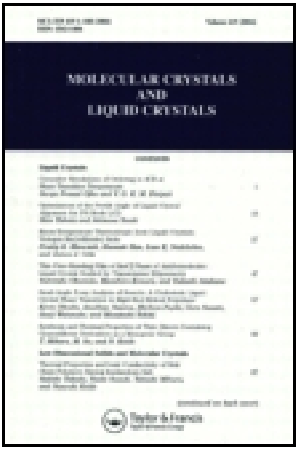

Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl19

Investigation of Optical Neuro-Computing System Based on Organic Photochromism

Kimio Sumaru [a] , Shigeru Inui [a] & Tadae Yamanaka [a]
[a] Department of Polymer Engineering, National Institute of Materials and Chemical Research, 1-1 Higashi, Tsukuba Ibaraki, 305-8565, Japan

Version of record first published: 24 Sep 2006

Mol. Cryst. and Liq. Cryst., 2000, Vol. 345, pp. 239-244
Reprints available directly from the publisher
Photocopying permitted by license only

Investigation of Optical Neuro-Computing System Based on Organic Photochromism

KIMIO SUMARU*, SHIGERU INUI and TADAE YAMANAKA

Department of Polymer Engineering National Institute of Materials and Chemical Research 1–1 Higashi, Tsukuba Ibaraki 305–8565 Japan

As a system, which put the optical neuro-computing into practice, a novel architecture based on organic photochromism was described. The performance of the system was examined concretely by means of computer simulation. Based on the result, a prototype system was constructed using a bulk amorphous thin film of diarylethene to prove the feasibility of the architecture. Using the prototype, preliminary experiment was carried out to confirm the function of optical data inscription and parallel analog operation. New concept of data processing device was also suggested from the discussion over the characteristics of the system.

Keywords: Optical Neuro-Computing; Organic Photochromic Thin Film; Analog Parallel Operation: Diarylethene; Spatial Light Modulator

INTRODUCTION

Neural network models, that are characterized by the property of analog and parallel data processing, are composed of a number of neurons (processing elements) and massive and plastic interconnections among

* E-mail:sumaru@nimc.go.jp

them[1]. In oder to put these theoretical models into practical hardware feasibly, optical neural networks have been studied actively for recent years[2,3]. In this architecture, massive interconnections, which do not interfere with one another, is realized taking advantage of the property of light. In this research field, inorganic photo-functional materials have been most often used in spite of the practical defects such as poor data retention (< 1 day) and high-voltage drive (~kV).

On the other hand in the research field of organic photochromic (OP) materials, the development of the diarylethene derivatives with heterocyclic rings brought remarkable improvements in thermal stability and repetition durability, which had been serious bottlenecks of OP materials[4]. Furthermore, comparing with inorganic bulk materials, high integration and high efficiency is expected for OP materials since optical function is originated in the individual OP molecules.

However, due to their low sensitivity, low contrast and the historical background, OP materials have hardly been investigated as data processing devices utilized in optical computing systems. In this paper, we describe the architecture of optical neuro-computing system based on organic photochromism, and report the result of computer simulation and preliminary experiment on prototype system. We also discuss over the characteristics of a novel data processing device taking advantage of the property of OP materials, which had been investigated solely for the application to optical storage media.

ARCHITECTURE

Although OP materials are still inferior in sensitivity and transmittance contrast to conventional inorganic ones, these power-supply free materials provide excellent stability in the data retention (> 1 year). Additionally, due to the nature of molecular device, the number of neuronal interconnections is estimated to be 100 millions for the OP thin film with the area 10mm x 10mm and the resolution 1μm.

We previously proposed a basic design of an adaptive optical neuro-computing system based on OP device (FIGURE 1)[5]. In this system, reversible and stable photoisomerization of OP thin film takes charge of analog memory. The product-sum operation, which is usually the heaviest load in the calculation, is executed in a moment by projecting the image of pattern onto the film with transmittance distribution and by detecting the intensity of transmitted light from each neuron (unit cell). In order to control massive weights of interconnection quite efficiently, we introduced a special layout regarding the film as a "black box" (SLM-OASLM strategy).

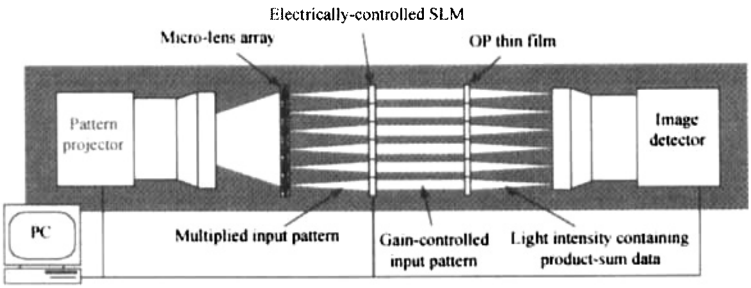

FIGURE 1 Schematic illustration of optical neuro-computing system based on organic photochromism.

