SYMPOSIUM V

Optical Data Storage–Materials, Mechanisms, and Emerging Technologies

April 19, 2001

Chairs

Herman J. Borg
Philips Research
Eindhoven, NL-5656
NETHERLANDS
34-10-2744287

Lambertus Hesselink
Dept of Electrical Engr
Stanford Univ
Durand Bldg Rm 353
Stanford, CA 94305-4035
408-269-7102

Matthias Wuttig
I Physikalisches Institut
RWTH Aachen
Aachen, 52056 GERMANY
49 241-807155

Symposium Support

Philips Research
Steag Eta Optik
Unaxis Balzers AG

A Joint Proceedings with Symposium T/U/V
to be published in both book form and online
(see *ONLINE PUBLICATIONS* at www.mrs.org)
as Volume 674
of the Materials Research Society
Symposium Proceedings Series.

* Invited paper

SESSION V1: PHASE CHANGE RECORDING: MATERIALS AND MECHANISMS
Chair: Matthias Wuttig
Thursday Morning, April 19, 2001
Golden Gate B1 (Marriott)

8:30 AM *V1.1
PROGRESS OF THE PHASE-CHANGE OPTICAL DISK MEMORY. Takeo Ohta, Matsushita Electric Industrial Co Ltd, Optical Disk Systems Development Center, Osaka, JAPAN.

Overwriting process of the phase-change optical disk memory includes melting by a pulsed laser spot and heating by the scanned laser spot. Laser heat mode recording, the temperatures are rather high, over 600°C for amorphous mark formation and 400°C for crystallizing erase process on the disk. The fine grain ZnS-SiO_2 mixed protection layer material, N_2-doped GeTe-Sb_2Te_3-Sb chalcogenide phase-change material and layer structure design make break through on cycle characteristics. Thin substrate phase-change optical disk structure promoted high density 4.7GB DVD(Digital versatile disk) and rewritable DVD. Laser optical mean only phase-change recording realizes dual-layer volumetric memory and multi-level memory which increase the recording density well. In this paper, I will discuss the interaction of the short pulse laser irradiation on phase-change layer compared heat mode interaction.

9:00 AM *V1.2
PHASE-CHANGE MEDIA FOR HIGH DENSITY OPTICAL RECORDING. Wouter Leibbrandt, Herman Borg, Martijn Lankhorst and Erwin Meinders, Philips Research, Eindhoven, THE NETHERLANDS.

Phase-change recording is the most widely used technology for rewritable optical storage, i.e. in the rewritable formats of CD and DVD. The next generation of optical recording, aiming at high densities using blue lasers and advanced optics, also calls for high data transfer rates. The write data rate is basically media limited. We will discuss the various factors that determine the maximum write data rate, such as materials composition, recording stack design and write strategy.
We compare two classes of phase-change material: Stoichiometric GeSbTe compositions on the GeTe-Sb_2Te_3 tie-line and doped eutetic Sb_{69} Te_{31}. The crystallisation behaviour of these materials is markedly different: In the stoichiometric materials the nucleation probability is high and the growth speed is moderate, while the eutectic compositions have a relatively low nucleation frequency and a high growth speed. The low nucleation frequency of the eutectic might be explained by the formation of an ordered hexagonal lattice, instead of a simple disordered cubic lattice as observed for $Ge_2Sb_2Te_5$ materials.
The difference in the crystallisation kinetics of both type of materials has important consequences for their application in phase change recording. The time required to erase (re-crystallise) amorphous marks determines the maximum write data rate of the system. Experimental results show that with decreasing laser spot size the erasure time of amorphous marks in growth determined materials decreases, whereas it stays essentially constant for nucleation determined materials. This so-called spot size effect results in significantly higher write data rates for doped eutectic $Sb_{69}Te_{31}$ materials in higher density storage systems. By optimising the composition of doped eutectic $Sb_{69}Te_{31}$, data rates of over 100 Mbit/s will be realised in the near future.

9:30 AM V1.3
THE QUEST FOR FAST PHASE CHANGE MATERIALS. Han-Willem Wöltgens, Ralf Detemple, Stefan Ziegler, Ingo Thomas, Walter K. Njoroge, Inés Friedrich, Volker Weidenhof, Matthias Wuttig, I . Physikalisches Institut der RWTH-Aachen, GERMANY.

