

Reaction-diffusion optoelectronics based on dispersed semiconductors

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Abstract. Since many dispersed semiconductors are capable of light energy conversion and possess photocatalytic and luminescent properties, and any discreet light-sensitive medium can be applied for the positional-sensitive light flux registration (similar to pixels and voxels in semiconductor-based image recording), the use of chemically active dispersed semiconductors allows to perform a direct signal / image registration based on light-sensitive reaction-diffusion redox systems without conventional CCD / CMOS devices. The image capturing in this case will correspond to the formation of the metastable dissipative structures in the active medium, with their morphological properties determined by the flux gradient and provided by the corresponding dispersed semiconductor medium sensitivity.

1. Prerequisites

Many dispersed semiconductors are known to be effective light energy converters, photocatalysts and photoluminescent nanoparticles [1-4]. At the same time a dispersed, i.e. a discreet photosensitive medium can be used in a position-sensitive light flux registration, and hence can be applied for the image recording similar to the CCD with the pixel function performed by the discrete semiconductor elements. The above mentioned chemical activity of the dispersed semiconductors allows to perform the charge transport and the image fixation based on the chemical principles. There are several light-sensitive autocatalytic reactions, such as Kuhnert reaction [5] which is a special case of the self-oscillatory Belousov-Zhabotinsky reaction where the redox processes occur in accordance with the light flux gradient. There also have been developed a number of advanced systems for image registration and neural network processing based on light-sensitive BZ-type reactions and other reaction-diffusion systems, including the biomolecular ones [6-10]. However, the lack of the semiconductor properties of the active medium prevents from the direct image capturing, directional data recording and transduction in such systems without using conventional optoelectronic devices (CCD or CMOS positional-sensitive sensors).

2. Our proposals

We propose to use self-oscillatory systems with the redox-catalysis / photocatalysis on the surface of the dispersed semiconductor nanoparticles involved as the redox-agents in the autocatalytic and reaction-diffusion processes. The image recording process in this case will correspond to the formation of the metastable dissipative structures in the dispersed medium, with their morphological properties



determined by the flux gradient and provided by the corresponding dispersed semiconductor medium light-sensitivity, as well as by the reversibility of the photoredox processes similar to those occurring in the photographic process where the silver halide micro / nanoparticles are also both dispersed semiconductors and photocatalysts [11]. The charge nature of the processes in the active medium makes it possible to perform a direct registration according to the principles of the "direct optoelectronics" without using CCD or CMOS active pixel sensors as the secondary image converters in the framework of the above approach [12,13].

Moreover, it is possible to perform registration of non-optical parameters using the appropriate converters of the arbitrary signals into the optical ones, fixed at the optical path in front of the reaction-diffusion medium. In particular, reaction-diffusion dispersed semiconductor registering "matrixes" allow to perform visualization of a number of important physical parameters of the sample, such as:

- a) magnetic field (using magnetic film indicators [14-18] or "flux-detectors"; either with or without the transition through the Curie point under the local laser irradiation)
- b) electrochemical parameters (using planar potentiometric / pH / pX indicators). A similar method with the local diffusion cell walls allows to perform the mapping of the local chemical composition (similar to the reagent indicator paper methods [19-22] but with the transparent carrier), where the light beam with the spectral parameters corresponding to those of the substance under investigation passes through the analyte, located on the optical path in front of the registering reaction-diffusion medium;
- c) laser beam transmission outside the visible spectral range (using the doped solid matrices) [23-26];
- d) distribution of the emitting regions in autoradiography (using the scintillation detectors with different quenching factors, from the simplest CsI(Tl) or CaI₂ [27,28] and other inorganic thin scintillators [29], including rare-earth activated sol-gel films [30], to organic plastic scintillators [31]. The above technology is particularly similar to the Scintillator Pixel Sensors [32], with the solid state optoelectronic components substituted by the reaction-diffusion medium which is sensitive in the optical spectral region of the scintillator emission under the penetrating radiation or particles. This is of special interest in comparison with the beam action on the oscillation reactions in the active medium without a scintillator, which have been comprehensively studied earlier [33-35]. This approach can be also applied to the electron beam-excitation assisted optical microscopy [36] and thin layer fluorography on the mesoscopic scale [37].
- e) polarization characteristics and the angular fluorescence polarization (using position-sensitive polaroids instead of a technique described in [38]; position-sensitive polarization systems can be also designed for both X-rays and gamma rays, but this is a more complex problem [39,40])
- f) the local temperature of the sample at different points (using thermochromic liquid crystals [41-43] or other specially prepared for a certain temperature and spectral emission range thermochromic mixtures and coatings for temperature fields measurements [44,45]).

Thus, reaction-diffusion optoelectronics based on dispersed semiconductors is perspective not only for the optical flux visualization, but also for the colocalization analysis of different physical parameters of the sample, drug or analyte, which can be visualized using various pre-converters of the physical parameter into the optical signal registered by the photosensitive reaction-diffusion medium. Of special interest are the works by Vanag on the self-oscillating reactions in heterogeneous media [46-48] containing a kind of pixels, since their implementation on the dispersed semiconductor medium allows one to perform a position-sensitive analysis without the external controlling factors of the beam structuring, but directly in the self-oscillating system due to the inherent properties of the medium which can be in this case interpreted as an adaptive dynamic system of sensitive elements (sensors).

3. References

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