DEVELOPMENT OF FILM STRAIN CONVERTERS BASED ON BISMUTH-ANTIMONY TELLURIDES

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DOI: 10.5958/2249-7137.2022.00203.8

ABSTRACT

The article discusses the mechanism of fatigue failure of a material and a method for determining the process of material fatigue by developing semiconductor polycrystalline converters based on bismuth-antimony tellurides. The technological process of obtaining semiconductor film sensors by the method of thermal vacuum evaporation of a mixture of granular materials is described.

KEYWORDS: *Strain Gauge, Sensing Element, Polycrystalline Films, Semiconductor Film Converter, Accumulated Fatigue Damage Sensor*

INTRODUCTION

It is known that a strain gauge measuring transducer is a parametric resistive transducer that converts the deformation of a solid body caused by a mechanical stress applied to it into an electrical signal. To measure deformations with the help of a strain gauge transducer, the active resistance of the strain gauge, which changes with deformation, is measured.

In its modern form, a strain gauge or strain gauge measuring transducer is structurally a strain gauge, the sensitive element of which is made of a strain-sensitive material, fixed with a binding adhesive on the part under study. In order to connect the sensing element to the electrical circuit, the strain gauge has lead wires. For ease of installation, some designs of strain gauges have a substrate located between the sensing element and the part under study, and also a protective element is located on top of the sensing element.

There are two main areas of use for strain gauge measuring transducers:

- Studies of the physical properties of materials, deformations and stresses in parts and structures;

- The use of strain gauges for measuring mechanical quantities that are converted into deformation of an elastic element.

The first case is characterized by wide ranges of changes in environmental parameters, in addition, a significant number of strain gauge points and the impossibility of calibrating the measuring channels. In this case, the measurement error is 2-10%.

In the second case, strain gauges are calibrated according to the measured value. Measurement errors lie in the range of 0.5-0.05%.

Parts subjected to alternating stresses fail at stresses that are much lower than the tensile strength, and sometimes even the proportional limit of the material. The process of gradual accumulation of damage under the action of alternating stresses, leading to a change in the properties of the material - the formation of cracks and the destruction of the part, is called fatigue failure, i.e. fatigue. Accumulation of damage is especially intense if the voltage amplitudes change not only in magnitude, but also in sign. The material consists of interconnected crystals, between which there are pores and various inclusions.

The mechanism of fatigue failure is associated with the inhomogeneity of the material: different sizes and configurations of individual grains, the direction of their crystallographic planes, the presence of inhomogeneous phases, inclusions, crystal lattice defects (vacancies, dislocations), and residual stresses [**1].**

To determine the fatigue process of individual (concrete) structural alloys, it is necessary to develop semiconductor polycrystalline converters that convert the deformation of a solid body caused by mechanical stress applied to it into an electrical signal. In its modern form, a strain gauge measuring transducer is structurally a strain gauge, the sensitive element of which is made of a strain-sensitive material, fixed with a binder (glue, cement) on the part under study.

Materials

The sensing elements (SE) of semiconductor film strain transducers, for example, a accumulated fatigue damage sensor are a heterogeneous material. We briefly dwelled on those achievements in the development of film strain gauges based on bismuth-antimony tellurides. They are obtained by thermal vacuum evaporation of the mixture on a polyamide substrate **[2].**

The mixture consists of a finely dispersed mixture of various initial components. For example, mixtures of bismuth-antimony telluride granules with cadmium.

Methods

When an irreversible cyclic deformation is imposed, the structure of the electronic subsystem of the sensitive element of the film sensor changes. This leads to a change in the effective electrical resistance Reff of the sensing element of the sensors of accumulated fatigue damage, which is rigidly mounted on the structural element. The changes are "autonomous" in nature, due to the principle of minimum Joule losses. Each original structure has its own "autonomy" forming the history of the process of restructuring its electronic subsystem. Structures that have the same "autonomy" are reproduced in a narrow technological interval. Therefore, a high level of automation of the technological process of obtaining films is used.

We have developed a system **[3-5]** designed to automatically control the process of deposition of semiconductor film sensors by the method of thermal vacuum evaporation of a mixture of granular materials. The control of the parameters of the spraying process and the control of individual units of the installation is carried out by a program computer such as IBM / PC according to the technological map drawn up in advance. During the process, it is possible to change its modes.