In the last decade a number of chalcogenide alloys has been identified which enable fast phase change recording. These materials include certain alloys of $GeSbTe$ and additives and quartenary alloys of $InAgSbTe$. To enable novell applications a further improvement in data transfer rate, i.e. the time to read, write and erase bits, is highly desirable. In the quest for materials with improved phase change kinetics we follow two different approaches. By comparing alloys with well-defined stoichiometries we identify the mechanisms which determine the transformation kinetics. Optical and electrical measurements determine the activation energy for crystallization to 2.24 ± 0.11 eV for $Ge_2Sb_2Te_5$ and to 3.71 ± 0.07 eV for $Ge_4Sb_1Te_5$, respectivly. It has been found that $Ge_2Sb_2Te_5$ also crystallizes in a hexagonal phase having an activation energy of 3.64 ± 0.19 eV. For $GeSbTe$-alloys with different composition the activation energy increases with Ge content. Power-Time-Reflectivity Change-diagramms of the films were recorded with a far field setup having a minimum pulse duration of 10 ns. For $Ge_2Sb_2Te_5$ a minimum recrystallization time of 100 ns and minimum crystallization time of less than 10 ns was observed. Whereas $Ge_4Sb_1Te_5$ has a minimum crystallization time of 380 ns and a minimum recrystallization time of 16 ns. While $Ge_2Sb_2Te_5$, in agreement with previous data, recrystallizes by the growth of subcritical nuclei, $Ge_4Sb_1Te_5$ however grows from the bit boundary. Even though this approach enables a systematic understanding of phase change properties the identification of compositions with improved kinetics is rather cumbersome. To speed up this process we employ concepts of combinatorial material synthesis. In this second approach films are evaporated with stoichiometry gradients. Then laterally resolved Secondary Neutral Mass Spectroscopy combined with diagramms of laterally resolved Power-Time-Reflectivity Change measurements are used to identify the composition with superior properties for phase change applications.

10:15 AM V1.4
MATERIALS ISSUES IN THE DEVELOPMENT OF HIGH DATA TRANSFER RATE PHASE CHANGE COMPOUNDS. Martijn H.R. Lankhorst and Herman J. Borg, Philips Research Laboratories, Eindhoven, THE NETHERLANDS.

The development of high data transfer rate phase change materials is complicated by the contradicting requirements that written amorphous marks should be erasable with very short laser-pulses, while on the other hand the marks should be stable against spontaneous crystallisation for many years at temperatures up to 50-70°C (archival life stability). In this paper these requirements are discussed in relation to properties of the phase change material. The resistance against spontaneous crystallisation of written amorphous marks is related to the glass transition temperature of the underlying phase change compound. In the paper a model is presented which can be used to estimate glass transition temperatures of phase change compounds of arbitrary composition from their atomisation energy. In phase change recording the maximum data transfer rate (in the direct overwrite mode) is limited by the speed at which previously written amorphous marks in the crystalline background can be erased by re-crystallisation. Crystallisation takes place by nucleation followed by growth, or by direct growth from the crystalline edge. According to theory, these processes are related to materials properties like viscosity, melting temperature, glass transition temperature, heat of fusion and solid-liquid interfacial energy. Although it is difficult to quantitatively compare calculated and measured crystallisation rates of known phase change compounds, it is possible to identify fundamental limits in the crystallisation speed from such an analysis. Using the above analysis, a novel ternary phase change compound was designed which combines high erasure speed with sufficient stability against spontaneous crystallisation. The measured crystallisation time for written amorphous marks is below 10 ns for specific compositions and appropriate stacks, while extrapolation of low temperature crystallisation experiments showed that written marks should be stable for more than 35 years at 50°C. In the paper the compound and its properties are further discussed.

10:30 AM *V1.5
SIMULATION ON READ/WRITE PROCESS OF PHASE CHANGE OPTICAL DISC. Hidehiko Kando, Yoshiko Nishi, Motoyasu Terao, Hitachi, Central Research Laboratory, Tokyo, JAPAN.

Read and Write process on Phase Change Optical Disc was analyzed through simulation. The simulation uses kinetics with nucleation, crystal growth, and re-crystallization at the border of amorphous and crystal. The simulator was combined with FDTD near field analysis of Joule heat generation by laser irradiation, and with thermal analysis by FEM. The simulation was applied to both GeSbTe recording layer and AgInSbTe to find the difference in nucleation frequency and crystallization rate. Also read-out signal was calculated for both materials to find that simulated signals have good matching to the experimentally obtained ones.

11:00 AM V1.6
ANALYSIS OF MULTIPULSE STRATEGIES FOR HIGH DATA RATE PHASE CHANGE OPTICAL RECORDING. Aparna C. Sheila, T.E. Schlesinger, DSSC, ECE Dept, Carnegie Mellon University, Pittsburgh, PA.

