estimates carried out in [3] showed that the relative error δ for determining of the instantaneous voltage values using the scan data of digital images of analog oscillograms is determined by the ratio:

$$\delta = \pm \frac{4}{|y_0 - y_i|} \cdot 100\%, \quad (1)$$

where y_0 is the coordinate of the digital image of oscillogram corresponding to zero voltage; y_i is the y coordinate of the point of the digital image of oscillogram were measurement takes place.

From expression (1) follows, that the relative measurement error of instantaneous voltage does not exceed $\pm 1\%$ if the resolution of a digital photo camera provides the value $|y_0 - y_i| \sim 10^5$.

The purpose of this work is to create a web application by the means of languages HTML, CSS, JavaScript and the Canvas technology, which allows high-precision measurements of volt-ampere characteristics by scanning digital images of analog oscillograms of voltage and current pulses.

Major part. To measure the volt-ampere characteristic, one can use the oscillogram of voltage and current pulses, recorded using an analog storage double-beam oscilloscope. In the case when such oscillogram is presented in the form of a digital image, software is required to perform scanning and process the scan data.

Such software can be implemented on the basis of an algorithm consisting of the following stages: 1). Loading a digital image of oscillogram into a browser window; 2). Input of the initial data: the thickness of measured sample L , the area of electrodes S , resistance of the precision resistor R used to register the current; 3). Determination of the scale of voltage M_{cU} and current M_{cI} of a digital image of analog oscillogram; 4). Determination of coordinates y_{0U} and y_{0I} of the zero lines of the oscillogram for voltage and current pulses, respectively; 5). Scanning the coordinates (y_{iU}, x_i) , (y_{iI}, x_i) for the voltage and current pulses lines in the oscillogram; 6). Calculation based on scanning data of instantaneous values of electric field strength E_i and current density J_i according to the formulas [3]:

$$E_i = \frac{1}{L}(M_{cU}(y_{0U} - y_{iU}) - M_{cI}R(y_{0I} - y_{iI})), \quad (2)$$

$$J_i = \frac{M_{cI}}{S \cdot R}(y_{0I} - y_{iI}), \quad (3)$$

as well as measurement errors δ according to formula (1); 7). Results output.

The algorithm described above is implemented using the languages HTML 5, CSS 3, JavaScript and the Canvas technology. The software environment for the program executing is Internet browsers.

The program interface was created using HTML 5 and CSS 3. This interface contains explicit and hidden blocks of toolbox serving for processing digital images, as well as blocks of instructions to the user that open for different processing stages. Explicit toolbox blocks are constantly displayed on the web page. Such blocks in-

clude the coordinate navigator of the current position of the mouse cursor in the upper right corner of the browser window (Fig. 1). For control of this block the program script is used that action at "mousemove" event. To upload digital images, a block with the heading "Image upload" is used. This block contains a form field of the "file" type and "Download" button (Fig. 1). Using a form field of the "file" type, user selects a digital image file and uploads it to the browser window. This is provided by the "change" event and a script with the "FileReader" object. The "Download" button is needed to embed the image into the canvas. Using the canvas makes it possible to visually display the scan results using vector graphics.

Block for the digital images processing under the heading "Block of processing" contains four buttons and an area into which hidden blocks are displayed for different stages of the processing algorithm. Pressing the button "Initial data" opens a block with form fields for entering the initial data of program. The scanning of pulsed signals on the digital image of oscillogram begins with a voltage pulse. After its completion, user presses the "Scanning U finished" button and starts scanning the electric current pulse. When scanning a voltage pulse, the program script draws a circle with the center having the coordinates of scanning point using Canvas and draws a vertical line of 1 pixel thick from its center. This line allows easily find the points with the same coordinate x_i when scanning a current pulse.

The "Correction" button is used to correct the scan results. When it's pressed, the coordinates of the last scanned point are deleted from the arrays for storage of scan data and the visual image of this point is erased on the canvas. The button of toolbox "Clear" is used to clear the arrays of scan data and fields of the forms for results output. It should be noted that the script executed when this button is pressed do not change the values of the program variables intended for storing the initial data, scales and coordinates of zero lines of voltage and current pulses. This makes it possible to re-measure the volt-ampere characteristic using earlier loaded digital image of analog oscillogram, bypassing the first four stages of the processing algorithm.

