Futuristic Protein based 3-D optical memory

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ABSTRACT
Computational memory storage media has undergone revolution with time. Novel memory storage technologies include use of biological material especially proteins such as Bacteriorhodopsin. Bacteriorhodopsin (Br) has great sensitive thermal, chemical and holographic (3-D volumetric) features. Bacteriorhodopsin stores data in a 3-D matrix. Three dimensional optical memories can theoretically approach high storage densities. 3D cubes of Bacteriorhodopsin provide much more space than two dimensional optical memories. Three-dimensional optical memory devices made from Bacteriorhodopsin utilize two photon read and write-method. Hence, a good choice for developing protein based optical memory. Future memory technologies also comprise of hybrid technology that hybridizes Bacteriorhodopsin with the solid state components of a computer. In the present paper focused on computational basis for bacterio-rhodopsin optical memory, advantages and applications. This paper also focuses on various algorithms based on computational methods like – Write -data, Read- data, Erase -data and Refresh -memory with emphasis on Bacteriordopsin.

Keywords:
Optical storage, protein based memory, Bacteriorhodopsin (BR), 3-D matrix, photo cycle.

INTRODUCTION
Computational memory storage media have undergone revolution with time to comply with the ever-expanding magnitude of digital data. The quest to meet the demand for faster, thinner, affordable and more efficient memory storage devices continues. In recent times, biological molecules such as proteins are being explored as alternative to magnetic storage technology.

Bacteriorhodopsin (Br), a photochromic protein found in the purple membrane of hemophilic Halobacterium halobium. In the bacterium, it functions to drive light-sensitive photon pump playing the key role in photosynthesis and respiration. It has characteristic optical-switching properties with stable intermediate forms, which can be used in wide range of bio molecular photonic applications such as all-optical switch based multiple-laser geometries involving holograms, refractive index modulation, enhanced photo induced anisotropy and excited-state absorption. The thermo-stable protein, due to its precise optical sensitivity coupled with molecular structure switching, is a good candidate for protein memory storage.

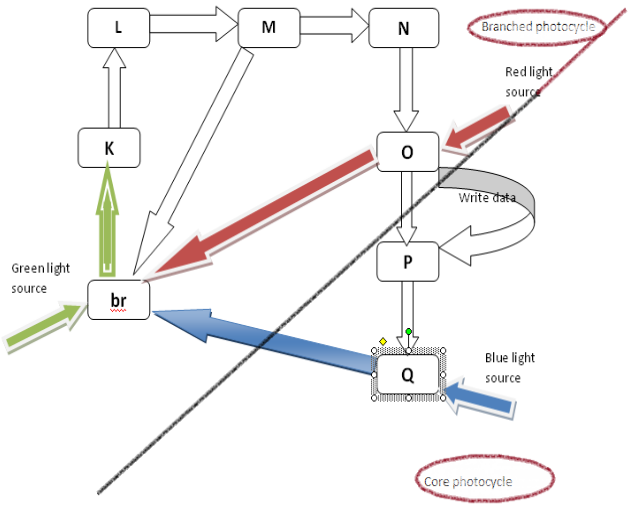
3-D protein based optical switch
A switch is the basic building block of information processing systems. Recently, there has been considerable research. Although the primary function of BR is to pump protons, it is the ability of the molecule to absorb and convert light energy that is of particular importance for use in photonic devices. Although BR is crucial for long-term cellular survival when oxygen is limited.Bacteriorhodopsin application as an active element in photonic and molecular electronic devices, with an emphasis on photonically based memory devices. Over two decades ago, research on Bacteriorhodopsin took an interesting turn towards its application as an active element in photonic and molecular electronic devices, with an emphasis on photonically based memory devices. As the functional element of two-dimensional memory applications (i.e., binary photonic and holographic), BR has the potential to be unmatched with respect to ultimate resolution (storage density), cyclist, efficiency and sensitivity. Two intermediates in the BR photo cycle, namely the Br and M states, form the basis for a bi-stable optical switch that can be used in to his applications.

Optical logic element comprising a light sensitive organic material which can undergo a photo cycle by irradiation light of one or more suitable wavelength, where the physical state is assigned a determined logical value and wherein a change of physical state of logic element cause a change in its logic value and take place by addressing the logic element optically for writing, reading, storing, erasing and switching of assigned logic value. The invention also concerns a method for preparation of a light sensitive organic material which undergoes a photo cycle by irradiation with light of one or more suitable metastable physical states, and light sensitive organic material is used as switchable or data storage medium .organic materials which undergo a two type of photo cycle.

1. **Branched photo cycle**: The intermediates in the branched photo cycle are not populated at physiological conditions. In this state molecule to go into the branchedphotocycle, the protein should undergo into some certain sequence of light. Such as RED, GREEN, BLUE.

2. **Core photo cycle**: normal function, the BR molecule remains in the core photo cycle.

The photocycle:



The core photo cycle could be used for dynamic short-term (volatile) memory applications, such as random-access memory and devices for fast non-destructive optical processing In this case, the ground state (BR) and the complex M state are usually used as the two binary states, that is, "0" and "1," respectively.