In this paper, we study some of the issues involved in designing multipulse techniques suitable for phase change recording at high velocities. GeSbTe materials have been found to give good erasability upto 50m/s. We therefore consider a phase change disk with GeSbTe as the recording layer and use an absorption controlled stack to compensate for the difference in properties between the amorphous and crystalline phases. By solving the thermal diffusion equation numerically and simulating the crystallization kinetics of nucleation and growth, we obtain the mark shapes under different conditions. The read back signal is generated from the written marks. Two velocities of 10m/s and 50m/s are considered for comparison. Using the simulated marks and signals as the basic tool, we investigate how some of the parameters in a multipulse such as the pulse widths, the cooling width and the bias power should be modified at high velocities to give performance comparable to that at lower velocities when using the same disk. For performance evaluation, we use the signal modulation level, the overwrite jitter and erasability. To study the overwrite jitter and the erasability we simulate overwrite of a small mark (say 3T) at different locations relative to a larger mark (say 6T or 8T). The cooling width is seen to be a critical factor in increasing erasability and minimizing the overwrite jitter. These studies are first carried out for the red wavelength. It is known that when using a blue laser, the cooling rates are different from that of the red due to the smaller spot sizes. The maximum velocities achievable will also be lower compared to red. We investigate how the use of blue wavelength affects the above mentioned parameters in the multipulse design for recording at low and high velocities.

11:15 AM V1.7
A NOVEL APPROACH TO OBTAIN GeSbTe-BASED HIGH SPEED CRYSTALLIZING MATERIAL FOR PHASE CHANGE OPTICAL RECORDING. Tae-yon Lee, Ki-bum Kim, Seoul National University, School of MS&E, Seoul, KOREA; Byung-ki Cheong, Taek Sung Lee, Won Mok Kim, Kyung Seok Lee, Soon Gwang Kim, Korea Institute of Science and Technology, Materials Design Laboratory, Seoul, KOREA.

A new approach is proposed to enhance the solid phase crystallization rate of GeSbTe-based recording materials for rewritable phase change optical storage. Composition modified GeSbTe-based alloy thin films are obtained by co-sputtering of a GeSbTe master alloy target with an another target of different composition. The compostion of that additional target alloy is selected from the metallurgical considerations for the formation of homogeneous single phase. Thermal, structural and optical analyses of the co-sputtered films are carried out by using DSC, XRD/TEM and ellipsometry, respectively and the results are compared with those from pure GeSbTe films. Kissinger analyses show that the crystallization activation energy of co-sputtered system is less than the pure GeSbTe system by around 0.4eV.

11:30 AM *V1.8
MICROSCOPIC STUDIES OF FAST PHASE TRANSFORMATIONS IN GeSbTe FILMS. Ralf Detemple, Inés Friedrich, Ingo Thomas, Volker Weidenhof, Han-Willem Wöltgens, I. Physikalisches Institut A, RWTH Aachen, GERMANY.

A vital requirement for the future success of phase change media are high data transfer rates, i.e. fast processes to read, write and erase bits of information. The understanding and optimization of fast transformations is a considerable challenge since the processes only occur on a submicrometer length scale in actual bits. Hence both fast temporal and spatial resolution is needed to unravel the essential details of the phase transformation. We employ a combination of fast optical measurements with microscopic analyses using atomic force microscopy (AFM) and transmission electron microscopy (TEM). The AFM measurements exploit the fact that the phase transformation from amorphous to crystalline is accompanied by a 6% volume reduction. Thus enables a measurement of the vertical and lateral speed of the phase transformation. Several examples will be presented showing the information gained by this combination of techniques.

SESSION V2: MAGNETO-OPTIC AND HOLOGRAPHIC RECORDING: MATERIALS, MECHANISMS AND NEW CONCEPTS

Chairs: Lambertus Hesselink and Herman J. Borg
Thursday Afternoon, April 19, 2001
Golden Gate B1 (Marriott)

1:30 PM *V2.1
ADVANCED MAGNETO-OPTICAL MATERIALS AND DEVICES TOWARD 100 Gb/in^2. Norio Ota, Hiroyuki Awano, R&D Division, Hitachi Maxell Ltd, Ibaraki, JAPAN.

Advanced Magneto-Optic storage materials enables very high density removable disk overcome 100 Gb/in^2 using the Magnetic domain expansion readout technology combining the Field Modulation recording method, Blue laser and high NA lens system. This paper shows the domain expansion principle and experiments showing the potential of 100 Gb/in^2, which will be very usefull for network archiving storage in near future.

2:00 PM *V2.2
SUPER-RESOLUTION READOUT FOR MAGNETO-OPTICAL DISK BY OPTIMIZING THE DEPOSITION CONDITION OF NON-MAGNETIC MASK LAYER. Takayuki Shima, Joo Ho Kim, Junji Tominaga, Nobufumi Atoda, Adv Optical Memory Group, Natl Inst of Adv Interdisciplinary Research, Tsukuba, JAPAN; Hiroshi Fuji, Adv Tech Research Labs, Sharp Corp, Tenri, JAPAN.