The hidden blocks of the toolbox and the user instructions are opened by the program scripts in accordance with the sequence of stages of the presented above algorithm for processing digital images of oscillograms.

Fig. 1 shows the view of the program window after execution. As it is seen, the error in measuring of the electric field strength E is less than $\pm 1\%$, and the error in measuring of the current density J reaches this value and increases as the instantaneous current values approach to zero current line. The zero voltage and zero cur-

rent lines in Fig. 1 are not visible because they are positioned below the bottom side of browser window.

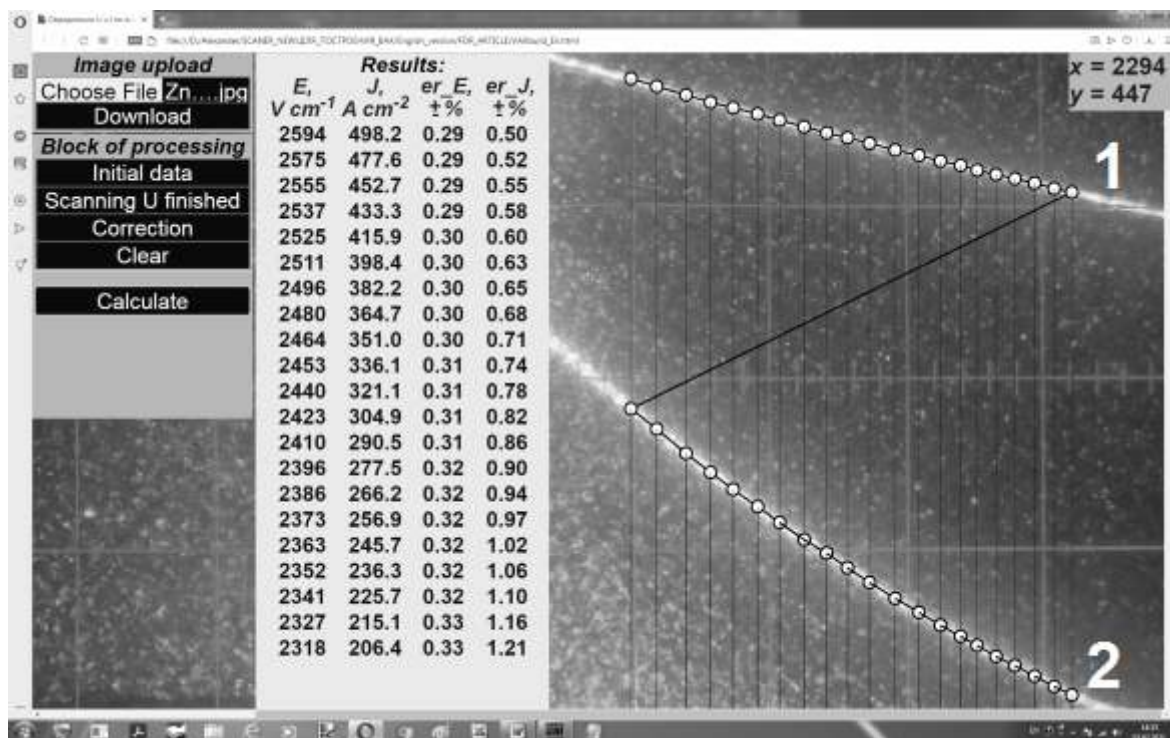


Figure - Program window after execution. Oscillograms of impulses: 1 - voltage; 2 - electric current. Measurements for a zinc oxide varistor ceramics sample

Conclusions. Using the languages HTML, CSS, JavaScript and the Canvas technology, a web application has been created to measure with high accuracy the volt-ampere characteristics of semiconductor materials by scanning the digital images of analog oscillograms. The application allows providing measurements with a relative error not exceeding $\pm 1\%$.

