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SOFTWARE FOR PROCESSING AND ANALYSIS OF EXPERIMENTAL DATA IN RESEARCHING OF GAS SENSORS

Abstract. Representation of structural elements, appearance and use of software for processing experimental data on the kinetics of the response of resistive gas sensors based on the KWW stretched exponential function model algorithm. The developed software allows the use of input data in the form of text files or Excel spreadsheets, which include special applications of measur ing equipment.

When using applications, the application of the concept of using various software packages and environments is most effective for each task of data processing and analysis.

The software allows the subsequent loading of data to measure the kinetic sensitivity of the gas sensor with the fixation of the parameters for measuring the level of its measurement (tempera ture sensor, partial pressure of the gas increase). The processing results can be represented by the dependences of the parameters of the KWW function on the operating parameter.

The application provides services such as data entry using Excel spreadsheet programs; calcula tions in the mathematical package "Mathcad"; test examples of the use of computational algo rithms and the transmission of reference information texts from circulation and the Internet.

Key words: algorithm, extended exponential function, gas sensor, kinetics, response, protection, calculation parameters

Introduction. At present, the development of hardware and software gives the prospect to form a technical and information environment for the development and implementation of intelligent information-measuring systems for non-destructive testing of physical and physicochemical properties of materials [1,2].

Intellectualization of information and measurement systems (IMS) allows expanding the functionality of IMS and increasing the efficiency and accuracy of research and control technology. An urgent issue in this direction is the creation of software for processing experimental data, which includes elements of their analysis in accordance with the existing, usually complex in a mathematical sense, theoretical models.

One of these tasks at the moment is the processing of the analysis of experimental data of measurements of gas-sensitive parameters of semiconductor sensors

in their study and application. The functional characteristics of sensors are determined by the static gas sensitivity (response), the times of detection and relaxation to the initial state and their dependence on the concentration of the active gas and temperature ... One of the directions for obtaining this and additional information is the study of the kinetics of sensor recovery after detection [3,4]. An effective means of obtaining information on the parameters of kinetic processes that determine the features of the electrical conductivity of gas sensors is the analysis of the response kinetics using the phenomenological model of the extended exponential Kohlrausch-Williams-Watts function [5–7].

It should be noted that the solution to this problem is associated with a number of difficulties associated with processing large amounts of data, the need to use complex algorithms and computer technology to ensure acceptable accuracy of calculations, etc.

The solution of this problem at the first stage of application development for the implementation of the algorithm for calculating the parameters of the Kohlrausch-Williams-Watts model for one kinetic dependence of the relaxation of the sensor response after elimination of the active gas was considered in [8]. The next step in the computerization of the processing of several of these kinetic dependencies, which distinguish some parameters of the measurement mode (for example, temperature or partial pressure of the active gas). Its logical result should be certain dependences of the model parameters on the used mode factor and visualized on the screen.

The solution of the problem naturally requires the improvement of the mentioned application by creating software corresponding to the formulated consumer functionality.

Problem statement. The article presents the elements of the structure, user interface and elements of technology for using software with the participation of the user based on a specialized window application. The software is designed to process the experimental kinetic dependences of the response of gas-sensitive sensors, calculate their parameters using the extended exponential function of Kohlrausch-Williams-Watts, determine and visualize the dependence of the latter on the parameters of the measurement modes.

Structure diagram. The software based on the application given in [8] and applied program modules, which are documents of the well-known mathematical package Mathcad and an Excel spreadsheet and has a generalized structure shown in Fig. 1.