For super-resolution near-field structure (Super-RENS) [1], antimony and silver oxide thin films have been used as an optically transparent aperture (TA) and a light scattering center (LSC), respectively. We have recently applied this technique to MO readout and have shown that a AgO_x mask layer can retrieve small marks beyond the diffraction limit [2]. In this work, we describe Sb characteristics under sputtering deposition and examine possibility for a MO disk mask layer. Also, deposition condition for AgO_x films is revealed to improve CNR of LSC-Super-RENS. Sb films were prepared by a heliconwave-plasma sputtering method. Refractive index change of Sb between crystalline and amorphous state is a key of the technique. The indices of the films were measured as functions of the sputtering pressure and film thickness at 632.8 nm. As increasing the thickness from 5 to 15 nm, phase of the film transformed from amorphous into crystalline; and the extinction coefficient k significantly increased. As further increasing the thickness from 15 to 100 nm, the phase remained crystalline; however, the coefficient k oppositely decreased to the value close to that of amorphous for films prepared at high sputtering pressure ($>$ 0.4 Pa). As an opaque mask layer for TA-Super-RENS, Sb film with a high k ($\sim$5.9) was deposited at 0.4 Pa by the thickness of 15 nm. Recording and retrieving signals were carried out at a wavelength of 780 nm and NA of 0.53. Small marks ($\sim$270 nm) less than the resolution limit can be retrieved even with the Sb mask layer. Also LSC-Super-RENS disks were prepared by a RF magnetron sputtering method. As AgO_x film thickness was optimized to 60 nm, CNR of 23 dB was obtained for 250-nm marks.
[1] Tominaga et al., Appl. Phys. Lett. 73, 2078(1998).
[2] Kim et al., Appl. Phys. Lett. 77, 1774(2000).

2:30 PM *V2.3
HIGH COERCIVITY FILMS DESIGNED FOR THERMALLY-ASSISTED MAGNETIC RECORDING. C. Brucker, T.W. McDaniel, M. Alex, T. Valet, Seagate Research, San Jose, CA.

We have carried out a combined experimental and computer simulation study to specify and identify candidate films to support high areal density, thermally-assisted magnetic recording. The motivation of this work is to utilize the enhanced writability of very high coercivity materials that thermal assistance can provide [1,2]. Media with high coercivity (and anisotropy K_u) are known to be essential to achieve a sufficiently high ratio of K_uV/k_BT necessary to maintain thermal stability at temperature T in media switching units (grains; single domains) of volume V. Nominally, we expect $V \propto D^{-3/2}$, where D is the medium areal density. A micromagnetic recording simulation tool with a capability of representing realistic grain size distributions and spatially-varying imposed temperature distributions [3] was employed to study the interplay of thermal and magnetic field gradients in the recording process. We could easily vary the thermal and magnetic properties of the medium in this thermomagnetic recording model to identify optimal combinations of attributes to support areal density targets. We fabricated suitable media samples with a multiple cathode DC magnetron sputtering system having 4 μPa base pressure and variable temperature processing. Our primary material focus has been perpendicular magnetic anisotropy Co/X multilayers, X=Pd,Pt. A starting goal for material development has been to achieve $H_c>640$ kA/m and suitable stability against thermal cycling in the recording process. Refinements in material properties have been tracked with standard characterization including VSM, MFM, TEM, XRD, and torque magnetometry. Single-sided disk samples have been evaluated using a modified HDD-component spinstand which enables medium heating by optical means during recording [2]. The tester uses a conventional integrated HDD head (inductive ring writer with GMR reader) and allows high spatial resolution mapping of the effect of thermal and magnetic fields on recorded patterns. We will report recording performance results from several media design iterations.
[1] J.J.M. Ruigrok, R. Coehoorn, S.R. Cumpson and H.W. van Kesteren, "Disk recording beyond 100 Gb/in^2: hybrid recording", J. Appl. Phys. 87, 5398 (2000); R. Coehoorn etal., "Hybrid recording", to be published in Proceedings of the NATO-ASI, Rhodes, Greece, June 2000.
[2] M. Alex, T. Valet, T. McDaniel, and C. Brucker, "Optically-Assisted Magnetic Recording", presented at MORIS-APDSC 2000, Nagoya, Japan, Oct. 2000; to be published in J. Magn. Soc. Jpn. (2001).
[3] Advanced Recording Model (ARM), Euxine Technologies, Broomfield, CO.

3:30 PM *V2.4
INTEGRATED SURFACE EMITTING LASER ARRAYS WITH FLAT-TIP SILICON PROBES FOR THE NEAR-FIELD OPTICAL DATA STORAGE. Young-Joo Kim, Kazuhiro Suzuki, Kenya Goto, Tokai Univ, Dept of Information and Communication Technology, Numazu, JAPAN.

