Application of Nanostructured Silver-Palladium Resistance Films for Measuring of Power and Frequency of Laser Radiation Pulses

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Abstract. It is shown that the electric signal taking off probe electrodes placed on a silver-palladium resistive film surface, at the effect by laser radiation essentially depends on power and frequency of radiation pulses. The irradiated area of a sensitive element gets an electric charge, due to originating of temperature gradient and charge carriers thermodiffusion current, as result the potential difference, recorded in the form of generated voltage signal, is created.

Keywords: resistive film, silver-palladium resistive films, laser, thermodiffusion, nanostructured, sensor

INTRODUCTION

Development of laser technics is accompanied not only increase the laser radiation power, but also occurrence of the automated laser complexes both in manufacture and applied science field, and in basic researches. The parameters of laser sources of radiation are still the subject of research and scientific development. Spatial, temporal, spectral and energy parameters allow you to judge the nature of the laser radiation. For carrying out of experimental works with laser radiation use it is necessary to solve a number of problems on control and measuring of the laser beam parametres, considering that applied detectors should stand powerful laser pulses effect without damage.

The photovoltaic effect has been detected during studying of silver-palladium resistive films obtained by the thick-film technology [1].

EXPERIMENTAL RESEARCH

Research of photovoltaic effects in thick-film Ag-Pd resistors at pulse laser effect has permitted to find out sufficiently quick electric response of these resistors to laser pulse effect. Resistive films with silver electrodes are made on ceramic substrates BK-94 by repeated cauterizing to a substrate semiconductor ink at the temperature 815 °C and resistive ink at the 605 °C in the conveyor furnace in the air atmosphere. Powder component Ag-Pd of resistive inks contains Ag_2O, Pd and C-660a glass. During thermal treatment of these inks there are the redox reaction resulting in resistive film forming which functional material consists from nanodimensional particles of Ag-Pd alloy and palladium oxide PdO [2].

Because of a high processing temperature on air the external surface of a resistive film contains PdO which thin layer is formed besides on a surface of Ag-Pd particles alloy. As Ag-Pd is metal, and PdO is the p-type semiconductor, during resistor forming on its surface the set nanodimensional areas with transient the metal-semiconductor layers, having property of Schottky barrier is created. Accordingly, the Ag-Pd thick-film resistor surface can have the properties similar to the properties of Shottki photo diodes, what causes their high-speed performance of the photo-electric response. PdO content on Ag-Pd thick-film resistors surface is also confirmed that on a surface of these resistors thermo-EMF originating is detected [3, 4]. When heated copper electrode contacts with a thick-film resistor surface which is at a room temperature, between an electrode and any resistor electrode appears a negative sign thermo-EMF (on the heated electrode), that indicates p-type conductivity of a the resistor surface [5].

The received resistors had resistance ~60 Ω at the size of a resistive film 6×6×0.02 mm and 300 Ω at the size 2×2×0.02 mm. The resistors contacts located along opposite sides of a rectangle between a ceramic substrate and a film, were formed from silver semiconductor ink PP-3 (Figure 1).

