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Photodimerization in substituted di- and oligopeptides by UV-light for optical data storage

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Abstract

Photodimerization in pyrimidine-substituted di- and oligopeptides, was investigated with a view to their application as new materials for optical data storage. The effects of variations in the amino acid sequence, the spacer and substituent effects on the chromophores were investigated. Three of the synthesized compounds were identified as possible media for optical data storage.

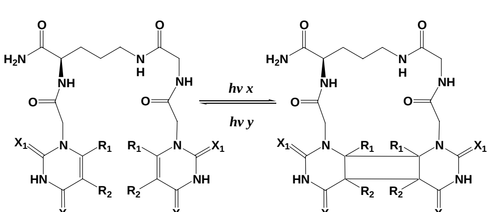
Objectives

To develop a film of pyrimidine-substituted peptides, possessing five important criteria for digital optical storage:

1. Large contrast between irradiated and non-irradiated areas of the medium (dimerization efficiency).
2. Fast response for recording
3. Stable during storage (-30°C and 50°C)
4. Good optical and mechanical properties
5. Cheap large scale production.

Introduction

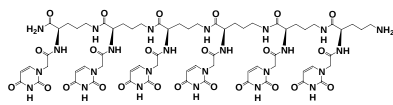
DNA is the ultimate data storage molecule, storing in four bases the information to make proteins and, essentially, life. The photodimerization of thymine, discovered long ago upon UV irradiation, is one of the most important reactions in photobiology. It is highly probable that dimerization in irradiated DNA constitutes one of the essential factors responsible for the sensitivity of nucleic acids and cells to the effects of UV-light. The dimerization takes place through the C5-C6 double bond of the pyrimidine and involves the formation of a cyclobutane ring, as shown in the figure below. Here we describe chromophores attached to a peptide backbone, where the storage of data can be achieved through the principle of photodimerization of neighboring chromophores undergoing (2π + 2π) cycloaddition, first in solution (H_2O), and then as a film applied onto a quartz plate, if good dimerization efficiency was observed.

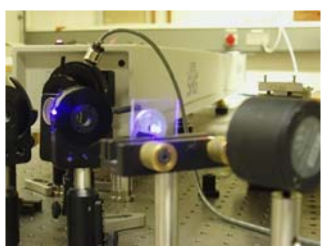


The photodimerization process, shown for a dipeptide (Orn-Gly). X = O, S and R = H, CH_3, F, Cl, Br, I.
$h\nu\, x < h\nu\, y$

Left: The UV-laser setup, during an experiment on a uracil ornithine hexamer.

Below: The chemical structure of the uracil ornithine hexamer



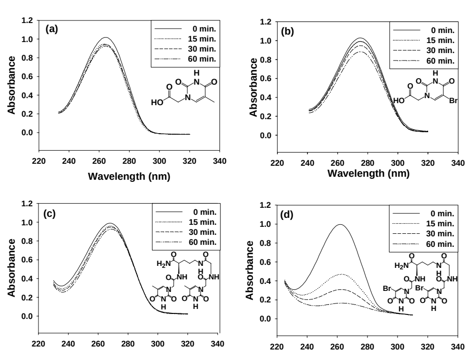


The peptide film coated onto a quartz plate, and mounted in the holder. Here the UV-laser light hits the film.

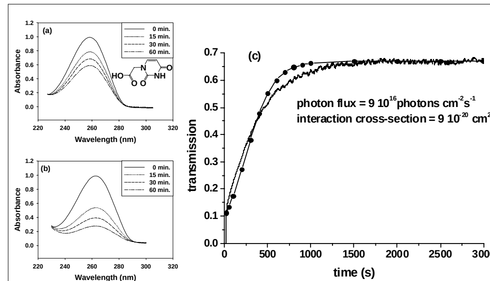
Experimental

The peptides were synthesized using the stepwise Merrifield SPPS method. The chromophores were synthesized using standard organic chemistry. The compounds were first tested in solution, and irradiated under a UV-lamp for 15, 30 and 60 min. If good dimerization efficiency was observed, the compound was prepared as a film and tested in our UV-laser setup, in order to test how fast the compound could reach maximum transmission.

Results



Absorption spectra of (a) thymine 1-acetic acid and (b) 5-bromouracil 1-acetic acid compared with the corresponding pyrimidine-substituted dipeptides (c) N^{α}, $N^{\alpha'}$-bis-(thymine-1-ylacetyl)-(N^{ε}-glycylornithine amide) and (d) N^{α}, $N^{\alpha'}$-bis-(bromouracil-1-ylacetyl)-(N^{ε}-glycyl-ornithine-amide), all in water, at different irradiation times.



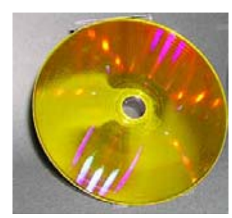
Experimentally measured absorption of (a) Uracil 1-acetic acid and (b) uracil ornithine hexamer in solution. Transmission through a thin film of uracil ornithine hexamer (c).

Conclusion

Overall we observed a significant increase in dimerization efficiency when going from a free chromophore in solution to a chromophore attached to a peptide. Furthermore the peptide films had good optical and mechanical properties, and were completely stable. Good correlation was found between solution and film, making solution testing an effective screening method. Finally, the peptides are environmentally safe and suitable for upgrade to large scale.

Perspectives

This new material for optical data storage using UV-laser, instead of red and Blu-ray, is a step towards the next generation. Bit storage at 257 nm can give a storage capacity of over 60 Gbytes compared to the latest Blu-Ray discs, and a further three fold increase in capacity can be achieved with multilevel storage. It is believed that a UV-diode laser will be on the market in ten years, and hopefully we will have been able to obtain a fully optimized material using peptides, which may store up to 1 terabyte on a conventional disc (12 cm).



A possible future technology, the Peptide Versatile Disc (PVD), as a conventional sized DVD.

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