Temperature fiber optic sensor using a thermosensible hydrogel

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ABSTRACT

Nowdays, polymers like hydrogels that respond to well defined stimuli, have a particular interest in fields like optoelectronics, biotechnology, materials, etc. One of this polymers is the NIPAAM, that posses thermo optics properties. This work is oriented to the design and implementation of a temperature sensor using fiber optics and having as sensitive part a sintetized hydrogel of polyNIPAAM and MeOXA of reversible thermosensible characteristics. For this setup we use a glass ampoule which is coupled to two pieces of plastic, inside the ampoule it is placed the hydrogel. The working principle relies in the turbidity changes in a well known temperature called critical. We present the experimental results of the designed and implemented device.

Keywords: Plastical fiber optic, hydrogel, temperature sensor, light intensity, polymer, critical temperature

1. INTRODUCTION

Currently, there is a developping of a great number of optical setups to detect several physical parameters. The use of fiber optics has proved to have advantages in the construction of optical sensors and devices. By using its properties in a convenient way, practical optical sensors can be developped. Plastical optical fibers (POF) have some advantages over glass fibers in low budget sensors, such as great flexibility, large diameter and numerical aperture, hardness, easy manipulation and low cost. These advantages make its use an interesting alternative in the field of instrumentation of engineering.

This work is about the evaluation of the sensor to changes in the temperature when it is submerged in liquids. A laser light is transported by the fiber optic until it reaches the sensible part where the hydrogel will manifest changes in its thermo optics properties, these device has an approximate working range from 35°C to 50°C.

2. THE POLYMER

We have started our work some time ago by studying first, the characteristics and possible use of the polymer N-isopropylacrylamide (NIPAAm). In Fig. 1, it is shown the simple setup we have used. For all the work done, we have used as light source a diode laser OS-8525, as a detector a high sensitive photodiode CI-6604 and our primary data adquisition system was a Science Workshop 750 Interface and later a National Instruments PCI-6023E.

The software used was Data Studio from PASCO and for the final part, MATLAB because of its programming facilities and easy to use graphical user interface tools.

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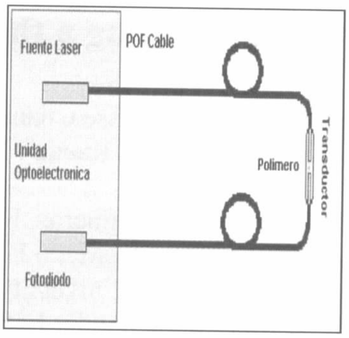

Fig. 1. Experimental setup

The typical response of this polymer for the configuration in transmission used above is shown in Fig. 2

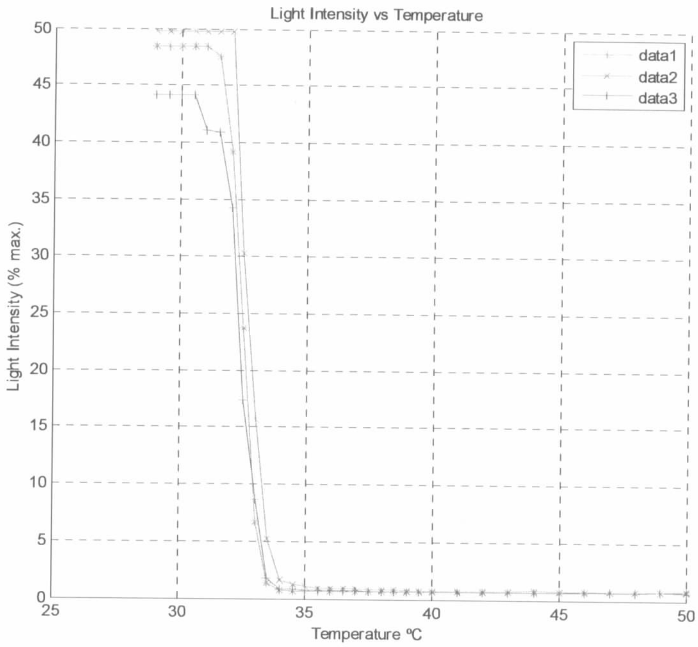

Fig. 2. Polymer optical transmission response

An optical temperature relay was one first application to be developped by taking profit of the critical temperature that is always the same and the fact that the response of the polymer presents a convinient hysteresis of about half a degree when is heating or cooling.

Several configurations were tested, in series, in parallel, by transmission and reflection. In the following figure is shown the setup for a parallel configuration.

An alarm system was implemented using this optical relay that fired a contactor that started or stopped an ac induction motor, when the optical setup was inmmersed in a small tank and was subjet to temperature changes.

