Session 2A2a
Femtosecond Photonics: Microfabrication and Optical Data Storage 2

Femtosecond Photonics for Multilayered Optical Memory

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Abstract—

Introduction: Three-dimensional (3-D) optical memory has been studied by many researchers in order to overcome the data storage capacity that is limited by the diffraction limit of light [1, 2]. 3-D optical memories based on two-photon excitation are the most promising techniques, because many technologies for current optical memories, such as pick-up optics, servo and tracking systems, will be used with some extensions or modifications.

In this paper, we propose a novel fabrication method of multilayered media by a laminating process using pressure sensitive adhesives (PSA). The proposed technique is very easy to pile up many layers and control the film thickness, so this technique is applicable to mass production of multilayered media.

Multilayered Medium Using PSA: We fabricated a multilayered media by wet coating and laminating process using PSA. First, the photosensitive layer and the PSA as a transparent layer were deposited on polyethyleneterephthalate (PET) release liner films, respectively. The photosensitive layer and the PSA layer were laminated together, peeling away the release liner film from the PSA film. Second, it was laminated on a substrate under the constant pressure, and then the two layered sheets were superposed on other layers repeatedly.

We have succeeded the fabrication of twenty recording layers as the multilayered medium. Figure 1 shows the cross section along axial direction observed with a reflection confocal microscope. The film thickness of the photosensitive layer was 1.6 μm and film thickness of the transparent layer was 4.6 μm.

Figure 2 shows recording and reading results of twenty recording layers. Bit distance is 2.0 μm. The recorded bits in all layers were clearly observed with high contrast. It was also recognized that the crosstalks between neighboring layers were small enough.

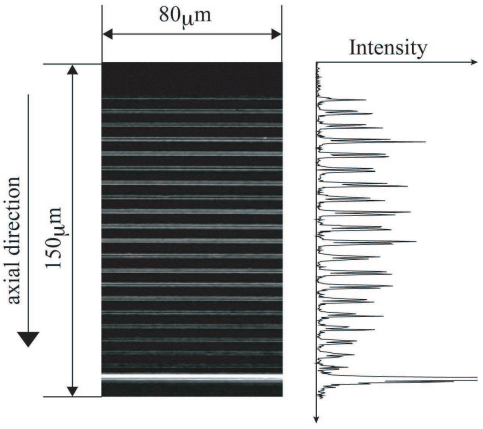

Figure 1: Cross sectional view of multilayered medium.

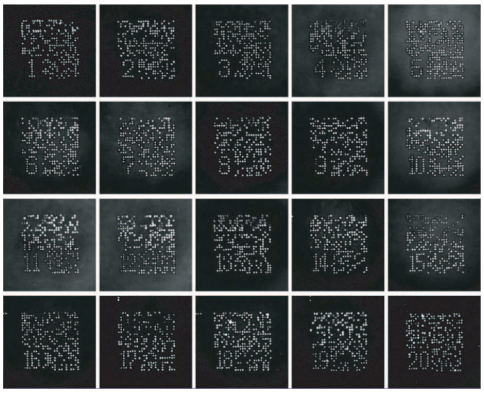

Figure 2: Recording and readout results of twently layers.

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Rewriteable Three-dimensional Optical Memory by Using Spatial Valence State Manipulation of Rare-earth Ions

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Abstract— We review recent research development on the recording, readout, and erasure of three-dimensional optical memory using the spatial valence-state manipulation of rare-earth ions. The mechanism of the femtosecond laser-induced localized photoreduction of rare-earth ions from $Re^{3+}$to Re^{2+} in glasses is discussed. Three-dimensional optical memory with ultrahigh storage density has been demonstrated. Photoreduction bit of 200 nm diam is recorded in a Sm^{3+}-doped glass with a femtosecond laser and readout clearly by detecting the fluorescence as a signal with excitation at 488 nm Ar^+ laser. The photoreduction bit that is stable at room temperature can be erased by photo-oxidation with a cw laser at 514.5 nm Ar^+ laser. Since photoreduction bits can be spaced 150 nm apart in a layer within glass, a multilayer structure with several hundred layers could be used to record data. A memory capacity of as high as 1 Tbit could thus be achieved in a glass piece with dimensions of 10 mm×10 mm×1 mm.We also point out the future tendencies of the related research.