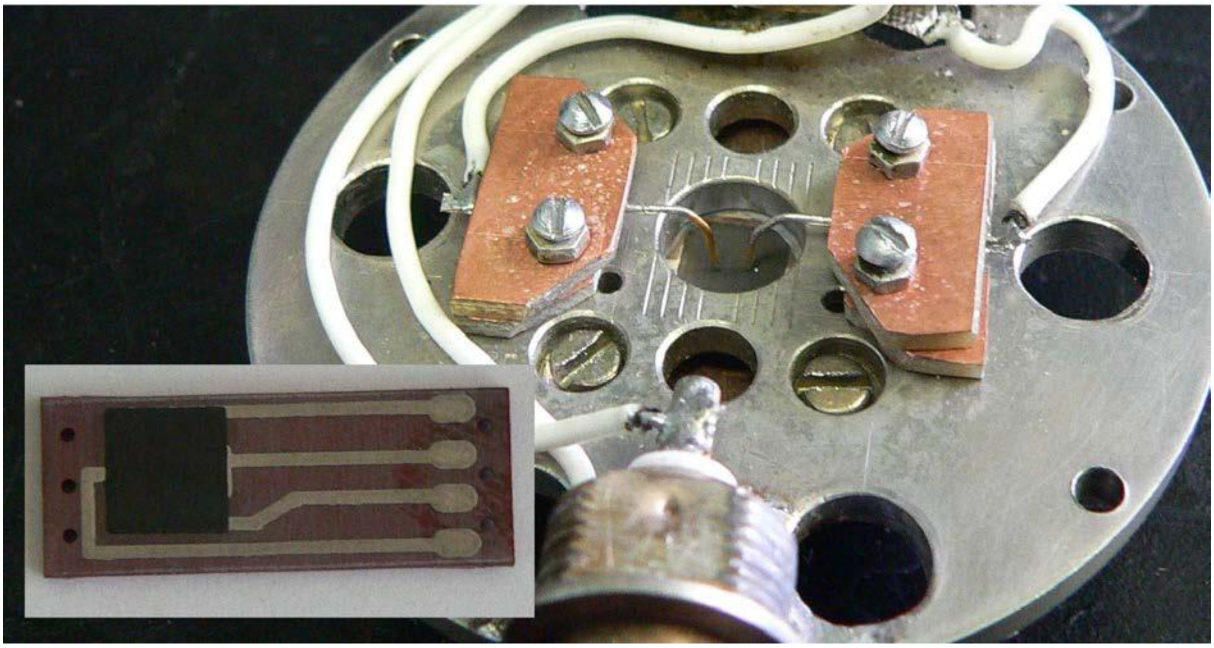

Figure 1. Exterior thick film silver-palladium resistor and probe electrodes on its surface

Researches were carried out with application as a source of radiation pulse CO_2 laser with radiation wavelength of 10.6 microns. In order to reduce external noise resistor placed in a shielding metal case. Immersion heaters with painted surface to the probe electrode was placed on the XY table. The distance from the focusing lens of the laser to the surface of the resistor was 70 mm. Focal length of the lens is 50 mm. Thus the surface of the resistor fell partially defocused bunch. This avoids modifying the surface of the resistor from the powerful heat of the laser radiation. The diameter of the laser beam normally incident on the surface of the resistor is approximately 1 mm. Exposure time of the laser to the surface of the resistor is 10 seconds. Electrical signals induced in the resistor on its surface, were recorded after amplification oscilloscope. Thus a fixed maximum value of EMF occurring between electrodes. Summing up the signal is taken from the surface of the resistor electrodes and electrodes on the edge of the resistor. After each measurement point of impact of the laser pulses on the surface of the resistor is moved over a distance of 0.2 mm increments using the screws XY table.

Laser radiation incidents normally to a resistive film surface. The film, being a sensitive element, possesses property of electric charges division on a surface during a laser radiation local exposure, due to forming of a temperature gradient and a thermodiffusion current of charge carriers, and forming in irradiated area of a spatial charge, differing on a sign from a charge of non-irradiated part of a film surface. Thus the spatial charge originating in the irradiated part of a surface creates a potential difference on non-irradiated part and at edges of this surface. The potential difference in the form of EMF signal can be taken off using the electrodes placed at its edges of a resistive film, and by means of probe electrodes, positioned to a surface. At irradiation of a sensitive element surface by laser pulses repeated by determined frequency there are charge fluctuations of an irradiated surface part, and accordingly, a potential difference created by this charge by the frequency corresponding to laser pulses frequency. The electric signal value on electrodes is thus proportional to laser pulses power, and frequency is equal to laser impulses frequency.

The signal value directly taken off a resistive film does not exceed several mkV. For registration the electric signal supplies to an oscilloscope through the amplifier. The power and frequency of laser pulses is determined by the amplitude and frequency of control signals.

