THE PRINCIPLE OF RECORDING INFORMATION IN DISTRIBUTED ENVIRONMENTS VIA SULEIMENOV-MUN'S WAVES

Dolayev M., MS
Obukhova P., MS
Almaty University of Power Engineering and Telecommunications, Almaty, Kazakhstan
Panchenko S., MS
Al-Farabi Kazakh National University, Physico-Technical Faculty, Almaty, Kazakhstan
Bakytbekov R.B., MS
Al-Farabi Kazakh National University, Faculty of Chemistry and Chemical Technology, Almaty, Kazakhstan
Ivlyev R.S., MS
Kazakh-British Technical University, Almaty, Kazakhstan
Chezhimbayeva K., PhD
Almaty University of Power Engineering and Telecommunications, Almaty, Kazakhstan

Abstract:

A new approach to information recording in distributed media based on the forced wave excitation involved by temperature fluctuations was proposed. The scheme of the device providing the implementation of the proposed approach is considered.

Key Words: Waves, nonequilibrium systems, phase transition, stimuli-sensitive polymer

Introduction

The problem of recording of information in nanostructures remains one of the important issues for nanotechnology in general [1]. To solve this, a variety of approaches are offered, which are reviewed in [2]. Unfortunately, none of them has been able to find a practical implementation on an economically feasible level. This makes it relevant to the development of the simplified scheme for recording information in nanostructures.

In general theoretical positions, in order to work with nanowildscale elements, it is appropriate to use different kinds of self-organization processes. In particular, by focusing waves of appropriate scale to a certain point in space, you can realize local changes in environmental conditions. Such issue makes it relevant to the solution of recording information problem in distributed media of different nature, based on the use of waves, spontaneously arising in this media.

This paper describes the use of a recently discovered type of waves [3] (Suleimenov-Mun waves [4,5]) for the purpose of recording information in distributed environments. The Suleimenov-Mun waves can be defined as fluctuations, developing in a nanoequilibrium medium near the phase transition. As shown in [3], such waves appear due to the time delay between the moment of reaching a critical temperature (or another critical parameter) and the actual moment of the phase transition. Due to the fact that the phase transition in solutions of stimuli-responsive polymers can be initiated by various external influences, there may exist various types of the considered waves.

Experimental

The example of experimental results [6], confirming the theoretical predictions in[3], are shown in Figure 1. 2% solution of copolymer NIPAA:AA 90:10 at pH 6-7 in the temperature range from 26 to 40 ^{0}C was investigated. Selected polymer has a phase transition temperature of about 32 ^{0}C, at which there is an abrupt turbidity. This allows to measure the content of macromolecules, passed into the partially soluble form by turbedimetry (measuring the intensity of light passing through the solution). In particular, it is possible to investigate the variation in the number of these macromolecules by measuring the optical density fluctuations.

The relative intensity of the light transmitted through the solution vs. time was recorded, the time resolution of the equipment was 1 ms, the unit assumed the value corresponding to the intensity of the light transmitted through the cuvette at the initial time.

The solution was placed in a rectangular cuvette with the optically transparent walls cooled by external water jacket. The wire element located inside the cuvette provides heating of the solution to the desired temperature. Figure 1 shows that the state of the thermosensitive polymer solution near the phase transition is characterized by fluctuations in the optical density, which have a regular (periodic) character.

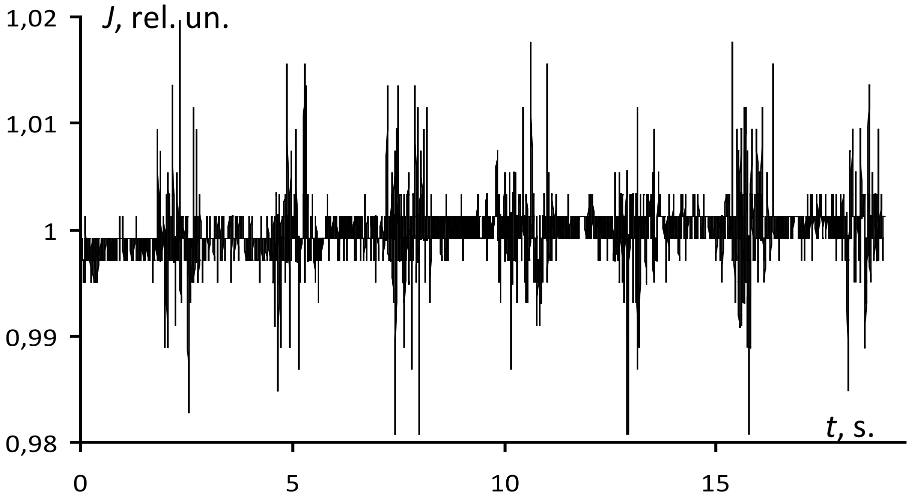

Figure 1 – Dependence of the relative radiation intensity passing through the cuvette vs. time; T = 38 ^{0}C [6].