Current optical data storage is challenging to increase its memory capacity and data transfer rate for realizing high-quality image and rapid service in the coming digital, multimedia and network era. To actualize more effective and simple data storage, novel parallel near-field optical system has been proposed using vertical cavity surface emitting laser (VCSEL) microprobe arrays. New parallel optical system is based on the multibeam recording head consisting of VCSEL array as light source and nano-aperture probe array as near-field wave exit. We have developed new microprobe array of flat-tip structure from materials of high refractive index, which has advantages for improving the optical efficiency and stabilizing the contact head system with optical media. Silicon nano-aperture probe array has been prepared successfully with the aperture size of 150 to 500nm using micro-fabrication techniques, including newly developed aperture forming process. Though silicon microprobe array prepared in this research shows good properties, we still have an obstacle for applying this array to near-field optical heads due to the difficulty of aligning and bonding it to VCSEL array. Thus, we are now developing the monolithic microprobe array by preparing flat-tip probes directly on the substrate of bottom emitting VCSEL arrays. Since the laser of 850-nm or less wavelength can't penetrate GaAs substrate, the substrate must be removed or replaced with other transparent substrates such as silicon or gallium phosphate to get the light on the bottom side. In this research, silicon-on-insulator (SOI) substrate is attached to VCSEL array using direct bonding method after removing its original GaAs substrate, and then the microprobe array is prepared with new silicon substrate. We believe that this integrated nano-aperture VCSEL probe array is sufficiently effective to be applied to the parallel recording head for the near-field optical data storage of high data capacity and fast transfer rate.

4:00 PM V2.5
NEUTRON DIFFRACTION AND OPTICAL ABSORPTION SPECTROSCOPY ON THE METASTABLE ELECTRONIC STATE Si IN $Na_2[Fe(CN)_5NO] \cdot 2H_2O$. D. Schaniel, J. Schefer, Laboratory for Neutron Scattering, ETH Zürich and Paul Scherrer Institute, Villigen PSI, SWITZERLAND; Th. Woike, Institute for Crystallography, University at Cologne, Köln, GERMANY; M. Imlau, Fachbereich Physik, Universität Osnabrück, GERMANY.

In $Na_2[Fe(CN)_5NO] \cdot 2H_2O$ (sodiumnitroprusside, SNP) two metastable electronic states SI and SII can be excited by exposure to light in the blue-green spectral range below temperatures of 200 K and 140K, respectively [1]. The extremely long lifetime of more than $10^9 s$ offers many applications such as holographic data storage as well as the possibility of a series of optical and other structural investigations on these two excited states. Currently there are two models to describe the excited state SI: the first is claiming an inversion of the N-O bond [2] the second uses a harmonic potential to describe a N-O relaxation [3]. Neutron diffraction on single crystals allows us to detect small structural changes and to decide which of these two models is correct, as N and O have significantly different scattering lengths. We performed also optical absorption measurements on SI in single crystals of SNP. By varying the polarization direction of the populating and analyzing beam with respect to the crystallographic axes of the crystal, we gained new information about transition energies, symmetry and lifetime of the excited state SI. Further a new and unexpected effect appeared: One of the absorption bands showed a clear dependence on the population of the metastable states both in position and intensity. Its dependence on the polarization of populating and analyzing beam revealed the origin of this signal. It is caused by holographic gratings, written into the single crystal by illuminating with laser-light [4]. The scattering of the analyzing beam at these gratings appears as an extinction band in the spectrum. Analysis of the behavior of this new signal as a function of the population of the metastable state gives the possibility to determine the light-induced modulation of the refraction index, which can be as high as $\Delta n \approx 2 \cdot 10^{-2}$ comparable to refractive-index modulations in photopolymeric films.
[1] Woike et al., Phys.Rev.Lett. 53 (18) 1767 (1984).
[2] Coppens et al., J.Chem.Soc., Dalton Trans.,865 (1998).
[3] Schefer et al., Eur.Phys. J. B. 3, 349 (1998).
[4] Imlau et al., Phys.Rev.Lett. 82 (14) 2860 (1999).

4:15 PM V2.6
EFFECT OF SCATTERING NOISE ON THE DATA FIDELITY OF HOLOGRAMS RECORDED IN PHOTOREFRACTIVE CRYSTALS. Mingyan Qin, Shiquan Tao, and Guoqing Liu, Beijing Polytechnic Univ., Dept. of Applied Physics, Beijing, CHINA.

In order to achieve the high capacity of holographic storage, data retrieval from holograms with high signal-to-noise ratio (SNR), and hence low bit-error-rate, is essential. It is demonstrated that the noise arising from holographic multiplexing is far less significant than the system noise including the scattering noise in the object beam that arises from the recording medium. We paid more attention to the study of influence of the scattering noise in photorefractive crystals on the quality of data pages before hologram formation. Experimentally, we measured the intensity of "fanning" light scattered from the crystals, as well as the signal to noise ratio (SNR) of images, formed directly through the imaging system with the crystal inserted in the optical path, before and after the crystal being exposed to one of the writing beams (actually, the reference beam) for a certain time. The degradation of image fidelity due to the coherent illumination was evaluated by the decrease of SNR. By using this method, we tested a variety of lithium niobate crystals doped or co-doped with different doping concentration of Fe, Ce, and Mn, and with different treatment after crystal growth. The recording configurations under investigation included transmission, reflection, and 90-degree geometry. The experiment results show that among the three recording configurations, 90-degree geometry is least subjected to light-induced image-fidelity degradation. The intensity of fanning light increases with increasing of the doping concentration, but there is no correlation between the fanning intensity and the fidelity degradation. Therefore, one should not determine whether or not a crystal is suitable for high-fidelity holographic storage only according to its fanning intensity. Separating the fanning light (coming from reference beam) from the object beam is more important. Holograms of data pages stored in a crystal sample, chosen by using the above method, reached satisfactory data fidelity.