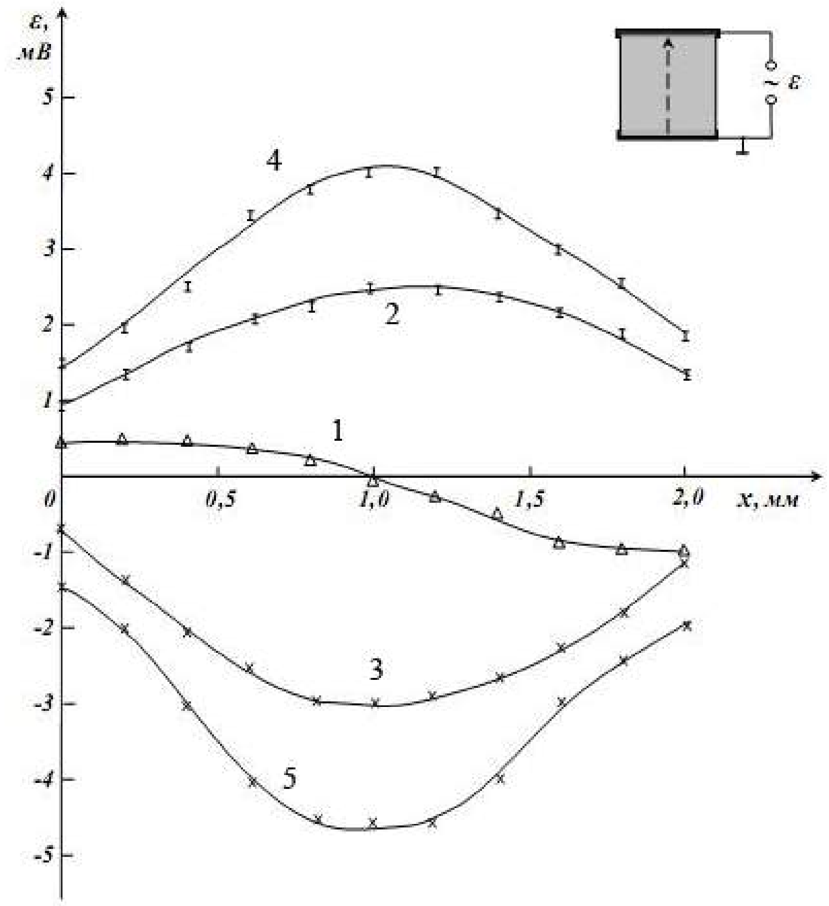

Figure 2. The amplitude of the EMF pulse bias voltage to Ag-Pd 300 Ω resistor by irradiating pulses of the laser: 1 – without applying a bias voltage; 2, 3 – a bias voltage + 0.5 V and −0.5 V, respectively; 4, 5 – offset voltage of +1.0 V and −1.0 V, respectively

For sensitivity increase to the electrodes located at edges of a sensitive element surface, voltage 1.5 and 3 V was applying constantly what created the electric field in a sensitive element internally, having an effect on a spatial charge in an irradiated part of a sensitive element surface. Due to it a spatial charge current appears in a sensitive element which creates on electrodes additional EMF, 10 times exceeding EMF on value, caused by a potential difference created by it (Figure 2).

The value of the constant EMF between electrodes depends on the point of impact of the laser pulses to the surface of the resistor. As seen in figure 2, its sign is reversed, when passing the point is the midpoint of the distance between electrodes.

The size of EMF between electrodes depends on the point of impact of the laser pulses to the surface of the resistor and the applied bias voltage. As seen in Figure 2, the sign of the EMF is reversed, when passing the point is the midpoint of the distance between the electrodes (curve 1). The bias voltage changes the nature of the relationship (curves 3, 4). Changing the polarity of the bias voltage dependence of the mirror displays rented signal (curves 3, 5).

In the Figure 3 typical oscillograms of EMF signals received from probe electrodes, positioned the Ag-Pd resistors surface at their surface irradiation by laser pulses of the frequency 1 kHz and from thick-film electrodes at resistor edges at laser pulses irradiation with frequency of 700 Hz are presented. Signals pulses are unipolar, have sharp front and shallow recession. As the laser generates radiation in the form of a pulses package with the set frequency, that, evidently, front duration of separate electric impulses is equal to duration of one package of laser radiation. On frequency 1 kHz, one can see from the oscillogram, impulses front duration is ~0.1 ms, on frequency of 700 Hz is ~0.2 ms.

