Automation of procedure for diagnostics of thin film electroluminescent indicators’ structure

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Abstract. Problems of measurement automation for creating a testing system are considered. This system accelerates the process of parameters controlling in the production and development of new samples of indicator (display) technology. The main parameters of the indicators are defined, the tasks of automation of measuring processes are indicated, the hardware and software structure of the system is developed. The main features of an integrated approach to solve the problems of automating the process of testing the structures of thin-film electroluminescent indicators were proposed, the parameters of thin-film electroluminescent indicators were considered as the basis for forming the composition of an automated testing complex, and the automation of processing the experimental results at the software level was described. The ideas outlined in this article make it possible to formulate a technical task for the development of a complex for automated measurement of the parameters of thin-film electroluminescent elements, as well as its components and software.

1. Introduction

In connection with the widespread use of computerized information processing facilities, indicator devices capable of satisfying both general and specialized requirements are of big interest.

In general, display facilities can be divided into two types - displays for general use and specialized displays. Users of civilian devices focus on the quality of the transmitted image and price; for specialized displays, reliability and weight and size parameters are especially important. Developers of indicator technology are faced with a difficult, complex task of finding a balance between effective designs of indicators with the best functional characteristics, price indicators and reliability of information display facilities. Among the devices of widespread use, liquid crystal displays predominate, which are gradually being replaced by matrices built using OLED technology. For structures for specialized purposes, strict requirements are imposed on the parameters and performance characteristics. In this regard, thin-film electroluminescent indicators (TFELI) are of particular interest.

The TFELI are characterized by high lighting and electrical performance, radiation resistance, and also have the necessary reliability. Today, this type of indicators has a low resolution, which defines it...
as a type of device, a purely specialized application. A serious drawback of these indicators is also the need to supply an alternating voltage with a large amplitude to generate luminescence, but this is compensated by the fact that currently available AC voltage inverters that convert a low-voltage DC signal into an alternating one with the required amplitude [1, 2].

The process of measuring the parameters of materials and structures of thin-film devices is complex, complex, and time-consuming. The task of creating systems for automated diagnostics and control of the functioning of thin-film electroluminescent structures in indicator devices is urgent, since it significantly accelerates the search for the necessary materials, the creation of optimal design options with the specified parameters.

2. Features of thin-film electroluminescent indicators as the basis for the formation of the composition of the automated testing system

To create a software and hardware complex for testing TFELI, it is necessary to determine the main parameters of indicators, create an algorithm for their measurement, and ensure the implementation of the principles of automation.

A thin-film electroluminescent structure is formed of five layers deposited on a transparent dielectric substrate: transparent lower conductive, lower dielectric, luminescent, upper dielectric, upper conductive [1].

Dielectrics are used as a limiter of the charge formed in the phosphor in the operating modes of the indicator device. Insulating layers are necessary due to the fact that the phenomenon of electroluminescence in thin layers of zinc sulfide and other materials entails electrical breakdown of semiconductors.

The phosphor is separated from the electrodes by two or more layers of dielectrics, which allows the TFEL to be presented as an electroluminescent capacitor.

The Volt - Brightness characteristic of these devices has a threshold character, when the supply voltage reaches a certain (threshold) value, a sharp jump in the brightness of the TFEL occurs.

The value of the threshold voltage is mainly associated with the characteristics of the phosphor materials: the threshold electric field strength, the magnitude and ratio of the capacities of the luminescent and dielectric layers [2, 3].

Let’s consider the main parameters. The range of operating voltages of the TFEL lies within the limits from the threshold (Uth) to the breakdown voltage (Umax). Uth is the instantaneous value of the voltage at which the luminescence process begins in the TFEL structure. When the supply voltage reaches the value Umax, degradation and destruction of the indicator occurs. During the measurement, the voltage on the indicator, at which the value of the brightness parameter (B) goes over zero, will be the threshold. Thus, the process of monitoring the operating parameters of the TFELI begins with the measurement of Uth, and the determination of Umax is possible only at the final stage of testing. When the voltage is less than the threshold, only the charge current (I charge) flows through the indicator, the dissipation of electrical power (P) practically does not occur [3]. In operating modes, the power is defined as the product of the consumed current (I) by the value of the supply voltage. The luminous efficiency of TFELI is defined as the ratio of the luminous flux to the power consumption:

\[ n = \frac{\pi B_{av} S}{P}, \]

where Bav is the average value of brightness, S is the area of the indicator [4].

3. Algorithm for collecting, processing and accumulating information

Any measurement process is about obtaining data about a physical sample and transferring it to the end user. The definite value of a particular parameter at a particular moment of time does not always represent valuable information in the study of research objects.

The study of the parameters of the TFEL structure is necessary to study the effect of the material of the element layers and the technologies of their deposition, to compare the experimental and calculated output parameters in order to determine the error and make recommendations for the design
of indicator structures, as well as to form databases of dielectric, conductive and luminescent materials.

