The effects of the Peak Temp and the Time above liquidus are not consistent for different component sizes and for SnPb and SAC305 solder joints.

The shear force of SnPb solder joints is higher than that of SAC305 solder joint because the wetting of SnPb is better than that of SnAgCu.

Additional work is needed to complete the quality study of this project, especially in studying the inter-metallic structure of the alloys.


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**Z. Hotra[1,2], M. Skoczylas[2]**

[1]Lviv Polytechnic National University, Lviv, Ukraine

[2]Rzeszów University of Technology, Rzeszów, Poland


# OPTICAL WAVEGUIDE TEMPERATURE SENSOR WITH LIQUID CRYSTAL




**Наведено результати розроблення та дослідження сенсора температури на основі пластикового оптоволокна та нематичного рідкого кристала. Сенсор характеризується простою конструкцією і легкою адаптацією до різних умов. Використання термо-оптичних ефектів в сенсорах є дуже зручним під час роботи з агресивними середовищами.**

**The construction and obtained results of temperature sensor operation based on plastic optical waveguide and nematic liquid crystal have been presented. Such sensor is characterized by simple construction and easy sensory adaptation. Using thermal-optical effects in sensor part is very useful for application in disturbed environments, etc.**


## 1. Introduction

The optical waveguide sensors have a strong positions in metrology as well as their undeniable advantages like immunity on electro-magnetic disturbances make such devices very useful for selected applications. The construction of temperature sensor where the temperature influence on optical properties of liquid crystal was used has been presented in this paper.

Nematics – as one-axial crystal – have two main refraction coefficients $n_0 = n_I$ i $n_e = n_{II}$. Usually $n_{II} > n_I$ and nematics double refraction Δn is positive. The values of the such coefficients are equal about 1,5÷1,9 and 0,4, respectively.

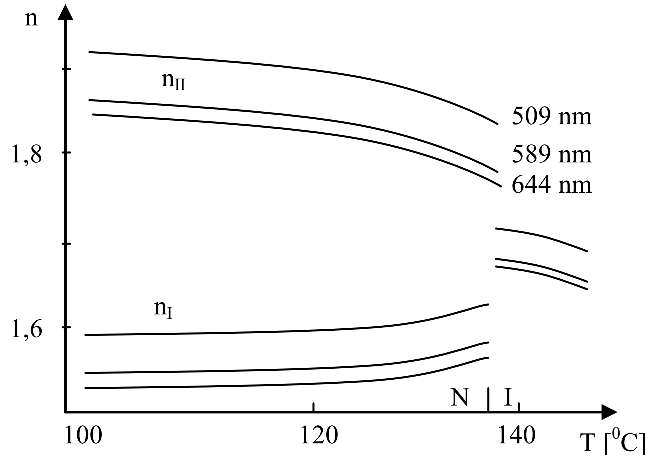


*Fig. 1. Light refraction coefficients for PAA vs. temperature with different wave lengths*

Sensor was built based on PUV 800N optical waveguide with 600μm core diameter and silicon coat with 700μm diameter. The whole optical waveguide is coated by nylon shield with 800μm diameter. The optical parameters were presented in Fig.2. This device has small attenuation for light length about 650nm and 800nm. From this reason the wave length emitted by light source should be from this range (it is very favorable – popular LED diode). Then, the sensor distance from electronic measuring systems can be significant.

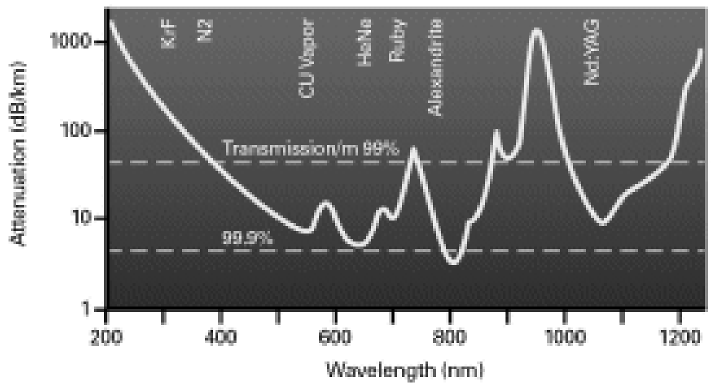


*Fig. 2. Attenuation vs. length of light wave for PUV 800N optical waveguide [1]*

The operation of jumped waveguide is based on principle of complete internal light reflection between coat and cover with constant coefficients of light refraction. The elaborated sensor operates on the basis of this phenomena but the part of removed cover was replaced by liquid nematic crystal where coefficient of light refraction is dependent on temperature. It has direct influence on amount of trickled modes from core under temperature changes – in other words – on light intensity on optical waveguide output.