Results and discussion

Qualitatively, the appearance of these fluctuations can be interpreted, starting from the assumption concerning the final rate of the phase transition. This assumption, in particular, means that there is a time delay between the moment of heating the local area within the polymer solution to the temperature T_{ph} and the time when molecules in this field changes its state.

This assumption seems more than justified, since the phase transition is accompanied by a change in size of the macromolecular coil. At temperatures below the T_{ph} the hydrophilic-hydrophobic balance is shifted towards hydrophilic interactions. It corresponds to the expressed interaction of macromolecule links with molecules of solvent. This, in particular, means that the macromolecular coils are in the swollen state in these conditions.

On the contrary, the hydrophilic-hydrophobic balance is shifted to the direction of strengthening the hydrophobic interactions by increasing the temperature T_{ph}. As a result, macromolecules partially lose their solubility and coils formed by them are compact. The transition from one state to another, at least requires sufficient time for diffusion (or directed movement) of macromolecule segments originally located on the periphery of the coil to its core. This shows a non-zero amount of time elapsed during the phase transition.

Similar conclusions can be obtained by examining the process of displacement of water from the coil when it is compressed. In this case, the parameter τ can be estimated as the time required for the outflow of the amount of water through the substance of the polymer.

We show that this assumption is sufficient to explain the occurrence of the predicted fluctuations in type observed in the work [3].

Let suppose that initially the temperature of solution was below T_{ph}. Assume that the solution is heated by some source of heat (in the simplest case, this may be a resistor immersed in solution). After turning on the heat source the solution will be heated and at a certain point in time the temperature rises to $T_{ph.}$ However, due to the finite speed of such phase transition, as it will be demonstrated later, the solution is heated to a temperature above $T_{ph.}$

Further, the phase transition will cause some cooling of the solution, due to energy loss associated with overcoming the corresponding potential barrier. Provided that power level of the heat source is close to the threshold value the cycle will be repeated again. The oscillation amplitude of a purely thermal character is small, but it can be significantly increased by directly heating the solution with electric current. It was theoretically described in [3].

Application

This type of waves can be used to record information in the media, where the phase transition occurs. The scheme realizing this approach is demonstrated in Figure 2.

The two-dimensional wave is used to record information, focusing through at some point. The amplitude exceeds the critical value in the area of focus, corresponding to stable phase transition while in the remaining sections of the medium amplitude has a value below the critical threshold.

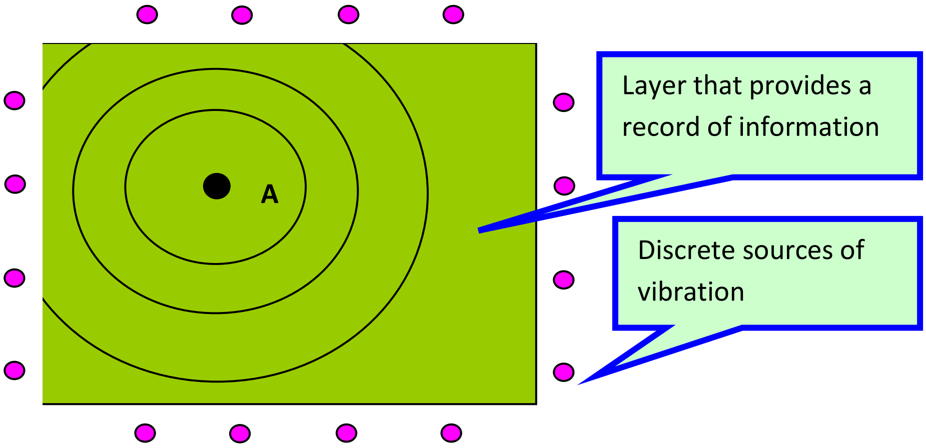

Figure 2. Scheme of a convergent cylindrical wave realization for recording information in a distributed environment.

Conclusion

The waves in Figure 2 are excited by the discrete sources of vibrations. For Suleimenov-Mun thermal waves conventional heating elements can be used. The synthesis of a required configuration of the wave is provided by the selection of phase delays between sinusoidal voltages applied to the individual elements. The record of information is implemented by irreversible changes in the environment, that are caused by the temperature (or other control parameter) exceeding a critical threshold.

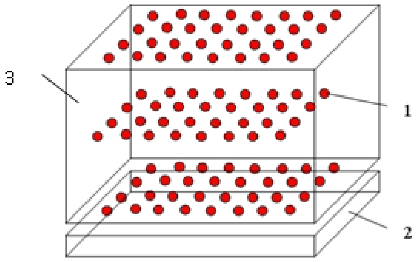

Figure 3. Using a grid made up of heating elements for the stabilization wave focusing, 1 – heating elements, 2 – medium, in which information is recorded, 3 – cuvette with a solution.