![Flowchart Diagram]

Fig 1. Algorithm of measurements

Diagnostics is to obtain information about the nature of the functioning of the TFEL-structure and the dependence of the values of the output parameters (operating voltage range, current, average dissipated power, average luminosity, light output) on the specified external conditions, such as:
characteristics of the supply voltage (frequency of excitation, amplitude), geometric data of layers [3]. Thus, two types of parameters can be distinguished: optical and electrical, in addition to them there are external factors (temperature, etc.). The task of collecting data is complicated by the fact that it is necessary to determine a number of parameter values, as well as to establish the dependence of these parameters from each other.

Based on the well-known calculation and measurement procedures [5, 6], the sequence for measuring the package of parameters of the TFEL structure was determined:
1. Selecting the required electrical parameters
2. Selecting the required optical parameters
3. Drawing up a list of external influences
4. Formation of the hardware part of the measuring complex
5. Determination of the sequence of measurements
6. Reading electrical and optical indicators
7. Carrying out calculations and drawing up dependencies
8. Formation of a database of experimental results

Figure 1 shows an algorithm for measuring these parameters.

Measurement system structure

Figure 2 shows the composition of the system for automated measurement of parameters. The core of the complex is a personal computer. This ensures the fulfillment of the requirements considered in clause 2. For the convenience of control and the most complete implementation of the principles of automation, the generator controlled by the USB interface has been selected by the power source for the thin-film electroluminescent element. The thin-film electroluminescent element is mounted on a special tripod, which is placed in a darkened box.

The current (I, I charge) of the TFEL1 is measured using a resistor connected in series, the voltage drop across which should not exceed 0.5% of the supply voltage value. The instantaneous values of brightness (B) are determined by means of a photosensor (photomultiplier tube). Further, the indicators I, Icharge and B are recorded through a digital storage oscilloscope on a personal computer using the software described below.

Thus, this structure allows you to realize the following advantages:
1. Easy to use and user training
2. High accuracy of measurement results and the possibility of their presentation in any format (table, graph, etc.)
3. High speed of the experiment
4. Possibility of carrying out an experiment using full-scale TFEL samples
5. Flexibility, versatility of the measuring system with the ability to quickly adapt to new requirements, conditions and tasks
6. Reliability
7. Possibility of interaction with the database of results and parameters of experiments
8. Cooperation via the Internet
9. Interfacing with computer-aided design systems TFELI [5, 6]
10. Possibility of further expanding the functionality of the system to work not only with thin-film, but also with other types of indicators
11. Ability to simulate the influence of external factors on the tested TFELI structure (high and low temperatures, vibrations)
12. Modularity of the system design, the possibility of expanding / reducing the functionality of the system by adding / removing modules and the interchangeability of the modules themselves
13. Possibility of comparative analysis of the measured characteristics of two or more measured elements
14. The ability to predict the characteristics of the measured elements, based on the analysis of elements of similar structures
15. Possibility of selection of optimal materials of construction of the measured elements for the required parameters.

The structure of the software of the complex for automated measurement of the parameters of TFELI is shown in Figure 3.

Fig. 3 Software structure
The principle of operation of the software shell of the measuring system is based on the use of test programs. This is a set of commands for controlling and interacting with the generator, oscilloscope and other blocks. The test program is executed using the module of the same name. Each test is designed to solve a specific problem, for example, determining the average brightness of the indicator, finding the threshold voltage, etc. The test program reads data from the oscilloscope and sends it to the control module. To meet the requirement of quick adaptation to new tasks being solved, the testing program can be edited, compiled and sent back to the execution unit.

The user controls the measuring complex by means of the control module. With its help, the operator can create and edit test programs, control the generator and other external units, form a database, interact with the TFELI computer-aided design systems via the Internet.

The test program editor allows you to edit existing tests and create new ones. Its functions also include verification of the program for errors, compilation into an executable file, which the user passes to the appropriate module.

The control units for the processing device, the generator and the device for simulating external action are the interface for the interaction of these devices with the operator, they are an intermediate link between the device driver and the user.

The database editor is responsible for creating, editing and storing the database with the conditions and results of the experiment.

The Internet-module is intended for cooperation of the complex of automated measurement of parameters of thin-film indicators with similar software using network protocols. This is necessary for organizing a large measuring network from several of the above-described complexes, as well as computer-aided design systems (via the corresponding module). Such a solution will significantly optimize the process of creating and researching structures and materials of indicators from the stage of theoretical calculations to conducting experiments with a specific physical model. This principle is especially relevant in the case of geographic separation of production from the TFELI developers.

4. Conclusion
The development of a system for automated control of TFELI parameters solves the following tasks:
1. Reducing time costs
2. Reducing labor intensity
3. Ensuring high accuracy of measurements
4. Achieving the required quality of the experiment
5. Maximum elimination of the influence of the human factor and related problems on the measuring process.
6. Creation of the most complete and accurate models of indicator devices.

The above studies made it possible to formulate a technical task for the development of a complex for automated measurement of the parameters of thin-film electroluminescent elements, as well as its components and software.

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