4:30 PM *V2.7
HIGH DENSITY, HIGH PERFORMANCE DATA STORAGE VIA VOLUME HOLOGRAPHY. W.L. Wilson, K. Curtis, M. Tackitt, A. Hill, T. Richardson, A. Hale, L. Dhar, A. Olson, M. Schnoes, H. Katz and A. Harris, Bell Laboratories, Lucent Technologies, Murray Hill, NJ.

Holographic data storage has long been considered an important emerging technology for developing high density, large capacity, fast transfer rate, data storage devices. Although this technology has been proposed since the 1970s it has failed to become viable because of five key reasons. 1) Methods: Previously proposed methods have been complex and difficult to implement. 2) Media: There has been no viable material. 3) Lasers: Initially proposed laser sources were expensive, complex and unreliable. 4) Detectors: Fast frame rate, large array detectors needed for readout have had relatively poor performance for this application and are generally low yield, high cost devices. 5) Data Input Devices: Suitable devices have only recently come into existence. The performance characteristics for storage applications have not been adequately tested.
Our team has made great strides toward resolving the five problems illustrated above. Our work suggests that development of a commercial storage device based on this technology may be viable at long last. First, a new series of methods for recording multiplexed holograms has been developed. These techniques can be implemented with an uncomplicated mechanical geometry. Individual holograms are addressed by a simple translation of the media allowing drive strategies similar to current drive technologies. Storage densities in excess of 350 channel bits/mm2 have been demonstrated in 4mm Fe doped $LiNbO_3$ at a capacity of the order of 4 Gbits, (14,000 holograms), while densities of ~48 channel bits/mm2 have been demonstrated for photopolymer films[1].
Many of the other technical challenges have been addressed and substantially reduced. First, using a organic, visibly initiated, photopolymer strategy, a WORM material has been developed. Currently the materials dynamic range supports 400 Gbytes of user density in a 5-1/4 disk. Currently all the parts needed for design of a commercial device are readily available.
(a) Compact low cost, reliable, high power solid state lasers have been and are being developed.
(b) Newly developed CMOS active pixel detectors, (APD) have been developed.
(c) MEMs based Digital Micromirror, technology resolves the input device need.
We have developed a demonstration storage system based on the new multiplexing method using the components listed above[2]. The ~480Kb/page system is the first of its kind using a photopolymer as media. Raw bit error rates of the order of 10-5 have been observed for the recorded data pages recovered. Error free recovery of a wide variety of stored data types, (text, video, etc.) , from photopolymer films has been demonstrated.
References:
1) L. Dhar, C. Boyd, S. Campbell, K. Curtis, A. Harris, A. Hill, N. Levinos, M. Schilling, M.C. Tackitt, and W.L. Wilson,; Optical Data Storage, 8, OSA Technical Digest Series, pp. 113 - 115 (1998). 2) S. Campbell, K. Curtis, A. Hill, T.J. Richardson, M.C. Tackitt, W.L. Wilson; Optical Data Storage, 8, OSA Technical Digest Series, pp. 168 - 170 (1998); William L. Wilson, et al, Optical and Quantum Electronics, 32,393, 2000.

SESSION V3: POSTER SESSION
OPTICAL DATA STORAGE: MATERIALS AND MECHANISMS
Thursday Evening, April 19, 2001
8:00 PM
Salon 1-7 (Marriott)

V3.1
HUMAN BRAIN LIKE MEMORY BEHAVIOR IN THE MAGNETIC DOMAIN EXPANSION TYPE MAGNETO-OPTICAL DISK.
Norio Ota, Hiroyuki Awano, Tani Manabu, Hitachi Maxell Ltd. R&D Division, Ibaraki, JAPAN.

Magnetic domain expansion magneto-optical memory(MAMMOS) shows human brain like memory behavior. Memory layer has so huge memory similar to deep unperceptional human memory, while readout layer shows no memory for small external stimulation. By some strong stimulations, readout layer amplifies synchronized information stored in the memory layer, thus we recognize once forgotten memory, sometimes fifty years ago memory. This phenomenon is also similar to memory association, analogy and reference ability. This paper opens the active readout scheme in MAMMOS.

V3.2
INVESTIGATIONS OF SPUTTERED SILVER OXIDE DEPOSITS FOR THE SUPER-RENS HIGH DENSITY OPTICAL DATA STORAGE APPLICATION. Dorothea Büchel, Christophe Mihalcea, Toshio Fukaya, Junji Tominaga and Nobofumi Atoda, Advanced Optical Memory Group, National Institute for Advanced Interdisciplinary Research, Tsukuba, JAPAN.