Light sensitive organic material uses: 1) Organic material which have photo cycle with various physical state is assigned a logical values which can be changed by addressing the element optically, element initially before the addressing is in a metastable state.2) Metastable optical logic element has been made by providing at least a colour slight source detector Adjacent to the light sensitive material. In 3D optical memory must meet several criteria to do work in efficient manner:

1) Active component of the material must respond to light two stable and long-lasting state.

2) Active component must not respond to actinic wavelengths used to write and read.

3) Optically transparent active component used if the light scattering.

4) Material remains stable over long period of time.

5) Active element should be switchable between states with efficiency.

In the method for optical addressing of the optical logic element steps for respectively writing ,reading and storing, erasing ,switching comprises generating transition between states in the photo cycle and detections of the states read, write, refresh ,delete 3D optical memories have the potential to offer great advantages over the semiconductors and platter-based systems. The performance of current software applications is often limited, not by the quality of the computer processor, but by the ability of the computer memory to manipulate stored information quickly and efficiently.

3D protein base optical memory process:

There are two or three most stable states of the protein would be used to record data in binary form. Molecules changes states within microseconds. Combined steps to read or write operation takes about 10 milliseconds. Devices obtain data pages in parallel. Speed is currently limited by data addressing. Following Data operation can be done using 3d Protein memory:

1. **Write data into memory**
2. **Read data from memory**
3. **Erase data from memory**
4. **Refresh memory**
5. **Reset Memory**

1. Write data into memory:

Green laser, called paging beams, activates the photo cycle of proteins in any selected square plane or page within the cube.

When the number of O intermediates reaches near maximum, the other laser array of red beams is fired. Second array illuminates the activated square where the data bits are to be written, switching the molecules to the P structure.

The P intermediate then quickly relaxes to the highly stable Q state. Then assign the initially-excited state, the O state, to a binary value of 0, and the P and Q states are assigned a binary value of 1.The P-state relaxes to form Q, a long-lived intermediate state. Let assume Br represents by bit 0, and P and Q represent by bit 1. Data can be written into any location within a solid polymer matrix containing the protein by using a combination of paging (Br--->K), later by orthogonal writing (O -→ P). The protein operates like an optical AND gate that is, data are written if, and only if, both the input conditions are satisfied.

This process is now analogous to the binary switching system which is used in existing semiconductor and magnetic memories. However, because the laser array can activate molecules in various places throughout the selected page or plane, multiple data locations (known as "addresses") can be written simultaneously. Following diagram illustrates how light absorb and activate the state.

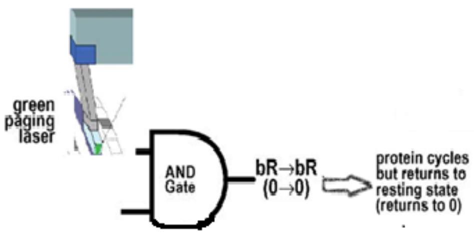


Fig. (a)Green Laser light absorb

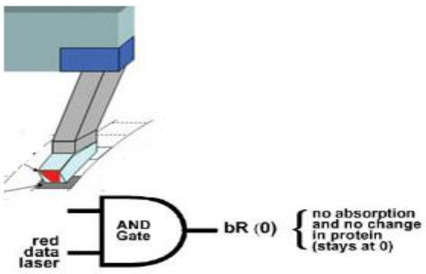


Fig. (b) Red Laser light absorb

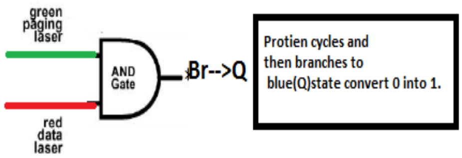


Fig. (c) Both Red and Green Light absorb

Procedure of Write Operation in 3D protein optical memory:

Step1: Start Procedure writes.

Step2: Accept array laser Red and green.

Step 3: Declare variable I and initialization to zero

Step 4: Repeat up to length of red and length of green.

Step5: if (green==Activate) then

Step7: Br--->Br (Binary 0-→0)

Step8: return (0) and Go to step 9

Step9: if (red==Activate) then activate p molecules and p relax q

Step10: O-→0(Binary zero)

P-→1(Binary one)

Q--→1(Binary one)

Step11: Write Parallel Location

Step 12: Increment variable i.

Step13: End Procedure

2. Read data from memory:

The system for reading stored memory relies on the selective absorption of red light by the O intermediate state of Bacteriorhodopsin. Data is read by shining laser beams on molecules and noting the wavelengths that don’t pass through the detector.

First, the green paging beam is fired at the square of protein to be read. After two milliseconds (enough time of O intermediates to appear), the entire red laser array is turned on at a very low intensity of red light. The molecules that are in the binary state 1 (P or Q intermediate states) do not absorb the red light, or change their states, as they have already been excited by the intense red light during the data writing stage.