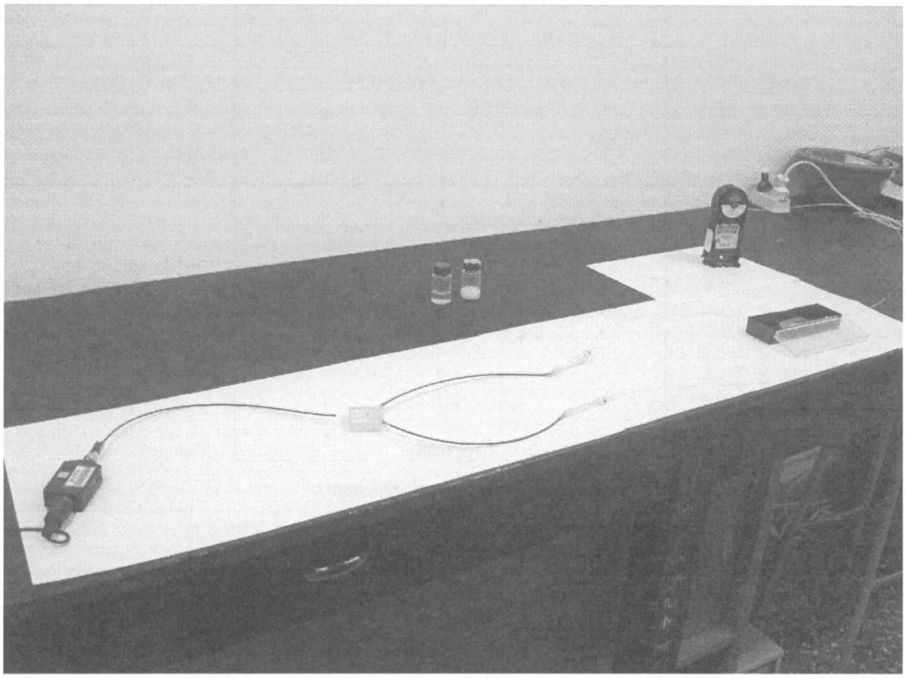

Fig. 3. Parallel configuration of the optical temperature relay setup

3. SYNTHESIS OF THE HYDROGEL

This hydrogel is based on the radical copolymerization of N-isopropylacrylamide (NIPAAm) and bis-macromonomers of 2-methyl-2-oxazoline (MeOXA). The hydrogels show conformational transitions at a defined temperature, which is a function of the molar ratio NIPAAm / MeOXA inside of the hydrogel, which experiments a quick and reversible phase transition when its hidrogen chains are below their critical temperature, passing from a swelling to a shrinking state.

The hydrogels are polymeric solids specially suited to form gels thanks to their large structure chains, the flexibility of these chains make possible their deformation to allow the introduction of disolvent molecules inside their tridimensional structure.

They swell in water considerable increasing their volume until reaching a chemical-physical balance, without loosing their shape. The swelling state is the result of the balance between dispersive and cohesive intermolecular strengths that acts in the hydrated chains.

The hydrogels can also present a swelling behavior dependent of the external medium. Some of the factors that affect the swelling of this type of hydrogels are the pH, ionic strength, temperature and electromagnetic radiation, mechanical tension, light, pression, etc. This phenomen has fueled the developping of technological applications in the fields of chemistry, medecin, environment, agriculture, etc

As the hydrogel optical transmission response is different in comparison to the polymer alone, instead of making a simple optical switch and in spite of the non linear response, we have proposed its use as a temperature sensor in a specific range.