However, waves of this type have sufficiently complicated dispersion law [3,6]. Therefore, it is appropriate to use a three-dimension structure, shown schematically in Figure 3,for their excitation . The periodic arrangements of heating elements in this case allow for a stabilization of the waves used by a spatial period and, thus, to eliminate errors associated with instability of the dispersion of Suleimenov-Mun waves. The environment, in which information is recorded, is located directly below the grid formed from the heating elements. This medium can be made of, for instance, a temperature-sensitive hydrogel, which has the phase transition temperature of the solution used.

In this paper, a model structure was implemented, based on three layers each of which is a diode-resistive matrix (Figure 4).

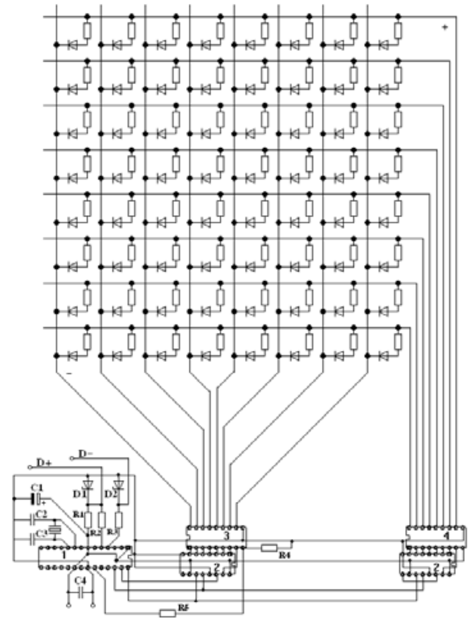

Figure 4. The scheme of the diode-resistor matrix for the stabilization system of a Suleimenov-Mun wave excitation

The use of SMD component provides a type of medium heating that can be described as "dotted". The diodes are used to prevent the appearance of parasitic reverse currents. The control circuit is a controller on the chip ATMEGA8-16P.

Conclusion

The test experiments have shown that this type of a grid really provides a resonant excitation of waves of this type, and can stabilize the spatial period of the wave, whose amplitude reaches 20 – 30% based on a modulation of the optical density of medium. Thus, the initial experiments conducted in this study show that there is a possibility of focusing waves spontaneously arising in a liquid-phase systems.

References:

Suleimenov I.E., Mun G.A. Osobennosti vozniknoveniya avtokolebatelnyh processov v zhidkofaznyh sistemah v oblasti fazavogo perehoda// Izvestiya nauchno-tehnicheskogo obshestva "KAHAK"// The features of self-oscillation processes in liquid-phase systems in the transition region// Proceedings of the scientific and Technical Society "KAHAK", 2012, № 3 (37), p.109 [3].

Suleimenov I., Mun G., Ivlev R., Panchenko S., Kaldybekov D. Autooscillations in Thermo-responsive Polymer Solutions as the Basis for a New Type of Sensor Panels, Proc. 2012 AASRI Conference on Modeling, Identification and Control, December, 10-20, Hong Kong, accepted [6].

Yergozhin Ye.Ye., Aryn Ye.M., Suleimenov I.E., Mun G.A., Belenko N.M., Gabrielyan O.A., Park N.T., Negim El-S. M. El-Ash., Suleymenova K.I. Nanotechnology versus the global crisis / Seoul, Hollym Corporation Publishers, 2010, 300 p. [1].

Yergozhin E.E., Zezin A.B., Suleimenov I.E., Mun G.A. Gidrofilnye polimery v nanotehnologii i nanoelektronike (monografiya) (In Russian language) // Hydrophilic polymers in nanotechnology and nanoelectronics (monograph)// Library of nanotechnology, Almaty-Moscow: LEM, 2008, p. 208 [2].

Yermukhambetova B.B., Semenyakin N.V., Abdykalykova R.A., TimofeyevA.V., Dergunov M.A., Kaldybekov D.K., Use of the Suleymenov-Mun Waves in PowerEngineering // 8th International Conference on Nanosciences & Nanotechnologies ", 7 - 15 July 2011 Thessaloniki, Greece. [4].

Yeligbayeva G., Shaikhutdinova A., Irmukhametova G., Bublik V., Shaikhutdinov E. Excitation of Suleimenov – Mun's waves at polymer composite surface // 7th IUPAC International Conference on Novel materials and their Synthesis (NMS-VII) & 21st International Symposium on Fine Chemistry and Functional Polymers (FCFP-XXI), Shanghai, 16-21 October, 2011 [5].