The goal for an increased storage capacity of disk media is to develop new methods offering extremely high resolution combined with high transfer rates and ease of application. An emerging approach is the Super-Resolution Near-field technique, super-RENS. Recording and reading out marks with sub-wavelength dimensions is achieved by the introduction of an additional mask layer to a common disk layer structure. This mask layer is responsible for the generation of a laterally confined, high light intensity near field zone that exposes conventional storage layers like phase change (PC) or magneto optical (MO) layers and generates marks with dimensions below the diffraction limit. In comparison to optical near field techniques like for instance NSOM, no distance control is necessary since the aperture is integrated in the disk structure. Furthermore, the record- and read-out process can be performed at very high speeds. Silver oxide mask layers play an important role in the recently developed Light-Scattering-Center (LSC) super-RENS technique. The mechanism for the super-resolution is still under discussion but seems to be based on the thermal formation of nanometer-sized silver clusters which exhibit optical local plasmons amplifying the signals of small marks in an adjacent storage layer. This work addresses a detailed examination of reactively sputtered silver oxide layers used in super-RENS applications. Spectroscopic methods like Raman-, IR-spectroscopy and ellipsometry are used to determine the silver oxide layer composition. To investigate their stability and decomposition pathway as a function of temperature we performed optical transmissions measurements on a micro heating stage. We found out that characteristic silver oxide compounds are forming while sputtering with specified oxygen concentrations. Furthermore, the thermal decomposition of the sputtered layers exhibits phase transitions between these compounds along with the formation of silver particles with nano-meter dimensions. The formation of the clusters could be confirmed by light scattering investigations.

V3.3
A STUDY ON BATCH METHOD OF THERMAL FIXING FOR MULTIPLEXED PHOTOREFRACTIVE HOLOGRAPHIC RECORDINGS. Zhuqing Jiang, Gang Meng, Guoqing Liu, Shiquan Tao, Beijing Polytechnic Univ, Dept of Applied Physics, Beijing, CHINA.

The volatility of stored information in a photorefractive holographic memory can be overcome effectively by using thermal-fixing technique. We have investigated systematically the batch method of thermal fixing for multiplexed holograms recorded in photorefractive crystals. The batch fixing process is pictured and analyzed for the first time to our knowledge. The behaviors of both electronic and ionic gratings are discussed in detail. Using the batch method, all the holograms to be stored in one location of a crystal are divided into several batches, each batch is recorded at room temperature and followed by a fixing process at higher temperature fixed at higher temperature. After all batches are recorded and fixed, they are revealed (developed) in whole at room temperature. Therefore, the batch procedure of thermal fixing includes the following processes: optical erasure of electronic gratings both by subsequent recordings in the same batch and by recordings in subsequent batches; ionic compensation during thermal fixing in one batch; smoothing of ionic gratings during thermal fixing of subsequent batches; and revealing of fixed ionic gratings. Based on mechanism of both optical erasure and smoothing repeated in batch scheme, we further design an experiment of thermal fixing for multiplexed holograms to measure the optical erasure time constant of inter-batch for given crystal samples. We have fitted out inter-batch optical erasure time constant and dark decay time constant of electronic gratings at elevated temperature for co-doped lithium niobate crystals according to the diffraction efficiency measured in every stage of all the batches. There is a good agreement between the experimental result on inter-batch optical erasure time constant and the theoretical prediction. The result shows that the hampering effect of ionic gratings on trapped electrons reduces optical erasing in batch procedures, and hence, enhances the diffraction efficiency of fixed multiplexed holograms.

V3.4
DYNAMIC BEHAVIOR OF AZOBENZENE POLYESTER USED FOR HOLOGRAPHIC DATA STORAGE. Arpad Kerekes, Emoke Lorincz, Technical University of Budapest, Department of Atomic Physics, Budapest, HUNGARY; P.S. Ramanujam, Risoe National Laboratory, Optics and Fluid Dynamics Department, Roskilde, DENMARK; Soren Hvilsted, Technical University of Denmark, Department of Chemical Engineering, Lyngby, DENMARK; Szilard Sajti, Optilink Hungary Ltd., Budapest, HUNGARY.