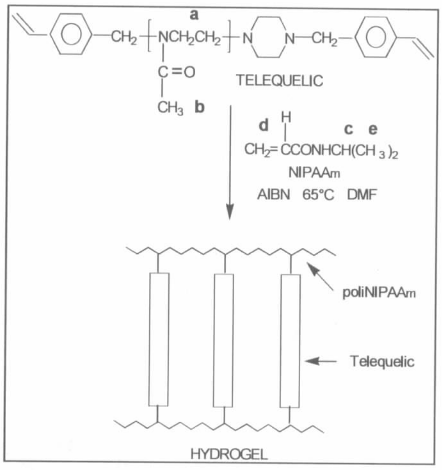

Fig. 4. Polimerization process

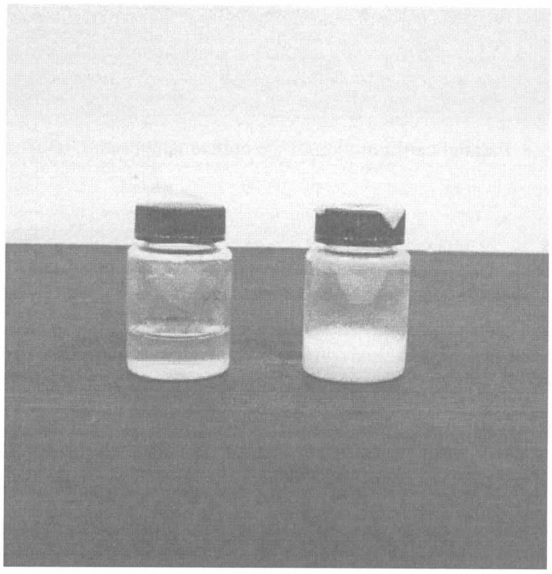

Fig. 5. Non dispersed and dispersed polymer

4. EXPERIMENTAL SETUP

In this work, we present the design and construction of a sensor based in a plastical optical fiber of PMMA, 2mm of diameter and core and cladding refraction index of 1,492 and 1,402 respectively, having a numerical aperture of 0,5.

We also use a cylindrical glass ampoule with a length of 65mm and a diameter of 3mm, coupled in the extremes to two pieces of plastical optical fiber, one of these fibers is coupled to a laser diode of 660nm and the other extreme to a PIN photodiode. Inside the ampoule is placed the hydrogel in a volume of 35ml as it is shown in the following figure and photography.

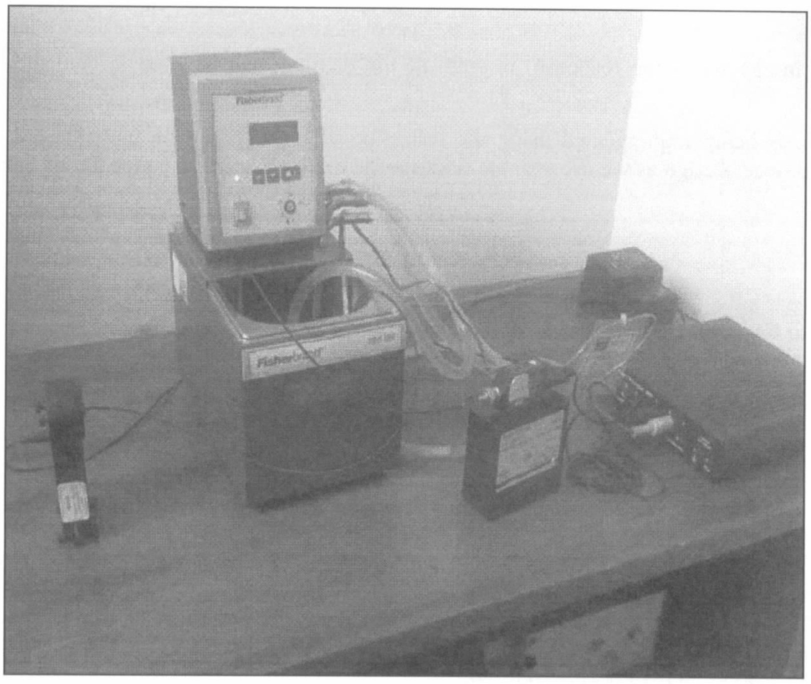

Fig. 6. Photography of the system

5. RESULTS AND CONCLUSIONS

The esperimental response, at different dates, of this setup is shown in the following figure

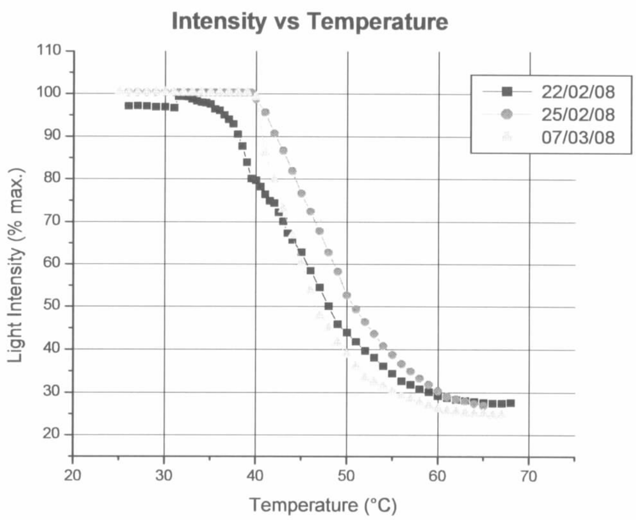

Fig. 7. Hydrogel optical transmission response

For this first setup, the shape of the response, in spite of the drifting, can be used to find the respective unknown temperature.

A more simple setup is being implemented using the reflection of the light in the fiber instead of the transmission, resulting in a more compact design as we use a single fiber for the transmission and collection of light.

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