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Editorial

Special Issue

Molecular Logic: From Single Logic Gates to Sophisticated Logic Circuits, from Fundamental Science to Practical Applications

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Moore's law predicts the exponential development of computing systems based on silicon materials and binary algorithms. This imposes high pressure on further component miniaturization and the speed of operation, a trend that challenges the limits of the current technological advance. Conceptually novel ideas and thinking outside the box are needed to overcome these limitations. In this context, the creativity of researchers working at the intersection of chemistry, biology, and physics has opened up several exciting paths in the general area of unconventional computing, including quantum computing and biologically inspired molecular computing. Molecular computing systems, even though they are often motivated by information processing in nature, are not necessarily based on biomolecules and can be equally integrated in tailor-made synthetic molecules with stimuli-controlled switchable properties. Synthetic molecular systems and nanoscale supramolecular materials have been designed to mimic the operation of Boolean logic gates and demonstrate basic arithmetic and memory functions using light, chemicals, or electrochemistry to address and read them. However, despite the unquestionable progress that has been made in the last fifteen years regarding several practical aspects such as recycled operation, long-term stability, and concatenation, the further increase of their complexity is very challenging. Interesting advances in the development of molecular information processing have been achieved with the use of biomolecules, such as DNA/RNA, proteins/enzymes, and even whole biological cells, conjugating the field with ideas from systems biology. An advantage of the biomolecular computing systems is their ability to be integrated in artificially designed complex chemical processes mimicking multi-step information processing networks. These systems are still far away from the efficient and robust information processing in cells, but constitute certainly a viable strategy towards higher complexity. In fact, biochemical reactions are at the core of the mechanism of life itself, and therefore one could set rather ambitious expectations for how far (bio)-chemical systems can be scaled up in complexity, if not speed, for information processing.

While in a long perspective a molecular computer might become a reality, particularly for some specific applications, for example, for solving complex combinatorial problems, the present state of the art does not allow any practical use of (bio)molecular systems for real computational applications. However, some other applications of (bio)molecular information processing systems are not that far from immediate use. One of them is binary sensing where multiple input signals are logically processed, resulting in YES/NO decisions in the binary (0,1) format. In this sub-area of molecular logic successful implementation of systems at the present level of complexity is at reach, particularly for biomedical applications. As a general trend, the research in (bio)molecular information processing, which has been motivated originally to progress unconventional computing applications, is broadly developing to areas not directly related to computing in its narrow definition. This research opens up novel concepts in sensing/biosensing, switchable smart materials controlled by logically processed signals, bioelectronic devices (e.g., biofuel cells) controlled by external signals, signal-controlled release processes, user authentication, and so forth.

The present special issue is a collection of invited articles covering different aspects of molecular logic systems. The articles are written by the most active researchers in this exciting area of research, representing various aspects of the broadly defined area of unconventional molecular computing. Beyond this issue, further information for interested readers can be found in recently published review articles[1–6] and books.[7–11]

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An invited contribution to a Special Issue on Molecular Logic

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