Probe with PVDF Sensor for Energy Measurements of Optical Radiation

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Abstract. *A concept of an inexpensive PVDF pyroelectric radiation sensor of large aperture is described. The design details of the pyroelectric sensor based on the PVDF polymer are given. The construction of the amplifier of the pyroelectric sensor signal is presented. The photoresponse of PVDF sensor to short radiation pulses is studied experimentally*

Keywords: pyroelectric detector, PVDF sensor, pyroelectric polymer

1. Introduction

In 1969, Kawai [1] discovered strong piezoelectricity in such polymers as polyvinyl fluoride (PVF) and polyvinylidene fluoride (PVDF). These materials also show substantial pyroelectric properties. The first pyroelectric films were commercially available in 1981. The use of polyvinylidene fluoride films (PVDF) as pyroelectric sensors for pulsed or chopped optical radiation has been frequently reported during the last two decades [1-4]. The main advantages of PVDF sensors are large integrating area, low thermal mass and very low cost. The development of low-cost pyroelectric polymer sensors has gained a great deal of interest due to the large number of applications.

In this paper the construction of a pyroelectric sensor based on PVDF for measurements of the pulse light sources energy (especially pulse lasers) is described. The details of amplifier system cooperating with the sensor are presented.

2. Pyroelectric materials

The theory of pyrolectric detection process and properties of pyroelectric materials are covered in details by many authors [5-6].

The pyroelectric materials can be classified into three categories: single crystals, ceramics and polymers. In the first group the most important are triglycine sulphate (TGS) and lithium tantalate ($LiTaO_3$), in the group of ceramics - lanthanum modified lead–zirzonate-titanate (PZT) and from among the organic polymers - polyvinyl fluoride (PVF) and polyvinylidene fluoride (PVDF).

Crystals and ceramic materials are often used in commercially available detectors, although they are not the ideal choice. These materials are hard, heavy and fragile, which makes them quite sensitive to vibrations. On the other hand, their use implies some technological problems because it is rather difficult to obtain very thin and light elements. As a consequence, the useful sensitivity of a sensor decreases and its price increases.

The most important attributes of such a polymer material as PVDF are: exceptionally good electrical properties, relatively wide of operation temperature range, high chemical resistance, insensitivity to moisture. It is possible to produce thin polymer films which thickness is only several μm. Although the pyroelectric coefficient is lower than such an coefficient specifying both crystal and ceramic materials, the sensitivity to be achieved at so light polymer detectors is relative high. Furthermore, a possibility to make elements of complex shapes is also a very important advantage. It should also be added that a price is very attractive, i.e. 0,1$/cm^2.

Despite low cost, easy availability and excellent pyroelectric properties of pyroelectric polymers, there has been essentially no commercially important application of PVDF.

Although such famous manufactures as e.g. Molectron and Coherent that currently produce devices for measurements of laser energy and power, do not use polymer materials in measuring probes a lot of articles still concern with investigations and applications of PVDF.

3. The sensor construction

A pyroelectric sensor based on PVDF has been designed and constructed. Figure 1 illustrates the sensor construction, while its main features are specified in Table 1.

Table 1. Main features of the constructed PVDF sensor

Parameter	
Aperture: diameter	13 mm
Aperture: area	1,69 cm^2
Material	Aluminium metallized piezo/pyroelectric film PVDF
Thickness of PVDF film	25 μm
Sensor configuration	Flat
Capacitance	590 pF
Voltage responsivity	70 mV/mJ

The sensing element is a piece of PVDF foil of 25 μm in thickness and 13 mm in diameter. Both sides of the foil are covered with aluminium. The front sensor surface which is exposed to radiation, is electrically connected to the head in order to avoid of electromagnetic disturbances. The back sensor surface is connected to the signal electrode of the sensor.

