Three-dimensional multi-layered optical memory using two-photon induced reduction of Au^{3+} doped in PMMA

Takuo TANAKA and Satoshi KAWATA

RIKEN Nanophotonics Laboratory, Japan, t-tanaka@riken.jp

I. INTRODUCTION

Recently, optical memory devices such as digital versatile disk (DVD) have made great progress in increasing the storage capacity of bit data, and they are widely used as storage devices for music, photographs, video and computer data. However, due to the diffraction of light, the recording density of these optical systems is ultimately limited by the minimum of the spot size, which is almost as large as half the size of the wavelength. The recording density of the current systems has already reached this limitation. To overcome this barrier, we have been studied three-dimensional multi-layered optical memory recording [1-4]. In this method, the longitudinal or axial (z) direction is utilized in addition to the lateral (x-y) dimension. The data are stored not on the surface of the recording medium, but three-dimensionally inside a thick recording medium.

II. FLUORESCENT RECORDING USING PHOTO-REDUCTION OF GOLD IONS

To develop three-dimensional multi-layered optical memory, an optical pickup must be able to read data from a particular layer without crosstalk from the adjacent layers. The optical system of the memory pickup is composed of nothing but a laser scanning microscope. As Nakamura and Sheppard reported, confocal laser scanning fluorescent microscopy has a transmission band even on the kz axis, which corresponds to the longitudinal direction; therefore, this type of microscopy has true three-dimensional resolving power [5, 6]. This means that confocal fluorescent microscopy can be utilized as the pickup in three-dimensional multi-layered optical storage. In order to use confocal fluorescent method for a read-out system, stored data must be recorded as a fluorescent pattern inside the recording medium. Accordingly, we developed a recording medium that can record bit data as a fluorescent pattern three-dimensionally inside a thick medium.

The recording medium we developed is a rhodamine-B and gold-ions (Au^{3+}) doped poly-methyl-methacrylate (PMMA) [7]. Figure 1 illustrates the reaction mechanism for recording the fluorescent pattern inside the medium. When Au^{3+} exists in the vicinity of a rhodamine-B molecule, the energy of the optically excited rhodamine-B molecule is transferred to the Au^{3+} and the rhodamine-B molecule is quenched; as a result, no fluorescent light is emitted (Fig. 1(a)). By irradiating femto-second near-infrared laser (fsec NIR laser) on this medium, Au^{3+} are photochemically reduced and changed to gold nano-particles whose diameter are around 10 nm (Fig. 1(b)). Since the reduced gold particles do not quench the rhodamine-B molecules, the rhodamine-B molecules are re-activated and become fluorescence-emissive (Fig. 1(c)). Using this mechanism, we recorded bit data as a fluorescent pattern inside the medium. The recorded data (fluorescence of rhodamine-B) were read by using a pick-up system that incorporates laser scanning confocal fluorescent microscopy.

III. EXPERIMENTAL RESULTS

Figure 2 shows an experimental result of the fluorescent pattern recording. This pattern consists of 135×100 dots with 2 μm distances. Orange area in this photograph is corresponding to the fsec laser irradiated area. From this result, the rhodamine-B molecules were activated and emitted fluorescence only in the area irradiated of fsec laser, while the fluorescence of rhodamine-B was eliminated by Au^{3+} in the non-irradiated area, and the high contrast fluorescent recording was done by using interaction between Au^{3+} and Rhodamine-B molecules, and two-photon induced photoreduction of Au^{3+} to the gold nano-particles. Figure 3 shows the result of three-dimensional multi-layered fluorescent recording. Five layers were recorded inside the developed recording medium at 10 μm distances. In each layer the bit data were written every 5×5 μm. Figure 3(a) is the top layer, which is nearest to

Takuo Tanaka
RIKEN (The Institute of Physical and Chemical Research), Nanophotonics Lab.
E-mail: t-tanaka@riken.jp
Fax: +81-(0)48-467-9170
Phone: +81-(0)48-467-9341
Address: 2-1 Hirosawa, Wako, Saitama 351-0198, Japan
Preferred category: Optical Storage Media

the surface of the medium, and (b), (c), (d), and (e) are second, third, fourth, and fifth layers, respectively. These results exhibit that the developed medium can record the fluorescent bit-pattern three-dimensionally, and that the recorded data on each layer are read with sufficient lateral and longitudinal separation by the use of a confocal fluorescent microscope pick-up. Figure 4 shows the multi-layered optical memory cube.

