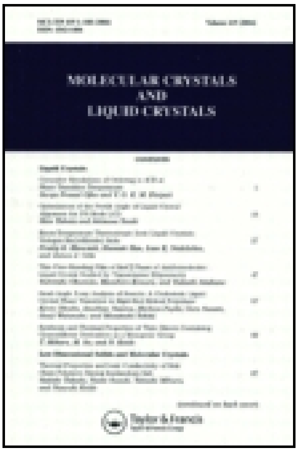

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Charge Transfer Processes in Biological Objects

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CHARGE TRANSFER PROCESSES IN BIOLOGICAL OBJECTS

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Abstract Charge transfer processes in biomembranes are considered on example of the photosynthetic reaction centers of the plants.

INTRODUCTION

In cells of living matter many processes of the energy conversion are conjugated with complex events of charge transfer (CT) occurring in specific molecular structures - biomembranes[1]. Vectorial nature of these CT processes is caused by electronic structure[2] of the molecular assemblies in which the CT take place. Efficiency of the energy conversion process in photosynthetic apparatus of the plants, determining by rates of forward and back transfer of charges in its reaction center, may be controlled by means of the delayed fluorescence (DF) under the action of the ultrashort laser pulses.

BIOMEMBRANE

Biomembrane is a bilayer of the lipid molecules with thickness of 5 - 10 A^{o}. For giving an additional hardness and forming different functional elements (ion channels, pumps for particles, etc) biomembranes are conjugated with appropriate proteins and other biomolecules[3].

Following three properties of the biomembranes are a great importance for the CT processes:

- There are transmembrane differences of the potentials and concentrations of ions making it possible controlling flow of particles through biomembranes;

- It is possible drawing up a long and complex chain of the molecule - carriers of the charge in biomembrane;

- Surrounding proteins may dramatically change the electronic structure of the molecules - carriers making it possible controlling the rates and efficiency of the CT process in different points of the chain;

These properties of the biomembranes are interconnected and complimented one another : transmembane potential arising from vectorial CT in biomembrane has increased the rate of CT itself. This circumstance permits considering the biomembrane as selfmaintaining system with high degree of adaptability to environment conditions.

High values of the electrical fields (10^5 v/cm) in biomembranes creating by transmembrane potential cause strong changes of the protein - protein interactions (dipole moment of the protein molecules may be up to 1200 D) and make it possible controlling to the permeability of ion channels.

CT IN PHOTOSYNTHETIC REACTION CENTERS

Functionally photosynthetic apparatus of the plants consists antenna and reaction center. In antenna light is harvested and migrated as a exiton so far has not trapped by reaction center, in which this energy is converted to the energy of separated and stabilized charges in result of the multistep CT processes. CT occurs with help of the molecules - carriers binding in assemblies with strong π - and σ - bonds, where may be realized ultrafast (up to picoseconds) transfer of the electron on the distance of 30 A^o. So dramatically moving the electron away from donor and lower midpoint potential of the acceptor ($\Delta\phi$ = 0.1 - 0.4 ev) do not allow fast back transfer through tunneling or thermoactivation and the rates of forward and back transfers (K^{for} and K^{back}, respectively) are determined by Boltsmann's factor[4]:

$$K^{for} / K^{back} = \exp(\Delta\phi / kT) \qquad (1)$$

The value of $\Delta\phi_i$ for each step of CT is determined from two conditions:

i) Electron transfer from i^{th} to $i+1^{th}$ molecule - carrier must be much faster compared with back transfer from i^{th} to $i-1^{th}$ one.

ii) Back transfer from $i+1^{th}$ to $i-1^{th}$ molecule - carrier must be as slow as possible under restriction i.

DELAYED FLUORESCENCE

A part of the light pulse absorbed by photosynthetic apparatus of plant is instantly reradiated by antenna because of its photochemical quantum yield is not equal to 100%. Moreover, in the case of inhibition of the CT process (e.g., under the action of herbicides) another type of emission - delayed fluorescence is arose. DF is caused by enhanced back transfer of the electron in reaction center and its time delay (and intensity) is determined by location of the point of chain, where start back transfer of the electron from. The time delay and duration of the DF may be varied from nanoseconds to seconds and as can be see from eq. (1) they are increasing (intensity of the DF is decreasing) exponentially with increasing $\Delta\phi$.

Because of its high sensitivity, time resolved laser fluorescent spectroscopy methods (e.g. boxcar integrating) are widely used for investigation DF. For simultaneously investigating of the different time components of the DF most suitable method is excitation with pulsed - periodical picosecond laser and registration with strobe - integrating technique[4].

High degree of adaptability of the biomembranes to external fields is clearly shown on the example of illumination. At sharp switching on the chain of CT in reaction center (e.g., transferring plant from dark to bright illuminated area) complex transitional processes related to accumulation of charges in certain points of the chain and adaptation of the assemblies of the molecules - carriers to fast or slow rates CT being proceeding for the several minutes are occurred. These processes may be tracing with help of DF. In figure 1 are shown inductive curves of the ratio of intensities DF of millisecond (0,5 ms) and microsecond (35 μs) components at different intensities of illumination of the plant leaves. As can see from figure with increasing of the intensity adapting time of the photosynthetic apparatus is decreased.

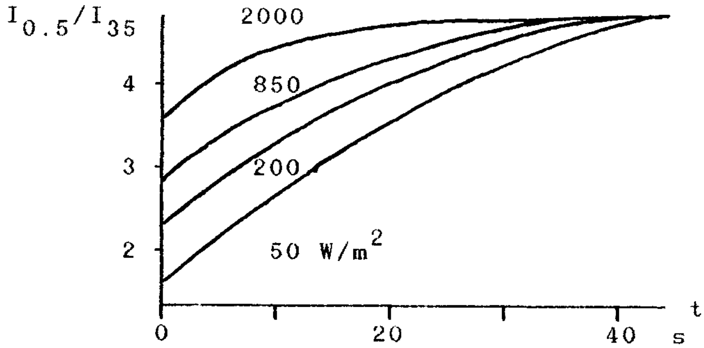

FIGURE 1 Inductive curves of the ratio of the intensities of the ms and μs components of the DF.

So, high adaptability of the biomembranes and CT processes in them may be investigated with help of DF of the different time durations.

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