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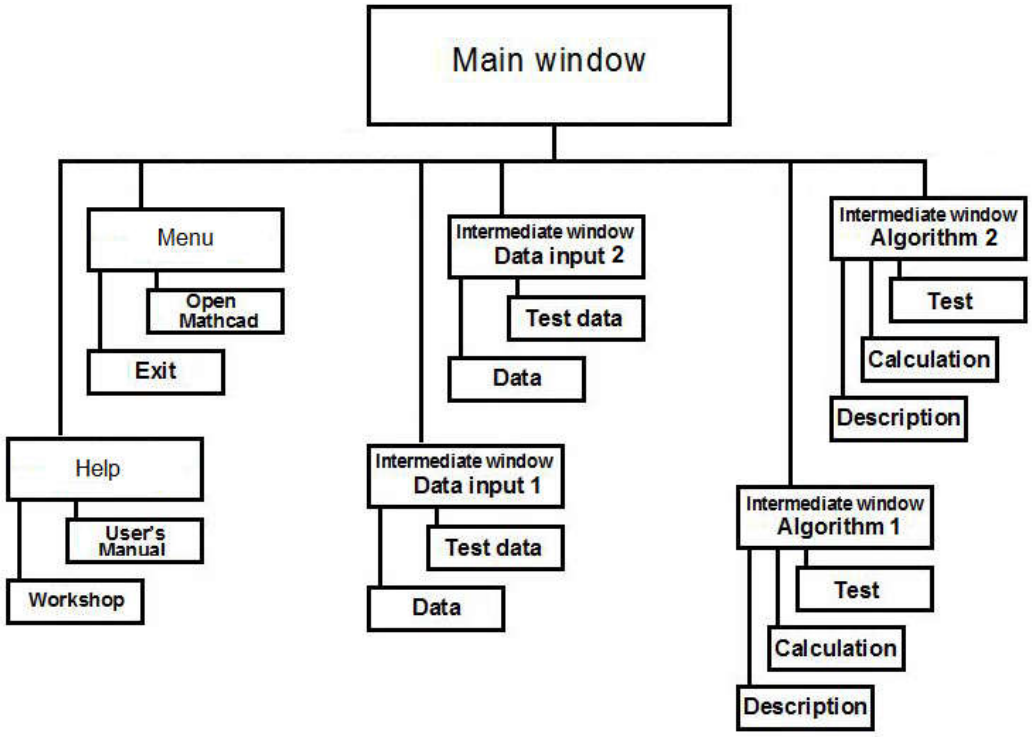

Figure 1 - Block diagram of software for processing experimental data of studies of the kinetic dependence of the response of a gas sensor

As shown in fig. 1, the software consists of the Menu and Help sections, similar to those given in [8], and four intermediate menus. The first two of them are designed to enter the initial information (experimental data) Data Input 1 and 2, and the other Algorithm 1 and 2, containing subsections that correspond to solutions to the problems of finding the parameters of the gas sensor under study and plotting their dependence on this or that factor.

The components of the library subsections (Mathcad documents) are presented in two versions: test and open for modification by user, and contain a description file for the corresponding method.

As additional services, the scheme provides for the possibility of directly calling the Mathcad mathematical package and exiting the program, as well as being acquainted with the user's manual and going online to obtain additional literature data.

The main menu of the package links all sections.

Design of the user interface window. The environment for the operation of the described software product is the Windows operating system. Navigation between sections is carried out using buttons and menus of various levels (main, intermediate and operating menus) [9].

To control the processing of the initial data, the Package Monitor is used, which is written using the C # language and the Windows Forms Application project type of the Visual Studio platform. The applied program modules of the library of computational algorithms, as already mentioned, are documents of the well-known mathematical package Mathcad (version 13). In addition, the application uses universal tools for working with files with extensions such as .xls, .docx and .pdf.

The main elements of the main window are buttons with labels, which mean assignments (Fig. 2).

