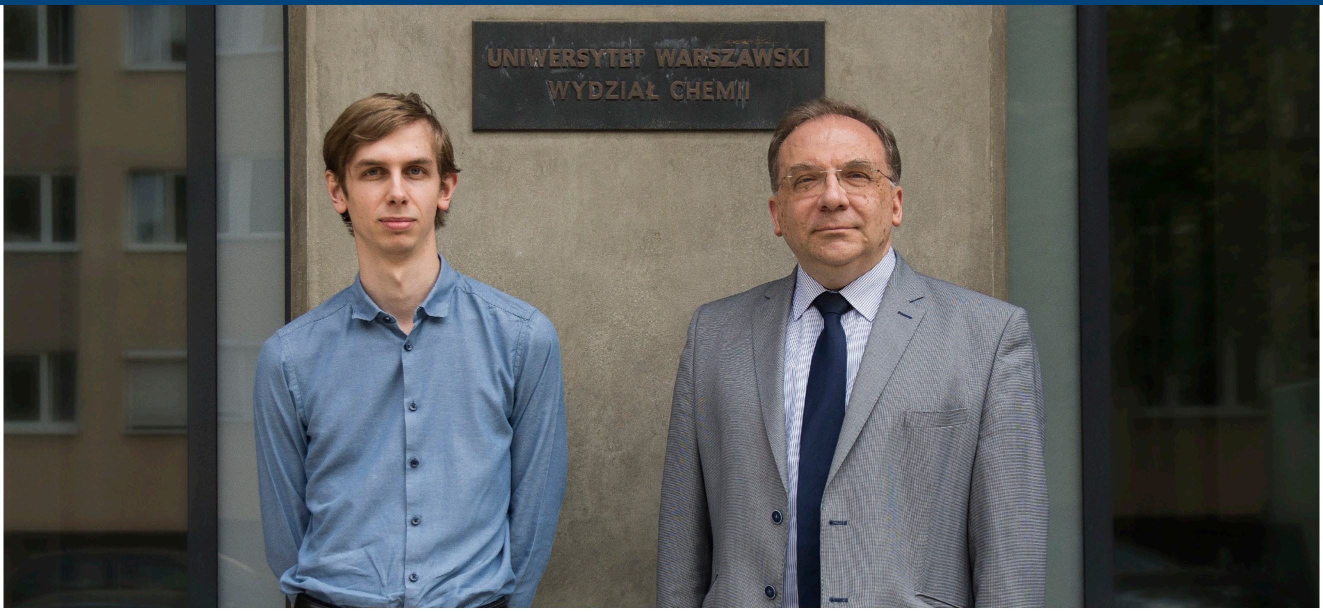
Group of Nonlinear Dynamics in Chemical and Electrochemical systems



HEAD:

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GROUP MEMBERS:

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RESEARCH PROFILE

Studies of dynamic self-organization of matter in chemical and electrochemical systems exhibiting nonlinear dynamics. Such phenomena, occurring beyond the state of chemical equilibrium, comprise (i) spontaneous oscillatory variations of the systems' state and (ii) multistability, i.e. the coexistence of more than one stable steady-state for the same set of control parameters.

Moreover, the coupling of transport (e.g., diffusion) with nonlinear (electro)chemical reactions can give rise to the non-equilibrium (dissipative) patterns. All these kinds of phenomena occur in various chemical and physical systems, mimicking thus the self-organization and pattern formation in biological systems (e.g. Turing patterns, pulsatory heart dynamics, circadian rhythm. etc.). The universal characteristics of those phenomena is given by their mathematical analysis, leading to the schemes of bifurcations common for various dynamical systems [1, 2].

CURRENT RESEARCH ACTIVITIES:

Recent research activity of the group focusses on the oscillations and pattern formation in the chemical oscillators based on the oxidation of sulfur-containing compounds by hydrogen peroxide. For the H_2O_2–SCN^- – OH^- – Cu^{2+} oscillator, the most important achievements include the reduction of its complex reaction mechanism to the so-called "minimal oscillator", i.e. the core reaction steps which are necessary to induce the oscillatory instability (Fig. 1).
Moreover, it was discovered that this system, in the presence of luminol as an indicator, gives rise to luminescent dissipative patterns only under condition of the non-uniform distribution of temperature, which

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causes the spatial distribution of the oscillatory reaction dynamics. Analogous experimental conditions applied to the H_2O_2 – $S_2O_3^{2-}$ – H^+ – Cu^{2+} system in the presence of the pH indicator caused the formation of travelling front of pH (Fig. 2).