The installation allows spraying up to three different mixtures in one technological cycle. Only two of them can be sprayed at the same time. The third mixture is sprayed separately, after spraying the 2nd mixture. 3 separate evaporators are used for spraying mixtures. During the spraying process, the required temperature regime is set on each evaporator. The evaporation temperature of the mixture is controlled by thermocouples.

One of the most important parameters in the deposition process is the temperature of the substrates. The substrates are fixed on a rotating carousel located above the evaporators. A halogen lamp is used to maintain their temperature. To control the temperature of the substrates, a thermal resistance is used, which is placed in the immediate vicinity of the place where the substrates are fixed.

For the stability of the characteristics of the obtained films, it is necessary to provide a certain speed of rotation of the carousel above the evaporators. Compliance with this condition makes it possible to expect the reproduction of the structure of deposited films. The system provides for continuous measurement and regulation of the speed of rotation of the carousel according to a given law.

Control over the process of obtaining films is provided by two witnesses - auxiliary and main. The auxiliary witness is located on the technological gate. By measuring the resistance of the auxiliary witness, the initial phase of film deposition is set. After reaching the specified resistance on the auxiliary witness, the technological shutter opens and the process of deposition onto the substrates begins. The deposition process is completed upon reaching the specified resistance value on the main witness.

All controlled parameters are recorded in a file for subsequent analysis and replay, which makes it possible to obtain films with the closest possible characteristics in different batches.

The system provides for automatic control of the process damper located above the evaporators. The damper position is controlled through the standard damper control unit.

Structurally, the entire system is made in the form of a separate unit, which is connected to other parts of the system through connectors. The unit is powered by 220 V 50 Hz. The rotation speed meter is mounted next to the engine. The synchronization block is made in the form of a separate board and is fixed inside the instrument rack of the process unit. **[6].**

The entire technological process is controlled by a program that runs on a computer. The program is written in C++ and Assembler and is optimized for execution on a computer. Before starting the technological process, it is necessary to enter data for the Work Protocol. To set the temperatures of the evaporators and the lamp, press the button with the image of the required heater and use the mouse to mark a point in the heater data window. The speed of rotation of the carousel and the position of the damper are set in the lower data window.

During operation, the System will begin to process the set values and display the corresponding measured values. When the right border of the window is reached, the program will automatically “scroll” the data windows one screen forward. The measured values are displayed as dots of the corresponding color and in the Information window. You can edit the data set in the Protocol and during the process, however, the program does not allow you to correct those points that have already been worked out during the work.

Events are processed by the program in a special way. If the resistance of the active witness is less than the one set in the event, the program automatically switches the damper and/or the witness. At the same time, the Damper state point is entered into the Protocol and all subsequent Damper states are changed to the opposite values. If Temperature Stabilization was set in the event, the Evaporator 1 temperature change stops and the next two points for Evaporator 1 change. The next point drops to the current temperature value and shifts to the current time. The next point after it drops to the current temperature value.

During the process, the program stores all measured values. Information is collected every second. The maximum time that the program can remember is 4.5 hours. After that, the program does not fix all subsequent values, but will work out all the control actions. The typed protocol of the process can be saved in a file on disk. When saving the protocol file, all data obtained during the work is automatically saved.

Results

Below are some experimental data for heterogeneous semiconductor materials (HSM) obtained at this facility. Under regular loading with an increase in the number of N - cycles of imposed irreversible deformation, the experimentally observed change in the resistance of the entire GPM (the value ΔR = Rn - R0) initially increases linearly, subsequently reaching the saturation state ΔRmax = (M-R0) (see Fig. 1).

Under actual operating conditions, the sensitive elements of the accumulated fatigue damage sensor installed on the structure are subjected to the action of a random spectrum of deformation **[4].** Below, the responses of the GLM to both of these situations are considered and a correlation between them is established. This makes it possible to calibrate the SE on benches with regular loading and then use them to create a accumulated fatigue damage sensor installed on real structures.