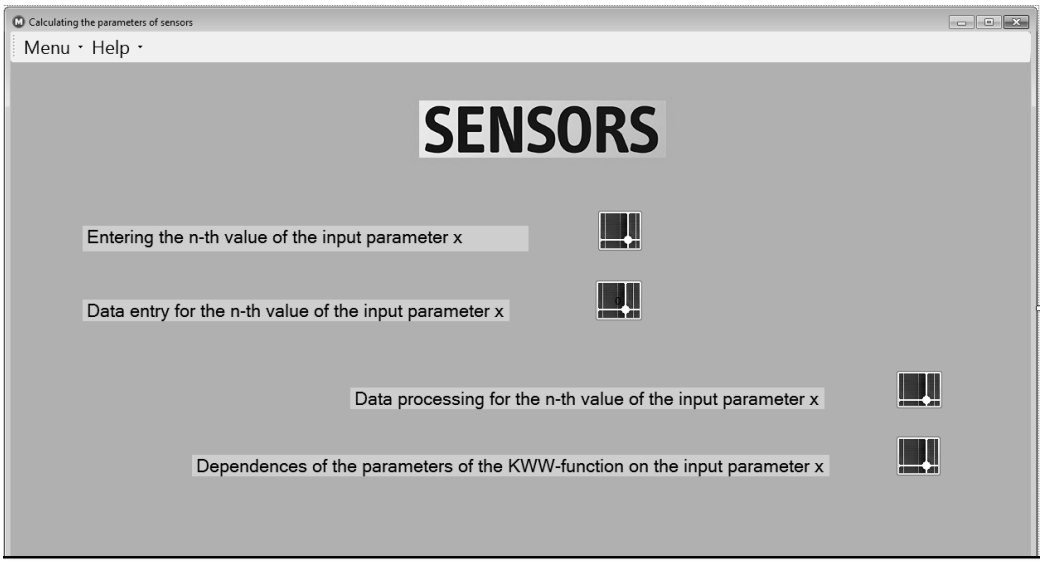

Figure 2 - Main window of the user interface

Pressing the buttons «Entering the n-th value of the input parameter x» and «Data entry for the n-th value of the input parameter x» call up intermediate menus (Fig. 3), where the layout of the input and output information is indicated, and the opportunity is given to go to the windows of the program «Excel», one of which contains data for testing («Test»), the other allows you to enter the experimental data intended for processing («Data»).

The remaining buttons «Data processing for the n-th value of the input parameter x» and «Dependences of the parameters of the KWW-function on the input parameter x» (Fig. 4) are designed to go to the intermediate windows of the same name, contain a short description algorithms and a menu of the following three items, which initialize actions in accordance with the block diagram in Fig. 1:

«Test» call the Mathcad package window with a test case (does not allow any changes);

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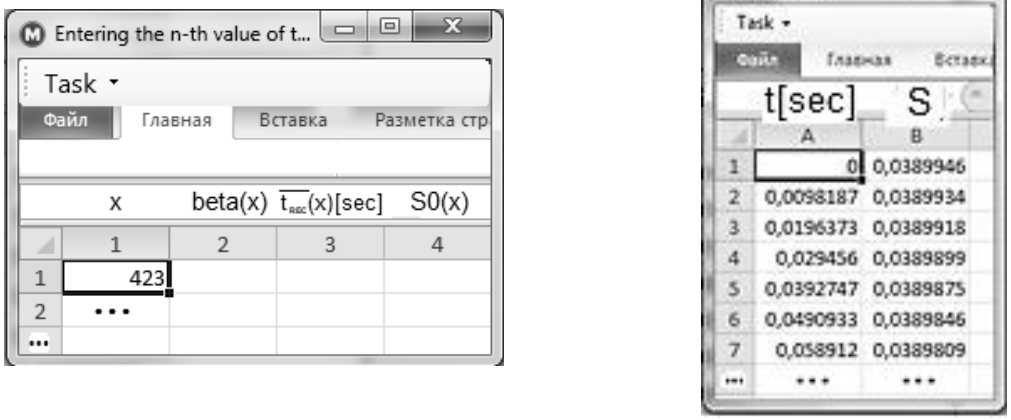
«Calculation» call the Mathcad package window with a similar file used to process the experimental data loaded for processing;

«Description» of opening a .pdf file with a detailed description of the selected method.