REFERENCES

1. Ivon A.I. Grain resistivity in zinc oxide and tin dioxide varistor ceramics / A.I. Ivon A.B. Glot, R.I. Lavrov, Zhen-Ya Lu // Journal of Alloys and Compounds.–2014, –V.616.–p. 372–377.
2. Ivon A.I. Digitization of oscillograms by raster images for rising of accuracy at signal parameters determination / Ivon A.I., Istushkin V.F. // System technologies.–2017.– issue 1 (108).– p. 37-40.
3. Ivon A.I. Processing of the digital images of analogous occillograms at pulsed measurements / Ivon A.I., Istushkin V.F., RybkaYu.M., Savran S.V. // System technologies.–2020.– issue 1 (126).– p. 54-65.

Received 04.02.2021.
Accepted 06.02.2021.

**Веб додаток для вимірювання з високою
точністю вольтамперних характеристик**

Описано прикладний веб-додаток, який дозволяє шляхом сканування цифрових зображень аналогових осцилограм імпульсів напруги і струму вимірювати з високою точністю вольтамперні характеристики (ВАХ) напівпровідникових матеріалів в області сильних електричних струмів. Цифрові зображення отримують шляхом фотографування осцилограм імпульсів напруги і струму з екрану двопроменевого аналогового запам'ятовуючого осцилографа при дії на зразок досліджуваного матеріалу поодинокого експоненціального імпульсу напруги. Розгортка напруги експоненціальним імпульсом дає можливість виміряти ділянку ВАХ і при зміні амплітуди імпульсу забезпечує вимірювання в широкому діапазоні електричних струмів.

Завдяки високій роздільній здатності цифрової фотокамери і абсолютній похибці сканування ± 1 піксель, забезпечується висока точність вимірювання миттєвих значень напруг і струмів з відносною похибкою не більше ± 1 %. Сканування відбувається шляхом клацання лівою клавішею миші в обраній точці цифрового зображення. При обробці цифрових зображень забезпечується візуалізація точок, де було виконано сканування і можливість корегування даних сканування.

Програма реалізована засобами мов HTML, CSS, JavaScript і технології Canvas. Програмним середовищем для її виконання є браузері мережі Інтернет.

**Веб приложение для измерения с высокой точностью
вольтамперных характеристик**

Описано прикладное веб-приложение, которое позволяет путем сканирования цифровых изображений аналоговых осциллограмм импульсов напряжения и тока измерять с высокой точностью вольтамперную характеристику полупроводниковых материалов в области сильных электрических токов. Приложение позволяет обеспечить измерение напряжения и тока с относительной ошибкой, которая не превышает ± 1 %.

Ивон Александр Иванович - профессор, д.ф.-м.н, профессор кафедры электронных вычислительных машин Днепропетровского национального университета имени Олеся Гончара.

Истушкин Валерий Федорович - доцент, к.т.н., доцент кафедры электронных вычислительных машин Днепропетровского национального университета имени Олеся Гончара.

Рыбка Юрий Михайлович - ассистент кафедры электронных вычислительных машин Днепропетровского национального университета имени Олеся Гончара.

Івон Олександр Іванович – професор, д.ф.-м.н, професор кафедри електронних обчислювальних машин Дніпровського національного університету імені Олеся Гончара.

Істушкін Валерій Федорович – доцент, к.т.н., доцент кафедри електронних обчислювальних машин Дніпровського національного університету імені Олеся Гончара.

Рибка Юрій Михайлович – асистент кафедри електронних обчислювальних машин Дніпровського національного університету імені Олеся Гончара.

Ivon Alexander - doctor of sciences (physics and mathematics), professor of the department of electronic computers of the faculty of physics electronics and computer systems of the Oles Honchar Dnipro National University.

Istushkin Valery - candidate of technical sciences, associate professor of the department of electronic computers of the faculty of physics electronics and computer systems of the Oles Honchar Dnipro National University.

Rybka Yuri - assistant of the department of electronic computers of the faculty of physics electronics and computer systems of the Oles Honchar Dnipro National University.