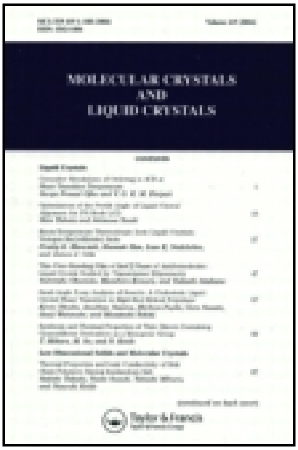

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High-Density Optical Memory using Photochromic Diarylethenes

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The great interest in photochromic materials for high-density optical memory has been increased for the past decade. A super-low power readout method has been proposed to solve a problem about degradation of recorded information by readout process. About 10^6-time readout was demonstrated by the method. New high-density optical memory, a super-resolution disk with a photochromic mask layer, was introduced. The super-resolution method has enabled us to increase the recording density of conventional optical disks. Ultra-high density near-field photochromic memory as a new innovative storage technology was also discussed.

Keywords: Photochromism; Diarylethene; Optical Memory; Super-resolution; Near-Field Memory

INTRODUCTION

As the world of multimedia has evolved over the last decade, the quantity of digital information being used has increased dramatically. Optical memory is indispensable for storing this information, and larger memory capacity is required. Advances in conventional techniques for

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high-density recording with existing magneto-optical or phase-change disks will be at a standstill in the near future. New innovative storage technologies such as near-field memory [1] or 3-dimensional memory [2], have been studied. The great interest in photochromic materials as memory materials for such storage technologies has been increased for the last decade.

In this paper, we introduce our recent studies about photochromic memory. The super-low power readout method, which minimizes the degradation of the recorded information on the photochromic memory, super-resolution disk with a photochromic mask layer, and ultra-high density near-field photochromic memory are reviewed.

SUPER-LOW POWER READOUT METHOD

One of the problems of the photon-mode photochromic recording is that the recorded information is destroyed during readout operations. To solve this problem, we have proposed a method which uses a superlow-power laser (superlow-power (SLP) readout method) [3][4]. The SLP readout method uses the combination of a minimum readout laser power, which satisfy sufficient signal-to-noise ratio (SNR) required for the system, and a photodetection method having a photocurrent self-amplification function. Our theoretical estimate predicted 10^5-10^6 readout cycles for a superlow laser power (about $10^{-9}-10^{-7}$ (W)).

An experiment about SLP readout was carried out for a photochromic disk containing a photochromic diarylethene [12]. The colored form of the photochromic compound converts to the open ring form upon irradiation with 550-700 nm light. Signal recording was carried out by photobleaching of the precolored state, and reading by detecting the reflectance changes using a focused 633 nm HeNe laser beam.

The readout power dependence of the carrier-to-noise ratio (CNR) was measured. The CNR was constant around 47 dB when the readout laser power was greater than 20 nW, and it was restricted by the media noise. On the other hand, the CNR decreases rapidly when the power was less than 20 nW, and it was restricted by the shot noise (quantum noise of light). Therefore, the minimum laser power was around 20 nW for this system.

Figure 1 shows the readout cycle dependence of carrier (signal) levels by the SLP readout method. The readout power was 20 nW as defined above. Under the condition of keeping the carrier level decrease less than 3 dB, the 10^5-10^6 cycle readout operation was possible by the SLP readout method.

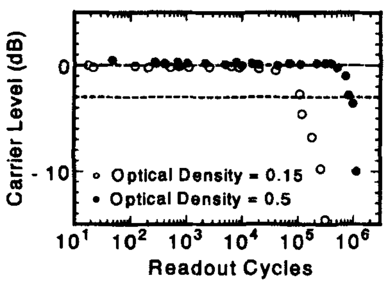

FIGURE 1. Readout cycle dependence of carrier levels.