Both latter results indicate the novel mechanism of pattern formation in aqueous media, complementing those proposed for the systems with uniform temperature distribution.

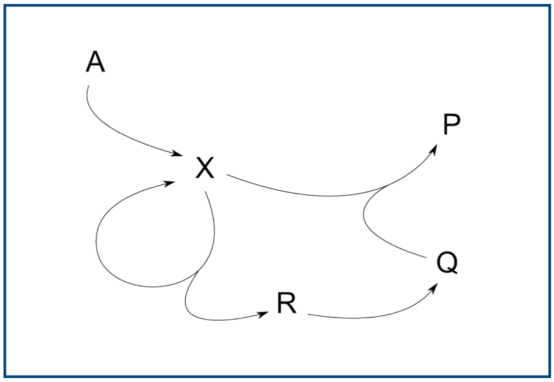

Fig. 1. Reaction network of the "minimal oscillator" of the H_2O_2 – SCN^- – OH^- - Cu^{2+} system in which X is autocatalytically produced from reactant A and then X is consumed by intermediate Q acting as a negative feedback species [4]. Reprinted from [4] with permission from John Wiley and Sons, Inc. © 2015.

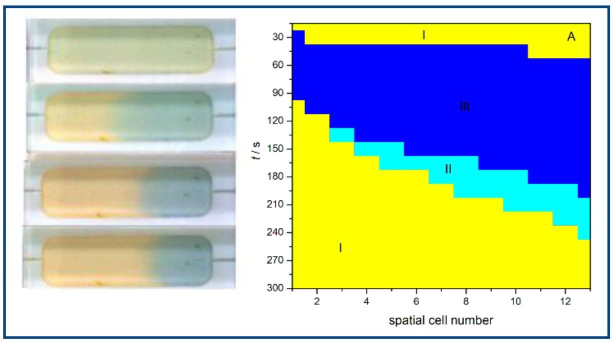

Fig. 2 (left) Experimentally reported color pH front moving in the H_2O_2 - $S_2O_3^{2-}$ - H+ - Cu^{2+} + thymol blue system subject to inhomogeneous temperature distribution; (right) mathematical model of this process [5]. Reprinted with permission from [5] Copyright 2016, American Chemical Society.

SELECTED PUBLICATIONS:

1. M. Jędrusiak, M. Orlik, The formation and spatiotemporal progress of the pH wave induced by the temperature gradient in the thin-layer H_2O_2 – $Na_2S_2O_3$ – H_2SO_4 – $CuSO_4$ dynamical system, J. Phys. Chem. B. 120 (2016) 3169-3177.
2. M. Jędrusiak, A. Wiśniewski, M. Orlik, The model of "minimal oscillator" derived from the kinetic mechanism of the H_2O_2 – NaSCN – NaOH – $CuSO_4$ dynamical system, Int. J. Chem. Kinet. 47 (2015) 791–802.
3. A. Wiśniewski, M. Jędrusiak, I. Mojzych, M. Orlik, Model calculations and experimental studies as a route toward simplification of the kinetic mechanism of the H_2O_2 – NaSCN – NaOH – $CuSO_4$ homogeneous oscillator, Int. J. Chem. Kinet. 47 (2015) 671–683.
4. M. Orlik, Self-Organization in electrochemical systems. II. Spatiotemporal patterns and control of chaos. In: Scholz F. (ed.) Monographs in Electrochemistry, Springer, Berlin-Heidelberg 2012.
5. M. Orlik, Self-Organization in electrochemical systems. I. General principles of self-organization. Temporal instabilities. In: Scholz F. (ed.) Monographs in Electrochemistry, Springer, Berlin-Heidelberg 2012.