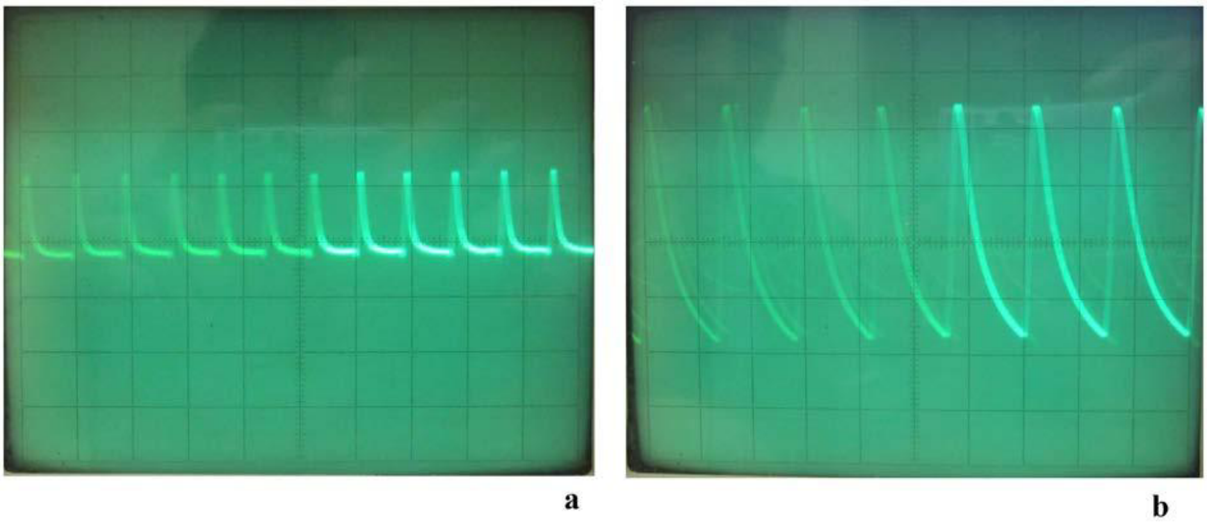

Figure 3. EMF oscillograms on Ag-Pd resistors surface at an irradiation by the CO_2 laser pulses when frequency is: 1 kHz (a); 700 Hz (b)

Conclusion

Pulse laser radiation effect on a surface of thick-film silver-palladium resistors result in thermo-EMF originating. Measuring the surface voltage in the Ag-Pd resistors when irradiated pulses of CO_2 laser shows patterns of change in the nature of EMF on the location of the point of impact of the laser beam on the surface of the resistor. The amplitude of the pulse and the polarity sign of the signal are significantly dependent on the coordinates of the laser irradiation. Pulse EMF component carrying information about the frequency and duration of the laser pulses, provides information on relevant parameters of the laser radiation.

Thus, the effects of pulsed laser radiation on the surface of the thick-film silver-palladium resistors leads to a thermo-EMF, which is detected by simple means of measurement. The dependence of the magnitude and polarity of the thermoelectric voltage between the electrodes on the surface of the resistors from the coordinates of the point of the laser radiation indicates the semiconducting properties of the surface of the p-type resistors. Occurrence of EMF on the surface when exposed resistors normally incident laser radiation may be explained fad carriers thermal phonons resulting in local heating and the occurrence of a temperature gradient on the surface of the resistors. The studies point to the use of silver-palladium thick film resistors as sensors for monitoring parameters of high-power pulsed laser radiation.

Thermo-EMF signal parameters relation between electrodes on a resistors surface from amplitude and pulse repetition frequency of laser radiation allows using silver-palladium thick-film resistors as detectors for the parameters control of powerful pulse laser radiation.

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