PHOTOCHROMIC SUPER-RESOLUTION DISK

Super-resolution disk method is a kind of technique to increase the recording density of the conventional optical disks[5]. Figure 2 illustrates the concept of photochromic super-resolution readout. The disk has a photochromic mask layer as well as a recording layer. When the (conventional) light spot irradiates the precolored (initialized) mask layer of the super-resolution disk, only the mask area corresponding to the spot center is bleached by the photo-reaction because of relatively high light intensity. A smaller effective super-resolution spot is formed in the bleached mask area, and the information is read/written through the effective spot.

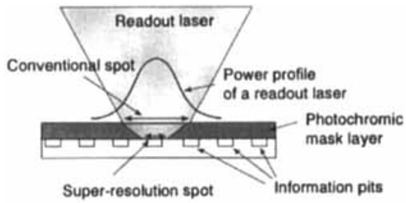

FIGURE 2 Concept of super-resolution disk method.

Figure 3 shows the absorption spectrum of the photochromic diarylethene used in our experiment. The open-ring state and the closed-ring state converts to the each other by photo-reaction, and the colored closed-ring state is bleached by irradiation of red light. A red laser beam was used for super-resolution readout.

Super-resolution readout was examined for read-only optical disk with 4-times recording density (3T (shortest) pit: 0.48mm, track pitch: 0.85mm) of a conventional compact disk[6]. The mask layer was prepared on the disk substrate by a vacuum evaporation method and the Ag reflective layer was overcoated. The readout pickup had a laser

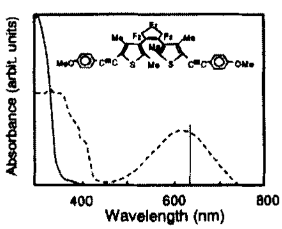

FIGURE 3. Absorption spectrum of photochromic diarylethene.

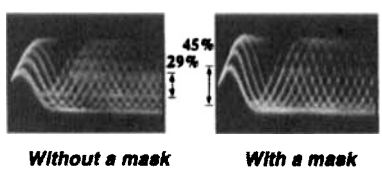

FIGURE 4. Comparison of readout signals

diode ($\lambda = 685$ (nm)) and an objective lens (NA=0.55).

Figure 4 shows reproducing signal comparison between the disks with a mask layer and without a mask layer. The amplitude of the shortest pit was increased from 29% to 45% by forming the mask layer. On the other hand, the crosstalk between adjacent tracks was also reduced to 18% from 42% by forming the mask layer. These results indicate that about three-fold recording density of conventional optical disks would be achieved. The super-resolution method is an effective method not only for increasing recording density of conventional optical disks, but also would be applied to high density optical disk mastering[7].

NEAR-FIELD PHOTOCHROMIC MEMORY

Near-field optical memory has been expected as one of the innovative technology for obtaining ultra-high density memory. Much smaller aperture than the diffraction limit of light is used to write/read information on the medium for attaining ultra-high recording density. Although the magneto-optical and phase change materials have been studied as recording material for near-field memory, photochromic materials is most promising because of its potential ability of high SNR, high resolution of the medium and high sensitivity[8].

Fluorescence change as well as reflectance/transmittance change can be used as readout mode of near-field photochromic memory[9][10]. We have succeeded the fluorescence readout from photochromic Naphthothioindigo media[11]. There are two kinds of write/readout mode: the bright spot recording (BSR) and the dark spot recording (DSR). The recording mark is formed as a fluorescent bit on the non-fluorescent area for the BSR, and as a non-fluorescent bit on the fluorescent area for the DSR. When the system needs wide bandwidth or low recording light power, the BSR has an advantage in the point of obtaining high SNR[12].

CONCLUSION

Photochromic materials are expected as recording materials for future ultra-high density memory as well as present optical disks. The super-low power readout method enables us to multiple-readout of photochromic medium about one million. The super-resolution method using a photochromic mask layer was introduced, and about three-fold recording density for conventional optical disks, such as DVD, was demonstrated. Furthermore, photochromic materials have been expected as promising materials for ultra-high density near-field memory.

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