Dynamic behavior of thin photosensitive polyester films was studied. These films containing polyester molecules with azobenzene side chains are candidates for the purpose of rewritable holographic storage. The material becomes locally anisotropic due to absorbing linearly polarized light of proper wavelength. Polarization holograms can be recorded by two beams with orthogonal circular polarization and the stored information can be erased by one efficient circular beam. Benefits of this media are high sensitivity resulting in high diffraction efficiency and low light scattering. Dynamic behavior of the recording material becomes important when Fourier holograms are stored. The high intensity zero order peak saturates the material. In practice, the material has an endurable limit for the intensity ratio of the reference and object beams. As a model of the Fourier holography, we carried out experiments using plane waves for recording. We found that the storing material has an optimal intensity ratio for a given reference intensity where the highest diffraction efficiency occurs. Moreover, the diffraction efficiency strongly decreases when high intensity ratios are applied. Similar saturation can be observed when studying the overall intensity dependence of hologram efficiency. Another interesting characteristic is the multiplexing feature of the storing material, which can be represented by the M# number. This factor is used widespread to characterize the holographic material. We carried out several experiments in order to determine it. Additional exciting question is the response of the recording media in the blue wavelength region, where high power laser diodes are available.

V3.5
MOLECULAR MEMORY OF CHIRAL AROMATICS USING CIRCULARLY POLARIZED LIGHT. Mi Jeong Kim, Dong-Yu Kim, Kwang Ju Institute of Science and Technology, Dept of MS&E, Kwangju, KOREA.

Molecular optical switches, which can interchange between two distinct states by exposing it to light with different wavelengths or polarization, are expected to play an important role in various novel organic optical devices. Chiral materials are good candidates for these purposes due to two distinct bistable structures with the same energy and non-centrosymmertic properties in both molecular and macroscopic levels. However, only a few chiral materials for optically switchable systems have been reported because it is difficult to design proper chiral structures whose two enantiomers are reversibly interchangeable by optical means. In this work, we synthesized unique helical-shaped aromatic compounds and aromatic amines with a switchable chiral center. The chiroptical properties of these chiral helicenes were investigated using UV-Vis spectroscopy, optical rotation and circular dichroism (CD). Photoresolution of molecular chirality by exposure to circularly polarized light was examined for the applications to optical switches and memory devices. Interconversion of chirality was studied in both solution states and doped states inside polymer matrices. Holographic data storage using these switchable chiral compounds was investigated as well.

V3.6
OPTIMIZING THIN *Al*-ALLOY FILMS FOR REWRITABLE OPTICAL DATA STORAGE APPLICATIONS.
Han-Willem Wöltgens, Walter K. Njoroge, Inés Friedrich, Matthias Wuttig, I. Physikalisches Institut der RWTH-Aachen, GERMANY.

Al films in rewritable optical storage media provide the required high reflectance needed for data storage applications. Nevertheless the good thermal conductivity of the *Al* films leads to undesirable heat losses for the heat generated in the storage layer. This ultimately limits the temperature rise in the storage layer and requires higher laser powers to reach a given temperature. Therefore the performance of the storage system could be considerably improved if the thermal conductivity of the metallic film would be drastically reduced without compromising the high reflectance of the metallic film. To achieve this goal, transition metals like Ti and Cr have been added and their influence on the optical, electrical and structural properties thin Al films have been studied. The optical properties were measured using optical spectroscopy in the range from 200 nm to 1100 nm, while the resistivity was determined using the van der Pauw-method. For Ti and Cr concentrations up to 15 at-% the reflectance at 830 nm was hardly affected, while the sheet resistance increased linearly with both Ti and Cr concentration. The highest resistivities were observed for $AlCr$. They should lead to a tenfold decrease of thermal conductivity of the reflective layer in recordable or erasable compact disks. This reduced thermal conductivity is achieved without compromising much of the high reflectance of pure Al films. Both alloy systems have a reasonable thermal stability. Resistivity measurements during annealing show phase separation above 230°C for $AlTi$ and above 310°C for $AlCr$ films. For $AlCr$ films, a sharp resistivity drop is observed. For $AlTi$ films, subsequent grain growth leads to a more gradual resistivity decrease. X-ray reflectometry, X-ray diffraction, atomic force microscopy and Rutherford backscattering (RBS) are used to corroborate these findings.

V3.7

MECHANICAL STRESSES UPON CRYSTALLIZATION IN PHASE CHANGE RECORDING MATERIALS. Tom Pedersen, Walter Njoroge, Matthias Wuttig, I. Physikalisches Institut der RWTH Aachen, Aachen, GERMANY; Frans Spaepen, Division of Engineering and Applied Sciences, Harvard University, Cambridge, MA.

The volume change accompanying the phase transition between the amorphous and crystalline state in phase change materials leads to considerable mechanical stresses. Since the volume change is of the order of 5% for many Te alloys employed for data storage, problems such as limited rewritability, crack formation or viscous flow are encountered. Even though all of these effects endanger the long term success of phase change recording, very little work concerning mechanical stresses in phase change materials has been reported. Here we present the first systematic study of stresses upon crystallization of amorphous Te alloy films. Our study reveals that considerable stresses of 100 200 MPa accompany the crystallization process. Interestingly, for some alloys the stress build up only occurs after the phase transition is already completed. This points towards the importance of viscous flow. Measurements of the temperature dependence of the viscous flow corroborate this finding.