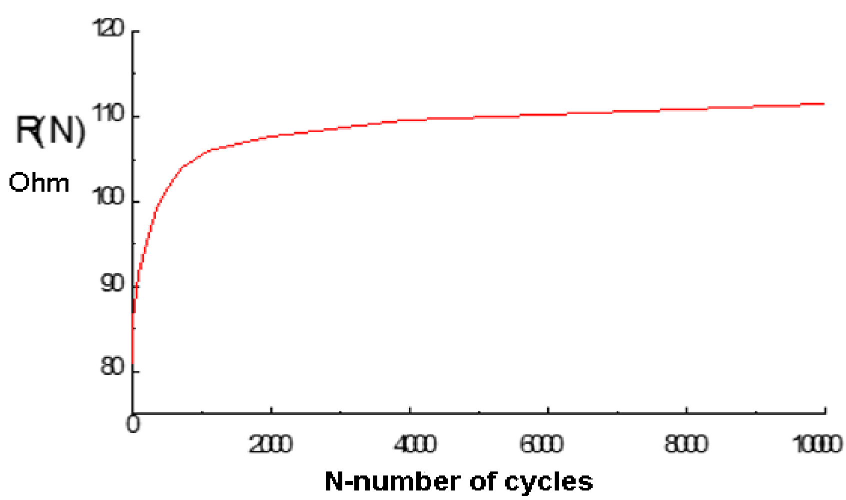

Fig.1. Dependence of Reff SE a accumulated fatigue damage sensor on the number N of superimposed load cycles. (with alternating frequency 10Hz)

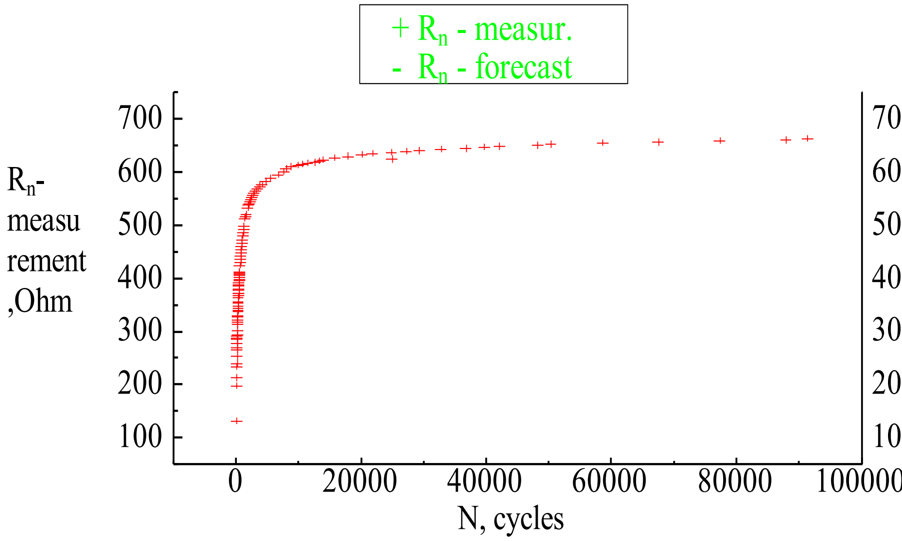

Fig.1a. Dependence of ReffSE accumulated fatigue damage sensor on the number N of applied load cycles. Simple loading mode (sign-alternating frequency 10 Hz bending vibrations of a cantilever beam with installed SE)

DISCUSSION

Under regular loading with an increase in the number of N - cycles of imposed irreversible deformation , the experimentally observed change in the resistance of the entire GPM (the value ΔR = Rn - R0) initially increases linearly, subsequently reaching the saturation state ΔRmax = (M-R0) (see Fig. 1). Under actual operating conditions, the sensitive elements of the accumulated fatigue damage sensor installed on the structure are subjected to the action of a random spectrum of deformation**.**

Below, the responses of the GLM to both of these situations are considered and a correlation between them is established. This makes it possible to calibrate the SE on benches with regular loading and then use them to create accumulated fatigue damage sensor installed on real structures. Transducers based on a heterogeneous structure must be subjected to a certain kind of “training” in order to stabilize their structure and increase sensitivity.

CONCLUSIONS

The results of the preliminary studies performed showed that the recorded parameters of sensors based on a heterogeneous structure can be used to judge the dynamic processes of fatigue damage. The need for additional research is also related to the fact that, as established, the signal shape of a heterogeneous structure carries certain information about the degree of fatigue damage, and the periodically restored signal shape, until it coincides with the change in stress in the cycle, possibly carries information about the passage of the transition point from one sub structural level to another. These measurements can be useful, for example, in laboratory studies of the fatigue characteristics of materials.

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