Organic Photochromic Materials for Optical Storage Memory

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Abstract: Two photochromic fulgides, 3-[2-(N,N-dimethylaniline)-5-methyl-xazolemethylene]-4-isopropylidenetetrahydrofuran-2, 5-dione (A) and 3-(1,2-dimethyl-5-phenyl-pyrrolmethylen e)-4-isopropylidenetetrahydrofuran-2, 5-dione (B), doped in PMMA as candidates of dual-wavelength optical memory for parallel recording are demonstrated. With 488nm-laser and 650nm-laser, both “cross” and “star” images are recorded on the same place of the sample and readout. Cross-talk between two fulgide compounds in PMMA matrix is also investigated.

Keywords: photochromic fulgide, optical memory, parallel recording, crosstalk.

INTRODUCTION

Optical memory devices such as compact disks (CD) and digital versatile disks (DVDs) are becoming essential items of audio and visual media as well as of external computer memory media. The need for large information storage and high speed input and retrieval of information is becoming mandatory in nowadays. Current effort in increase of optical memory density is to develop durable short wavelength compact lasers that emit blue or green light. [1-3] Doubling the frequency of the laser reduces the beam-spot radius by two thereby the density is increased by four. In order to increase the density of memory by 100 times on the current benchmark, a laser beam with output wavelength as 10 times shorter as those currently available has to be employed. This requirement is obviously impossible because neither the laser material for such an ultra short wavelength nor optical component, particularly lens, can be manufactured when the wavelength is in the range of 70-80nm. Therefore the density of optical memory is limited and present techniques have almost reached this limitation in those optical memories that are commercially available as CDs or DVDs. To enlarge the capacity and increase density of memory, new innovative storage technologies have been developing such as 3-dimensional memory, [4-5] near-field memory, [6-7] holographic memory, [8-9] and multi-wavelengths memory. [10]
Photochromic materials are promising as recording media for optical memory \[11-15\] because of application to erasable/rewritable information in photon-mode. For photon-mode recording, light characteristics such as wavelength, polarization, and phase can be multiplexed in information storage and thus the density of memory can, in a potentially dramatic ways, be increased. Herein we employed fulgides 3-[2-(N, N-dimethylaniline)-5-methyl-xazolemethylene]-4-isopropylenetetrahydrofuran-2,5-dione (A) and 3-(1,2-dimethyl-5-phenyl-pyrrolmethylen)-4-isopropylenetetrahydrofuran-2,5-dione (B) as dual-wavelength memory for parallel recording. Fulgides (A) and (B) are prepared according to the literatures \[16-17\] and the photoisomerizations of two photochromic fulgides A and B are presented in scheme 1.

![Scheme 1: photoisomerization of fulgides A and B](image)

**RESULTS AND DISCUSSION**

The absorption changes of two photochromic fulgides in cyclohexane before and after irradiation are shown in figure 1. By irradiation with UV light the absorption bands $\lambda_{\text{max}}$ at 360nm ($\varepsilon_{\text{max}} = 8.7 \times 10^4$ mol$^{-1}$ l cm$^{-1}$, in cyclohexane) decrease along with the increase of a new absorption band $\lambda_{\text{max}}$ at 518nm ($\varepsilon_{\text{max}} = 1.2 \times 10^5$ mol$^{-1}$ l cm$^{-1}$, in cyclohexane), which corresponds to the ring closed form of fulgide A. Similarly, the absorption bands $\lambda_{\text{max}}$ at 380nm ($\varepsilon_{\text{max}} = 9.3 \times 10^4$ mol$^{-1}$ l cm$^{-1}$, in cyclohexane) for open form of fulgide B decrease along with the increase of a new absorption band $\lambda_{\text{max}}$ at 638nm ($\varepsilon_{\text{max}} = 1.0 \times 10^5$ mol$^{-1}$ l cm$^{-1}$, in cyclohexane), which corresponds to the ring closed form when the solution of fulgide B is irradiated with UV light. Both the original absorption spectra are, respectively, recovered completely upon irradiation ($\geq 510$nm). It indicates ring closed formed of two fulgides can be reversed back to open form.
Figure 1. Absorption spectra changes of A and B in cyclohexane (1×10^{-5} M) before (—) and after irradiation(—).