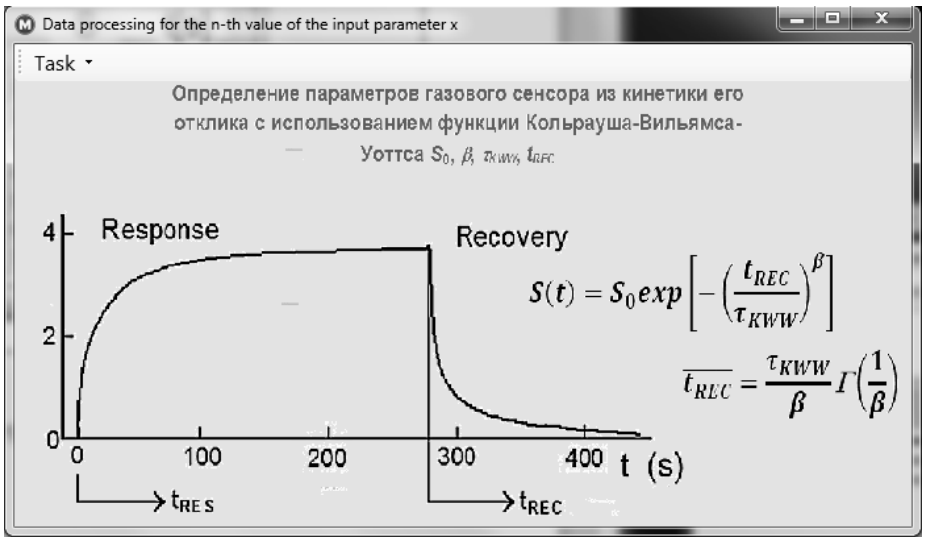


3a 3b

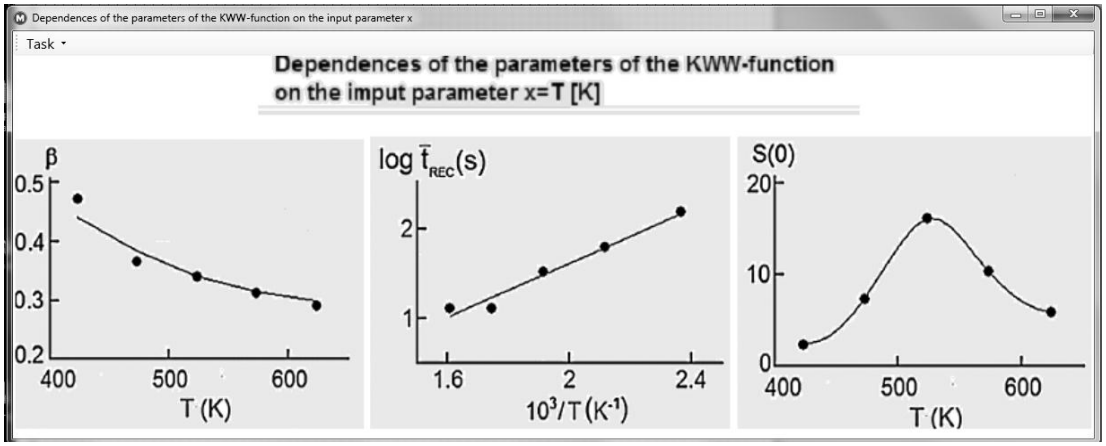
Figure 3 - Intermediate windows for switching to reference pdf-file windows and test and working windows of the «Excel» program for setting the value of the measurement identification factor (a) and entering the corresponding experimental data (b)

The first of these algorithms provides the processing process with the participation of the operator entered in the window Fig. 3b data in accordance with the algorithm described in [3,4,8] for one (corresponding to a specific value of the argument) studied kinetic dependence in the environment of the Mathcad package (Fig. 4a). The purpose of the second algorithm is to fix and accumulate an array of values of the parameters of the Kohlrausch-Williams-Watts function that approximate the observed kinetics of changes in the resistance of the sensor under study, followed by visualization of their dependences on a given factor (Fig.4b).

The main window also contains a toolbar with two buttons «Menu» and «Help». The Menu button contains two items. When you select the first of them, «Open Mathcad», Mathcad will be launched or the screen will ask you to select the Mathcad launch file yourself. When you select the second item «Exit», the application will be closed. The Help button also contains a two-item menu. The item "User's Manual" opens the document with the user's manual. The item «Workshop» launches a browser to access the Internet.