However, the molecules which started out in the binary state 0 (the O intermediate state), do absorb the low-intensity red beams. A detector then images (reads) the light passing through the cube of memory and records the location of the O and P or Q structures; or in terms of binary code, the detector reads 0's and 1's.Reading take place by activating the emitter with a short duration voltage pulse on low level ,such that only green light irradiates the bacteriorhodopsin structure .Large laser part of the light goes through the structure and is detected by the detector element.

3.Data Erasing:

To erase data, blue laser returns molecules in the Q state back to the rest state. The blue light doesn't necessarily have to be a laser; it cans bulk-erase the cuvette by exposing it to an incandescent light with ultraviolet output.

4. Refreshing the memory:

To ensure data integrity during selective page-erase operations, Birge caches several adjacent data pages. The read/write operations also use 2 additional parity bits to guard against errors. Each page is monitored by a counter, and after 1024 reads, the page is refreshed via a new write operation. Write and read speeds are limited by the contents of the photo cycle, which lead to access time in millisecond range.so reading of stored data will reduce the contrast of these, such that it becomes necessary with refresh after a certain number

5. Reset the Memory:

Reset may be achieved by continuous illumination with red light .Emitter will supply low voltage over a certain time period. Elementary logic cell may be switched from one state to another possibly reset to binary 0.

Other protein candidates for optical 3D memory devices:

1. Pharaoh is Phoborhodopsin (PR): All-optical switching in PR protein based on nonlinear excited-state absorption has multiple potential applications.
2. Photoreceptor sensory rhodopsin II (sRII): synthesized from Natronobacterium pharaonis prototypical sensory rhodopsin for crystallography and structure/function studies.
3. Ferritin: a protein commonly found eukaryotes and prokaryotes that facilitate iron storage: to build memory on thinner substrates such as memory chip measuring less than 1 micron in thickness.
4. Rhodopsin Receptors of Photo taxis in Green Flagellate Algae: detected by a special photoreceptor apparatus consisting of the photoreceptor membrane and eyespot.
5. Army is increasingly dependent on computers and electronic tools to achieve high levels of situational awareness on the battlefield. Biotechnology for Future

Army Applications goals towards bacteriorhodopsin expressed in Escherichia coli.

6. Photosynthetic reaction centers, cytochrome c, photosystems I and II, phycobiliproteins, and photochromic are novel bio molecular targets for IT applications.

Advantages of protein based 3D memory

i. If you turn off the memory system's power, the bacteriorhodopsin molecules retain their information. This makes for an energy-efficient computer that can be powered down yet still be ready to work with immediately because the contents of its memory are preserved.

ii. The characteristic time of the optically induced transitions between certain intermediates can be on the order of a few picoseconds. This implies that the fundamental limit of the data rate in a protein- based system is far beyond the fundamental limits for competing magnetic or semiconducting technologies.

iii. BR can be easily isolated with minimal effort and cost. In addition, it is nearly infinitely customizable through genetic and chemical manipulation.

iv. The protein acts as a latched AND gate, and data are stored in naturally long-lived ground-state intermediates. Parallel accessing of data is inherent in the design of the branched photo cycle volumetric memory, enhancing speed of both reading and writing operations.

v. Its sensitivity to light allows it to change structurally and would be a good representation of a logic gate, the primary building block of memory cell. A series of lasers is then used to excite the protein molecules and read or set their states. Bacteriorhodopsin is being developed to represent binary data. Bacteriorhodopsin can be used in any number of schemes to store memory;

vi. Parallel accessing of data is inherent in the design of the branched photo cycle volumetric memory, enhancing speed of both reading and writing operations.

vii. Bacteriorhodopsin stores data in a 3-D matrix. 3D cubes of Bacteriorhodopsin provides much more space that two dimensional optical memories. Three dimensional optical memories can theoretically approach storage densities of one trillion bits per cubic centimetres but there are some limiting factors which prevents in getting this high storage density.

Limitation of protein based 3D memory

1. To implement 3D volumetric optical memory, various paging principles have been proposed to access information in selected regions during both writing and reading steps. With paging, the intersection of two beams of light is used to select specific regions. This often makes 3Drecording devices relatively bulky and complex.

Other Potential Applications of 3D-memory :

Most successful applications of bacteriorhodopsin has been in the development of holographic and volumetric three-dimensional (3-D) memories.

1) Reversible holographic memory

2) Ultrafast random-access memory

3) Neural logic gates

4) Spatial light modulation

5) Nonlinear optical filters

6) Photonic-crystal band gap materials,

7) Pattern-recognition systems

8) High-contrast displays

9) Optical switches

10) Pico second photo detectors.

11) To develop Gamming Application

12) Computer Simulations of Protein Folding

13) In Army the enemy detractor sensors Applications can be developed

14)3D Protein Databases

CONCLUSIONS:

3D optical memories have the potential to offer great advantages over the semiconductors and platter-based systems. A thinner, faster computer with large storage capacity is what most consumers want and protein-based memory devices do seem to hold a lot of potential in that area. With fast random access capability, better reliability and transportability, moving to a new era in computing. Large pools of data could serve as a unique platform for investigation of artificial intelligence. With ultra high density RAMs, the machine would handle large databases with very high speed.

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