Description for the general public

Due to growing requirements set before information processing systems a vast part of research efforts aim towards the concepts alternative to conventional silicon electronics. Although, recent studies indicate the possibility to transcend the next threshold of miniaturization (10 nm technology), further reduction in the size of electronic components is not a universal remedy. This is due both to reasons of fundamental nature, as well as because of technological and economic aspects. It is therefore reasonable to assume that some of the studies on information processing systems will focus on the use of tools that are provided by molecular electronics, optoelectronics and other less conventional approaches.

Recent years have brought a wide variety of practical solutions and theoretical models, which led to the rapid development of alternative methods of information processing. One of the milestones has been coinage of the molecular diodes concept (in 1974 By Avirama and Ratner), which contributed to the creation of new ideas based on systems working in a molecular scale. The first transistor incorporating the organic material was constructed shortly afterwards (in 1986 Tsumury group, Koezuka and Ando) – it was a field-effect transistor, the heart of which was made of polythiophenes derivatives. These groundbreaking researches led eventually to the practical implementation of logic functions (in 1993. A. P. de Silva proposed a molecular AND gate) at the molecular level and the constitution of a new branch of electronics – the so-called molecular electronics. Further works carried out simultaneously by hundreds of research groups around the world have enabled the development of these original ideas, which ultimately led to the construction of biochemical sensors, logic gates, molecular optoelectronic components and many other devices that could become the foundation for the future electronics.

Using the new approach offered by alternative branches of electronics, one may be tempted to formulate a thesis assuming the possibility for creation of a fully synthetic molecular/hybrid circuits, which would operate in a manner similar to the structures constituting the central nervous system. Such attempts have been made by researchers working on memristors – i.e. the fourth, missing passive element, which has been postulated theoretically in the early 70s., and realized experimentally in 2008. The results of these efforts are, of course, far from what may be achieved by complex biological structures, but still, some of the memristors circuits properties successfully reproduce basic functions of systems found in nature.

An interesting way to develop some of these concepts could be provided by a combination of selected elements taken from the molecular electronics with the ideas belonging to the neuromorphic engineering. At the same time, drifting away from conventional silicon chips could facilitate the introduction of multi-valued logic within the designed systems, which would plasticise possible ways of communication with the device and between individual elements. This in turn reflects the situation that we find in the biological structures, where information transfer does not depend entirely on the simple bivalent logic, but rather utilises the paradigms of multi-valued logic and fuzzy logic (a similar argument can be found in the works of Pier Luigi Gentili and other researchers).

This expansion of the set of logic states or even switching to the fuzzy logic can be the first step towards the creation of prototypic bio- and chemosensors that through the implementation – at the level of material and device – selected concepts neuromorphic engineering (including synaptic plasticity) could exhibit significantly greater sensitivity, selectivity and reduced response time compared to systems based on the silicon elements and the binary logic. On the other hand, the combination of these ideas within a single device can open up new paths for development of electronic and optoelectronic components, and in the future can contribute to the construction of systems that process information based on new, more advanced – compared to the binary logic – paradigms.

Designing prototypic systems will require to plan syntheses and testing procedures to examine photoelectrochemical properties of materials. The formulation of models describing the interactions between individual components of the nanocomposites will be also necessary. However, the effort made seems to be a rather small price, taking into account the possibility that the created devices will be capable of mimicking some of the function of structures constituting our sensory system and the nervous system.