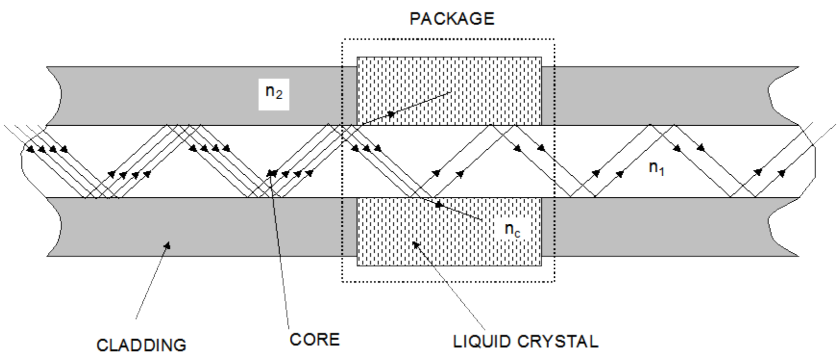


*Fig. 3. Construction and operation principle of optical waveguide temperature sensor with liquid crystal as active element*

As sensor encapsulation the copper was used as material with very good thermal conductivity. The sensor prototype is presented in Fig. 4.

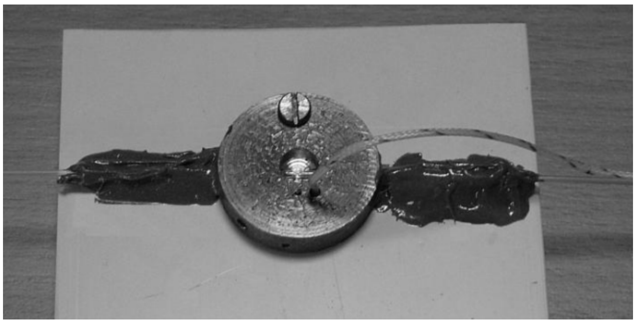

*Fig. 4. Prototype of temperature sensor*

## 2. Measuring procedure

The conception of the measuring stand was presented in Fig. 5. Sensor was placed in heating chamber with temperature stabilization. The light source was built based on LED diodes (635nm and 950nm). The light intensity was measured using OR-2 optical power meter. Additionally, the reference temperature was measured by TES 1307 K/J meter with J-type thermocouple.

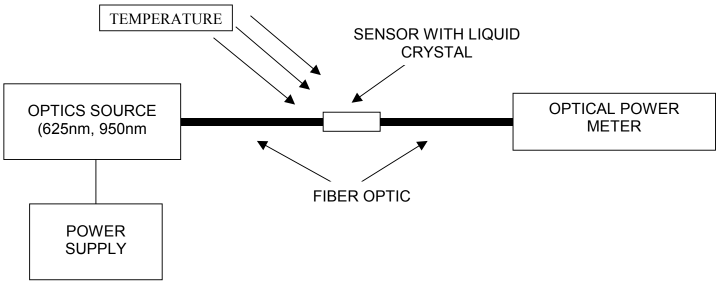


*Fig. 5. Block diagram of measuring system*

## 3. Results

The measurements were carried out for two wave lengths – 625nm and 950nm. The results are illustrated in Fig.6.