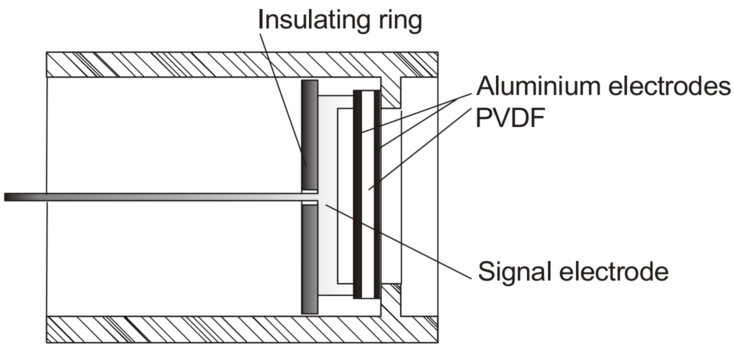

Fig. 1. Schematic of the sensor with PVDF foil

Figure 2 presents the view of the constructed sensor.

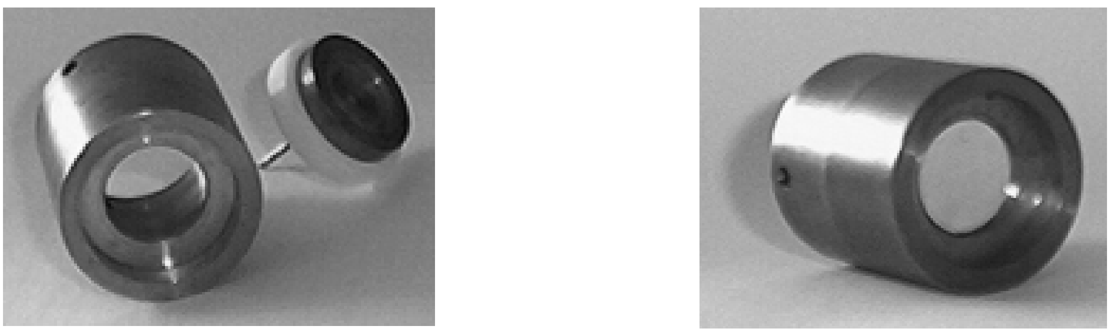

Fig. 2. View of the constructed PVDF sensor

The exemplary record of an output signal acquired from the realized PVDF sensor allows a determination of the response time of this sensor. In particular, it is possible to determine three components of the total response time: rise time, decay time and recovery time. Fig. 3 and Fig 4 .show the voltage detector response to a short (20 μs) radiation pulse.

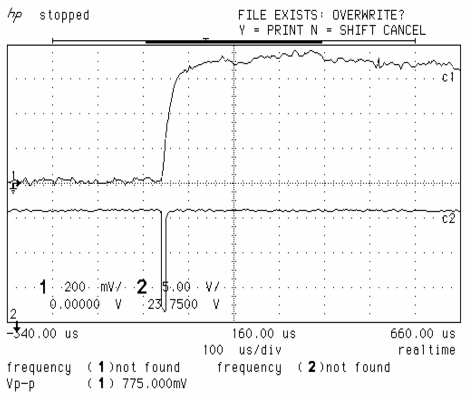

Fig.3. Rise of voltage response signal (c1)of the constructed PVDF sensor excited with a short (20 μs) radiation pulse (c2)

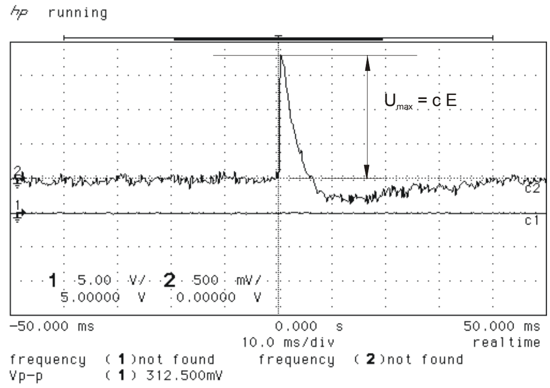

Fig.4. Voltage response of the constructed PVDF sensor to a short radiation pulse (width of pulse is 20 μs)

Results of the experiments show that the recovery time is equal about 34 ms, while the decay time is 6 ms, and the response time is about 120 μs.