Polarization-dependent Memory of Light via Ultrashort Pulse Laser Irradiation

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Abstract— The remarkable phenomena in ultrafast light-matter interactions manifested as a localized structural change in transparent material and an evolution of one-dimensional metal nanoparticles in liquid ablation are observed. The periodic nanostructures composed of oxygen depleted regions of 20 nm size with periods as small as 140 nm inside silica glass, are aligned perpendicular to the laser polarization. The polycrystalline copper nanowires with a length of 1.0 μm and a diameter of 85 nm are also successfully formed only under the linear-polarized laser irradiation. The growth mechanism of copper nanowires under the femtosecond laser irradiation was suggested to be a nucleation growth process. The periodic nanostructures inside silica glass and the copper nanowires in ethanol solution can be interpreted in terms of a created pattern via coupling between photon and plasmon waves; consequently a material could memorize the direction of the light polarization.

Fs Laser Micro Fabrication Method and Its Application in Multilayer Data Storage

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Abstract— In this talk our recent progress of femtosecond laser micro-fabrication method is presented. It includes the fabrication apparatus, the laser-materials interaction, the optimizing method for novel micro optical and photonic devices, and the applications in living cell and in optical multi-layer data storage. Some challenges of improving the laser spot quality and optical driving are discussed.

Lasing with the Shortest Wavelength in Substituted ZnO and Laser Spectroscopy Study on High Density Exciton in Nanocrystal

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Abstract— At femtosecond pulse laser pumping, stimulated emissions are observed in $Zn_xMg_{1-x}O$ epilayers. Among them, spectral blue shifts are dependent on the Mg substitution concentration; and the highest lasing photon energy (in ZnO series materials even reported) of 3.51 eV is observed. Furthermore, experimental results also show that by high concentration Mg substitution, a red shift of the electron-hole plasma stimulated emission is reduced and its efficiency doesn't decrease with the Mg substitution concentration. These results imply that the lasing frequency of ZnO series materials can be modified by substitution. Study on the high density excitons in single semiconductor nano-crystal by femtosecond laser spectroscopy, an interesting new collective behavior of high density excitons in single semiconductor nano-crystal is revealed. We anticipate our discovery to be a starting point for new developments of active nano-optoelectronic devices, which not only benefits to the development of nano-technology but also quantum information processing and quantum communication.

Optical Filter Based on One Dielectric Reflector

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Abstract— By theoretically analysis both in frequency domain and time domain, we demonstrate a dielectric compact optical filter based on only one reflector. The structure analyzed is a dielectric omnidirectional mirror suspended in air and perforated with rectangular lattice of air holes. The periodic dielectric index provides resonance features, sharp resonant modes with nearly complete transmission appear. Based on this phenomenon, when resonant modes are in band gap of the mirror and can radiate out of the mirror, the structure can then act as an optical filter. This kind of transmission filter is more compact than the conventional dielectric thin film devices. Resonant states in a filter depend on the lattice constant, radius of the air holes, and thickness of each layer of the reflector, without changing the reflector's thickness, a transmission mode can be determined by lattice constant and radius of the air holes, thus different filters can be easily integrated in one reflector, space-variant optical transmission filter are achieved.

Furthermore, there are several parameters can be changed to change center wavelength, shape of resonant modes, by carefully changing lattice constant, radius of air holes and thickness of layers, two resonant modes can overlap each other, flat-top optical-filters are developed and achieved. To design this kind of flat top filter do not need additional layers as conventional dielectric thin film devices, the more number of defect layers the conventional dielectric filter has, the more square the band shape.

This kind of filter is expected to be used in optical communication devices and vertical cavity surface emitting lasers.