Ph.D. Dissertation
„Information processing in neuron-imitating chemical systems”
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Abstract

The Ph.D. dissertation is devoted to chemical systems exhibiting properties similar to those characterizing the neuron cells and to their possible applications in a novel interdisciplinary branch of information theory called unconventional computing.

The studied systems are based on the classic oscillating Belousov-Zhabotinsky reaction, exhibiting, among others, periodic pulses of concentration of catalytic metal complexes involved in the reaction. These pulses, known as chemical waves, behave similarly to nerve impulses in living systems – they demonstrate e.g. excitability (the „all-or-nothing” response) and refractory period. For this reason, their interactions became a starting point for the construction of chemical information processing devices, some of which were demonstrated for the first time in the Institute of Physical Chemistry.

The first system is powered by the modified, light-sensitive Belousov-Zhabotinsky reaction taking place in a gel layer. When using an appropriate mask, the chemical waves can be spatially limited to a non-illuminated area corresponding to the mask. The shape used in the thesis is a triangular capillary, becoming narrow towards one of the tips. The chemical pulses entering the capillary exhibit complex behaviour, which finds confirmation in numerical simulations. The precise type of behaviour depends strongly on external conditions, mostly on illumination level outside the channel, which allows us to treat this system as a detector. The experimental studies are conducted in a flow reactor, which extends the timespan of stable pulse behaviour approximately ten times when compared to previous work.

The second part contains the description of research concerning an unconventional computing system which resembles nerve systems structurally as well. This is the first such system of a purely chemical nature. It consists of aqueous droplets of diameters on the order of 1-2 mm, containing the reagents of the oscillating reaction, surrounded by a phospholipid solution in decane and contacting through lipid bilayers. The properties of the system, such as influence of the composition and size of the droplets on the oscillations, as well as the optimum composition of the oil phase, are discussed. Then follows the description of the propagation of pulses between droplets and the frequency transformation occurring on the border of droplets differing in excitability. By tuning the density of the organic phase, it is possible to build systems that pave the way for construction of three-dimensional droplet networks, which would increase their capabilities enormously.