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Editorial

# A random walk to and through the photoelectrochemical cells based on photosynthetic systems

The energy crisis and environmental problems are among the most important challenges that humanity must solve in the XXI century. Many of the current investigations are focused on the development of energy sources which must be renewable, sustainable and eco-friendly. Sunlight is the most accessible and reliable among these renewable energy carriers. There are two main pathways for utilizing solar energy: photosynthesis and the photovoltaic. The photosynthesis is a process through which light energy is converted into energy contained in the chemical bonds of organic compounds by photosynthetic pigments such as chlorophyll (Chl) *a*, *b*, *c*, *d*, *f* or bacteriochlorophyll. Photosynthetic processes occur in phototrophic organisms which include higher plants and many types of bacteria, including cyanobacteria. The other pathway i.e. photovoltaic converts light energy into electrical energy through photoactive semiconductor materials. The efficiency of the light energy conversion into electric current by commercial silicon photovoltaic cells is typically less than 20%. Moreover, it is unfortunate that the materials and components used in the photovoltaic systems are exhaustible and cannot be fully recyclable. Devices serving to convert solar energy into usable energy are called solar cells. The solar cells, in which organic photoactive materials act as a photoactive element, have several advantages over traditional silicon solar cells. The cost of production of such cells is less due to less strict requirements for their production, and that the field of their application is wider.

As photosynthetic organisms operate with a quantum yield of charge separation close to 100%, it is reasonable to use this natural process for energy conversion applications. Therefore, for many years photosynthesis has attracted the attention of researchers and designers looking for alternative energy systems as one of the most efficient and eco-friendly pathways of energy conversion. The latest advances in the design of optimal solar cells include the creation of converters based on thylakoid membranes, photosystem 1 (PS1) and photosystem 2 (PS2) and whole cells of cyanobacteria immobilized on nanostructured electrode (gold nanoparticles, carbon nanotubes, nanoparticles of ZnO and $TiO_2$). The main advantage of using membrane thylakoids for the generation of photocurrent is that during the isolation process, the integral membrane protein complexes remain in their native state. This leads to greater stability and greater power output as compared to the results that may be achieved by using isolated photosystems.

Some researchers have also conducted studies to generate photocurrent by cells based on isolated PS1. There is less influence exerted by the other redox systems on the electron transfer in the PS1 chain. Reaction centers of the photosystem are closer to the electrode facilitating direct electron transfer to the electrode. PS1 is a good photo biocatalyst, but has several disadvantages as a photosensitizer. Firstly, the process of the complex isolation is more laborious compared to the isolation of thylakoid membranes. Secondly, the isolated PS1 complex is less stable.

The main advantage of the PS2 *vs.* the PS1 is the fact that the electron source, which is required to activate the electron transfer, is water, which is abundant in the environment. Both the PS1 and the PS2 are highly sensitive to photoinhibition but they are effectively protected by protective compounds present inside the chloroplast. It is evident that the stability of isolated photosystems is impaired after their isolation from their native environments.

Photocells, in which isolated photosynthetic structures such as thylakoids, PS1 and PS2 are used, have significant disadvantages. The components of these cells are quite expensive, have a short running time, require laboratory procedures such as isolation/purification and are relatively unstable. These limitations could be overcome if whole cells of photosynthetic microorganisms would be used as a biocatalyst or/and sensitizer. These microorganisms have a good potential to simplify the conversion and storage of solar energy and extend its application to many areas. Besides, the technologies based on microorganisms are mainly dependent on the application of renewable resources, and hence there is little waste. One of the main advantages of cyanobacteria *vs.* individual components of the photosynthetic apparatus is that they are considerably less susceptible to dehydration.

Overall, the mode of solar energy conversion through photosynthesis has a great potential as a source of renewable energy while it is sustainable and environmentally safe as well. Photosynthetic processes take place only under visible light in the region of 400-700 nm which constitutes approximately only 50% of the total solar energy, therefore, it is important to use the region beyond 700 nm. Application of pigments such as Chl *f* and Chl *d* (unlike Chl *a* and Chl *b*), by absorbing the far-red and near infrared region of the spectrum (700-750 nm), will allow to increase the efficiency of such light transforming systems. Another possibility for an increase in the efficiency of solar cells would be the immobilization of hydrogen-producing biocatalysts on the cathode. Here, a key problem which needs to be addressed before such systems can get closer to real application is the stability of immobilized photosynthetic systems on electrodes at long-term illumination. The potential exploitation of the photoprotection mechanism in photosynthetic materials will allow to improve the long-term stability of solar cells. In a future perspective, an improved design of the systems by performing a controlled energy transfer would be highly desirable. We suggest that energy photoconverters based on photosynthetic systems will be an indispensible part of the energy generation systems in future decades to come.

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