4a



4b

Figure 4 - Intermediate windows for switching to reference pdf-file windows or test and working windows of the Mathcad program for processing measurement data of individual kinetic dependencies for a given value of the measurement identification factor (a) and graphical presentation of the dependence of the calculated values of the parameters of the KWW function on the values of this factor after processing several specified kinetic dependences (b)

It should be noted that before using the described software product on a specific computer, you must install it together with the standard mathematical package Mathcad, Excel, a browser and reading tools for files with the .pdf extension. Setting up the product presented here comes down to writing in the Visual Studio environment the corresponding file addresses in its monitor, which contain specific software implementations of computational algorithms from its library

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Algorithms of calculation. The algorithm for servicing the presented software for processing experimental data based on an application for calculating the parameters of a gas sensor using the extended exponential function of Kohlrausch-Williams-Watts includes the following operations:

1. Data entry using the above user interface.

1.1. In the window «Entering the n-th value of the input parameter x», in the first column of a new Excel table, load the value of the factor x (temperature, partial pressure of the active gas or the physical parameter of the sensor under study), which is the argument of the dependencies of the parameters of the Kohlrausch-Williams function. Watts, approximating the observed kinetics of changes in the resistance of the sensor under study (Fig. 3). The rest of the column fields (specified parameters) will be filled in because of the processing.

1.2. In the «Data entry for the n-th value of the input parameter x» window, load into the Excel file table of the experimental data S (t) obtained as a result of measurements of the relaxation part of the kinetic dependence of the resistance response at the specified value of the factor x (Fig. 4).

2. In the window «Data processing for the n-th value of the input parameter x», initialize the process of calculating the parameters beta, tREC and S (0) for the given value of the factor x. The calculation algorithm is described in detail in [8]. Its features are

2.1. Entering factor x values

2.2. Determining the row for the next entry in the table in Fig. 3 calculation results

2.3. Implementation of the settlement process under the control of the operator. (its main task is to correct the choice of the interval of the required form for calculating the beta parameter).

2.4. Writing the obtained parameters for the value of the factor x in the table in Fig. 3.

3. Repetition of points 1 and 2 for all values of the factor x.

4. By activating the button «Dependences of the parameters of the KWW-function on the input parameter x» go to the window of the same name of the Manhcad package, where 4.1. initiate loading of the table fig. 3 and visualization in the form of graphs of the calculated dependences of beta, tREC and S (0) on the used factor x.

Conclusions. A version of specialized software for processing data from experimental studies of the kinetic dependences of the response of gas-sensitive sensors,

based on their approximation by the known model of the stretched ponential function of the Kohlrausch-Williams-Watts function, is presented.

The software is based on the complex use of dissimilar software products and provides the following service functions for processing and analyzing the specified data:

- data entry using Excel spreadsheets;
- calculations in the mathematical package "Mathcad" of the specified parameters;
- visualization of the obtained dependencies in the form of graphs;
- providing the necessary textual information about the used calculation algorithms and test examples of their use;
- Internet access if necessary for additional information.

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Программирование в Windows Forms: [Електронний ресурс]. Режим доступу: https://metanit.com/sharp/windowsforms

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Програмне забезпечення обробки та аналізу експериментальних даних досліджень газових сенсорів

Метою роботи є розробка програмного забезпечення для обробки експериментальних даних кінетики відгуку резистивних газових сенсорів на основі алгоритму моделі розтягнутої експоненційної функції Кольрауша Вільямса Уоттса.

У статті наведено елементи структури, інтерфейсу та технології використання програмного забезпечення. Розроблений додаток дозволяє користувачеві використовувати вхідні дані у вигляді текстових файлів або файлів електронних таблиць Excel, які формуються вимірювальною апаратурою, що безпосередньо застосовується.

При створенні програмного забезпечення застосовано концепцію використання різних програмних пакетів та середовищ, найбільш ефективних на кожному етапі обробки та аналізу даних.

Електронний додаток надає можливість послідовного завантаження даних вимірювань кінетичної залежності відгуку газового сенсора з фіксацією значень параметрів режиму її вимірювання (температура сенсора, парціальний тиск активного газу). Результати обробки програми є залежними параметрами функції Кольрауша Вільямса Уоттса від режимного параметра.

Додаток надає такі функції, як введення даних за допомогою програми електронних таблиць Excel; розрахунки в математичному пакеті Mathcad; тестові приклади використання обчислювальних алгоритмів та надання необхідної текстової довідкової інформації із внутрішніх джерел та Інтернету.

Реалізуються сервісні функції, які дозволяють проводити обробку групи експериментальних кінетичних залежностей і одержувати дані (у в табличному чи графічному вигляді), які ілюструють вплив того, чи іншого фактору на фізико хімічні процеси, що характеризуються параметрами моделі розтягнутої експоненціальної функції.

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