The cross-talk between fulgide A and fulgide B is investigated by employing 488nm-laser (Argon-ion) and 633nm-laser (He-Ne) to record spots on the spin-coated sample film \[^{[18]}\] that contains fulgide A and fulgide B doped in PMMA. The device structure for cross-talk is presented in figure 2 and the film is irradiated by UV light for 30min before recording. In the recording process, a 488nm-laser beam is firstly employed and focused on a point in the film (power: 1.0mW, exposure time: 50µs), photoisomerization of fulgide A on the medium is induced at the focus point because of extremely high intensity. Followed by focusing another point on the same place with 633nm-laser (power: 2.0mW, exposure time: 100µs) and photoisomerization of fulgide B is induced as well on the same medium. By scanning of the focus laser beam, other spots can be recorded on the sample film in the same procedure above. For readout, the scanning velocity of the laser beam is 0.2mm/s and powers are 60µW and 150µW for 488nm-laser and 633nm-laser, respectively, the reflectance is detected by photosensitive detector, the output is transformed into voltage and the reflectivity
of the reflective Al layer (a disc without recording layer) is used as standard of 100% (figure 3). The results presented in figure 3 show that both signals of 488nm and 633nm are detected clearly, respectively, when 488nm-laser beam and 633nm-laser beam are employed respectively to readout. It indicates no significant cross-talk is detected between fulgide A and fulgide B. Besides, the nondestructive readout is also investigated for fulgides A and B and it is found the reflectivity of both recorded states are not markedly changed after 201 times readout.

Figure 4 presents the two images recorded on sample film by parallel recording and experimental setup for micro optical imaging on the film is described in the figure 5. The pictures presented here show the feasibility of optical memory device based on dual-wavelength photochromic materials. The mask “star” is recorded firstly by focusing 488nm-laser beam on the sample (size: 350µm × 460µm) with intensity 385mW/cm² in the center of the beam and time of exposure of 10s. The mask “cross”
is then followed by 633nm-laser beam on the same place with intensity 165mW/cm² in the center of the beam and time of exposure of 90s. Both “star” and “cross” can be read out clearly with 488nm-laser beam and 633nm-laser beam, respectively. As shown in figure 4, the cross-talk between the materials is too small to be detected. Avoiding cross-talk among the recording materials plays a key role in multi-wavelength optical memory. Organic compounds containing large conjugation usually have a widen absorption band, how to develop organic materials without cross-talk but being sensitive to commercial laser gives a challenge to organic material chemists.

![Figure 5. Experimental setup for micro optical imaging on the film](image)

The argon laser beam with 514.5nm 100mW and the diode laser beam with 650nm 40mW are employed to write in and readout, respectively. The sample film containing two photochromic compounds is mounted in the middle of Lens. The CCD camera is used to readout the images on the film and also used to monitor the surface of the film to ensure the image is accurately recorded on the surface in the recording process. The shutter is used for controlling the exposure time of recording and readout. Both “cross” and “star” were presented as mark 1 and mark 2, respectively.

**CONCLUSIONS**

In conclusion, a dual-wavelength optical memory consisting of two photochromic fulgides for parallel recording is demonstrated. From the viewpoint of application to multi-wavelengths optical recording, it is desired to develop materials that have sensitivity to commercial laser beam without cross-talk in writing and reading. Besides, thermal stability, fatigue resistance, nondestructive readout ability and high speed of photoreactions are also important factors for optical memory. Further study on multi-wavelengths optical memory for parallel recording is in progress.
ACKNOWLEDGEMENTS
We are grateful to the National Science Foundation of China (NO 60337020 and NO 60277001) and the National Principal Research Project “973” (G 1999033005) for financial support.

REFERENCES
[18] The sample was prepared as follows: 5-Dicyanomethylene-3-(1-methoxyphenyl-2-methyl-5-phenyl-pyrrol(methylene))-4-iso propyldenetetrahydrofuran-2-one [9] (1.5mg) was dissolved in PMMA-cycloheanone solution (10%, w/w, 0.1ml). The mixture solution was then spin coated on a glass slide (size: 25mm × 25mm × 1.5mm) to which the aluminum reflective layer was over coated on by vacuum evaporation first and dried in air. The film was then mechanically rigid and kept darkness at ambient temperature. The thickness of the film was about 10µm. The sample was irradiated with UV for 10 min before being recorded.