COMPUTER SIMULATIONS

In the operation of the system, there are a lot of restrictions due to its architecture and the properties of OP device. In order to settle them, we developed the evaluation function and the dynamics to optimize the interconnection weights, which are compatible with the architecture[5]. Then a series of computer simulations are carried out to prove the principle and to estimate the practical performance of the system.

FIGURE 2 shows the result of computer simulation emulating "self-organization pattern mapping (SOPM)", for 36 learning patterns and 16 x 16 neurons[5]. SOPM is well-known neural network proposed originally by Kohonen, and its application to the pattern recognition and associative memory has been investigated from the practical viewpoint[1]. The figure shows that the system memorizes the input patterns putting ones adjacent to their similar types.

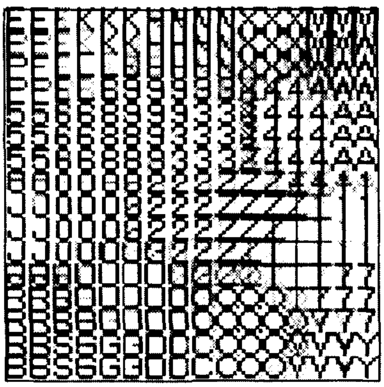

FIGURE 2 Result of computer simulation emulating SOPM based on the characteristics of OP materials. Attention should be drawn to the "similarity linkages" recognized as I-1-T-7-Y-V, Z-2-3-9-8-6-0-O etc.

The time required for the learning process was estimated to be a few minutes at projected light intensity 100mW/cm^2. Although this slow learning rate is inevitably due to the low sensitivity of OP device, it is not influenced basically by the increase of the resolution and neurons. The computer simulation was also carried out to emulate another algorithm "novelty filter (NF)"[1]. From these results, it was strongly suggested that the architecture should be able to emulate several different models of neural network.

EXPERIMENTAL

On the basis of these theoretical studies, a prototype system was constructed by using an OP device, a DMD pattern projector and a cooled CCD digital camera. In this prototype, the DMD projector emulates the functions of pattern projector, lens array and electrically-controlled spatial light modulator (SLM). As an OP device, we prepared a bulk amorphous thin film (1.3μm thickness) using a diarylethene derivative, which had been kindly supplied by Prof. M. Irie of Kyushu University. It was confirmed that the film is colored by UV light (300-370nm) and is bleached by visible light (500-600nm) at high efficiency. The transmittance contrast (T_{max}/T_{min}) of the film was found to be more than 2; this value is extremely large for OP solid film with the thickness ~1μm.

(a) (b)

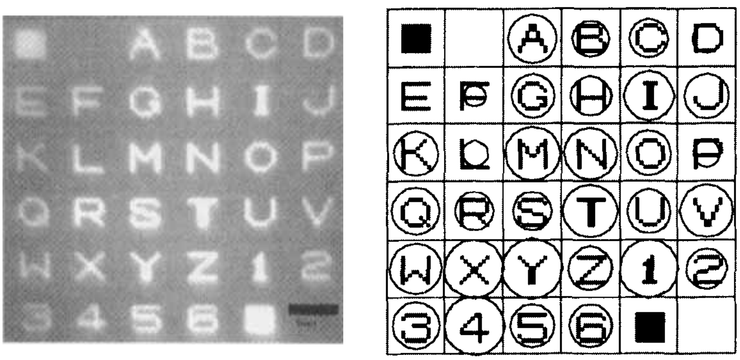

FIGURE 3 (a) Image of 32 patterns inscribed onto OP thin film and (b) optically calculated correlation function. The area of circle is corresponding to the "distance" between pattern "E" and each pattern inscribed on the OP film.

UV light projection is not available on the prototype in the present state. Therefore a preliminary experiment was carried out using the OP thin film colored in advance with Hg lamp. FIGURE 3 shows the image of 32 patterns inscribed onto OP thin film, and optically calculated correlation function between patterns. The patterns were inscribed with the resolution 70μm onto the film by bleaching with green light from the DMD projector. The calculation of correlation function, which contains massive product-sum operation, was executed optically.

DISCUSSION AND CONCLUSION

Based on the characteristics of OP thin film, novel architecture of optical neuro-computing system was proposed, and its function was investigated by the computer simulation and by the preliminary experiment with the prototype system. From these discussion over the property of OP materials with respect to stable, power-supply free and highly integrated data retention, novel concept of data processing device has been deduced: the system which accumulates the "experience", and treats the complicated and ambiguous problems based on it.

Acknowledgements

The authors would like to acknowledge Prof. M. Irie of Kyushu University for providing us the newly developed diarylethene sample.

References

[1] T. Kohonen, *Self-Organization and Associative Memory,* Springer Verlag (1984).
[2] M. Mori et al., *Appl. Opt.* **37**(14), 2852–2857 (1998).
[3] M. Ishikawa et al., *Appl. Opt.* **28**(2), 291–301 (1989).
[4] S. Kobatake et al., *J. Am. Chem. Soc.*, **121,** 2380–2386 (1999).
[5] K. Sumaru et al., *Opt. Eng.*, **38**(2), 274–283, (1999).