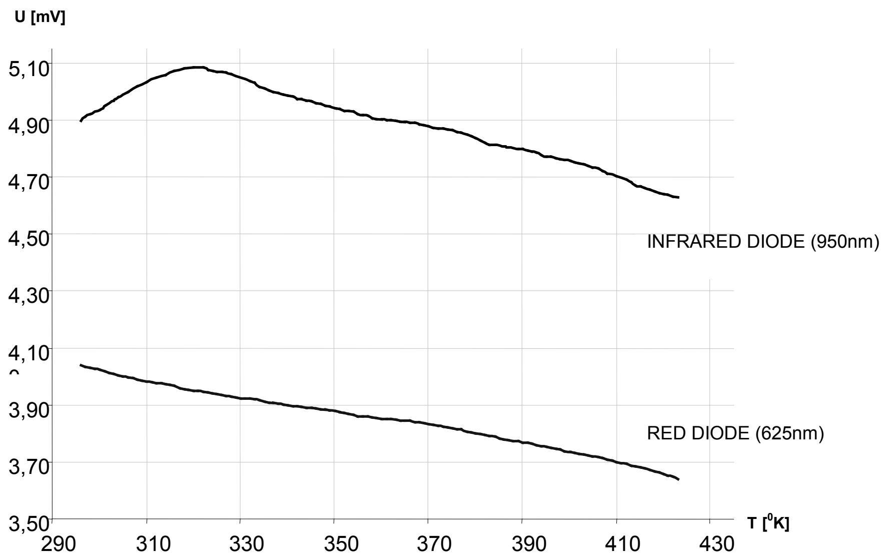


*Fig. 6. Light intensity on sensor output vs. temperature with using infra-red and red diode*

The widest range of measured temperature was obtained with wave length equal 625nm. The sensor was characterized by very good linearity. The application of wave with length equal 950nm causes the narrowing of measuring range – the nearly linear change of output signal is observed for temperature over $330^0$K. The absolute error of the sensor is presented in Fig.7 (reference temperature was measured using professional meter). In the tested temperature range the value of absolute error was equal no more than 1,2%.

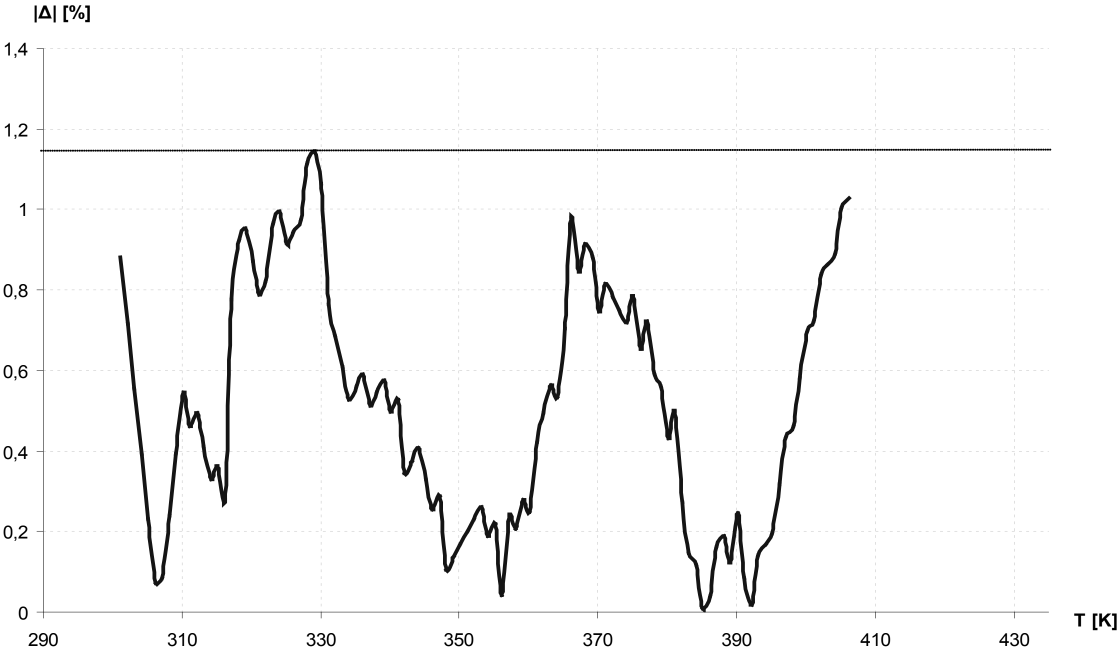


*Fig.7. Absolute error of sensor for wave length equal 625nm*

## 4. Conclusions

The application of liquid crystals (their optical parameter changes under selected external factors) together with optical waveguide (as transmission medium) for measurements of physical quantities is very perspective. Such sensor has a many advantages in relation to the other solutions.

The elaborated sensor is characterized by good linearity In the measured temperature range. The increasing of sensitivity and measuring resolution can be obtained by increase of light intensity which supplied of sensor. The change of wave length emitted by light source has also big influence on sensor parameters. The proper selection of optical waveguide type, liquid crystal and supplying parameters can determines about functional parameters of sensor.

The big advantage of optical waveguide sensors is their immunity on external electromagnetic fields, so they can be applied in industry, medicine and other specific environments.


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