4. Scheme of the amplifier of the PVDF sensor signal

The amplification of the output signal of the detector can be realised either in the voltage mode with a high impedance amplifier or in the current mode with a transresistance amplifier (current-voltage converter). The operation in the voltage mode permits getting a relatively high output voltage signal, while the current mode ensures a possibility of measuring the energy of radiation pulses of high frequency of repetition. Designed and constructed amplifier system operate in the voltage mode. A scheme of the amplifier system is shown in Fig. 5.

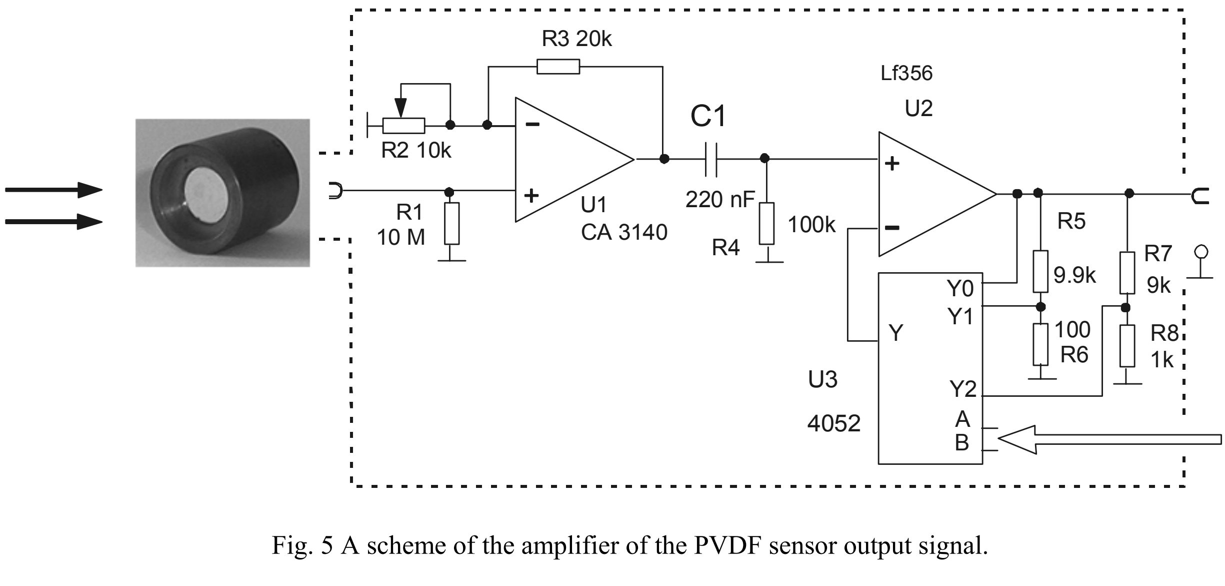

Fig. 5 A scheme of the amplifier of the PVDF sensor output signal.

The system comprises a preamplifier providing a possibility of a variable amplification, based on the operation amplifier U1 (CA 3140), and an amplifier U2 (LF356) allowing adjustment amplification in the ranges: x1, x10, x100. The resistors in the feedback loop of the amplifier U2 are switched by an analogous key U3 controlled by digital signals A0, A1. The system is carefully shielded and mounted in the case of the probe. Designed curcuit of amplifier cooperates with converting system is reported in articles [7-8].

5. Conclusions

In the paper a brief review of currently used pyroelectric materials is presented. The design and construction of a sensor for measurements of impulse radiation energy have been described. The main element of the sensor is a polymer PVDF detector of relatively large area of a very low price when compared to that of standard sensors for radiation energy measurements. A system of an amplifier cooperating with the sensor has been designed and constructed. The study is in progress.

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