CONCLUSION

We have developed a novel recording medium for three-dimensional multi-layered optical memory. The material can store the bit data three-dimensionally as a fluorescent pattern using the energy transfer between rhodamine-B and Au^{3+} doped PMMA. In addition, we have already developed the structured multi-layer optical disk in which recording layers and buffer layers were alternatively fabricated. Incorporation of the buffer layers realizes high axial resolution and low cross talk. In my presentation, I will talk also about this three-dimensional memory disk with a experimental result of three-dimensional focusing and tracking servo system.

REFERENCES

[1] S. Kawata, T. Tanaka, Y. Hashimoto, and Y. Kawata, Proc SPIE 2042 (1993) 314-325.
[2] Y. Kawata, H. Ueki, Y. Hashimoto, and S. Kawata, Appl. Opt. **34** (1995) 4105-4110.
[3] Y. Kawata, T. Tanaka, and S. Kawata, Appl. Opt. **35** (1996) 5308-5311.
[4] A. Toriumi, J. M. Herrmann, and S. Kawata, Opt. Lett. **22** (1997) 555-557.
[5] O. Nakamura and S. Kawata, J. Opt. Soc. Am. A **7** (1990) 522-526.
[6] C. J. R. Sheppard, Optik **72** (1986) 131-133.
[7] T. Tanaka, K. Yamaguchi, and S. Yamamoto, Opt. Commun. **212** (2002) 45-50.

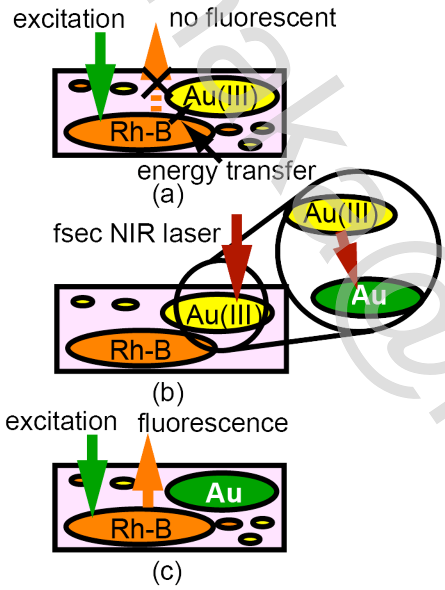

Figure 1. The recording mechanism of the fluoscent bit data

Figure 2. Recorded fluorescent image. 135x100 dots, 2μm pitch.

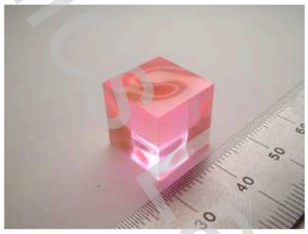

Figure 4. Multi-layered optical memory cube

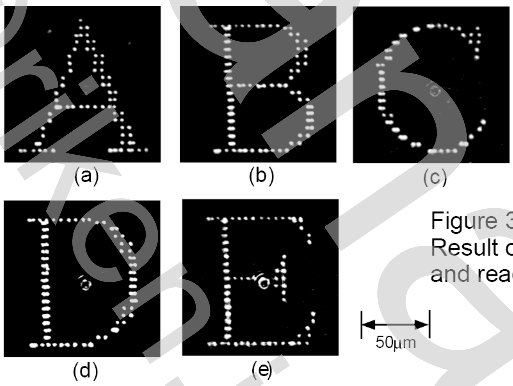

Figure 3. Experimental Result of 3D data recording and readout