Emerging concepts in Memory Technology

Dr. A. Subrahmanyam

Department of Physics
Indian Institute of Technology Madras
Chennai 600036 India
manu@iitm.ac.in

Semiconductor Laboratory, Dept. of Physics
Organization:

An Introduction to memories

Optical memories

Nano silver for Optical memories
Nanotech in electronics will start early and spread fast versus other sectors.

Source: October 2004 Lux Research Report “Sizing Nanotechnology’s Value Chain”
International Symposium on Ultra-High-Density Optical Storage (UHDOS 2001)
March 2-3, 2001 (Friday-Saturday)
Room 1-311, Tokai University, Numazu, JAPAN
Research Program for the Future of Japanese Science Promotion Society
"Ultimate Information Processing Devices Using High-Functional Spatial Light Modulation"

Sponsored by
School of High-Technology for Human Welfare, Tokai University
Industry-University Liaison Association (IULA), Tokai University
Present status:
The Present Technology:

1. Magnetic Disks (Hard Disks) : Magnetic materials
2. CD ROM : Thermo - Optical
3. DVD
4. Blue ray Technology

Emerging Concepts:

1. Thermo Mechanical (IBM)
2. Pervoskite Defect Control (Concept from NCSU)
External Memories:

1. Magnetic disk---Floppy disk, hard disk
   magnetic materials based (Iron Oxide); magnetic sensing
2. Magnetic tape

3. Optical Memory---CD, CD-R, CD-RW…
   DVD, DVD-RW.
   Optical sensors: Where ever you want to write you create 0 by burning the metal and where you want 1 you leave the metal unburnt.
   The reflections from these burn pits reads 0 and 1s.
0.1-0.2 microns
1 bit

5-10 microns
1-track width

Magnetic disk (HD)
Magnetic Disks

Disk surface spins at 3600–15,000 RPM

The surface consists of a set of concentric magnetized rings called tracks.

Each track is divided into sectors.

The read/write head floats over the disk surface and moves back and forth on an arm from track to track.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sun T9840C</th>
<th>Sun T9940B</th>
<th>IBM 3592</th>
<th>Sony SAIT</th>
<th>SDLT 600</th>
<th>HP LTO-3</th>
<th>IBM TS1120</th>
<th>Sun T10000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity (Gbyte)</td>
<td>10</td>
<td>200</td>
<td>300</td>
<td>500</td>
<td>300</td>
<td>400</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>Data rate (MByte/s)</td>
<td>30</td>
<td>30</td>
<td>41</td>
<td>30</td>
<td>39</td>
<td>80</td>
<td>100</td>
<td>120</td>
</tr>
<tr>
<td>No. of parallel data channels</td>
<td>16</td>
<td>16</td>
<td>8</td>
<td>5</td>
<td>16</td>
<td>16</td>
<td>16</td>
<td>32</td>
</tr>
<tr>
<td>Tape width (mm)</td>
<td>12.7</td>
<td>12.7</td>
<td>12.7</td>
<td>12.7</td>
<td>12.7</td>
<td>12.7</td>
<td>12.7</td>
<td>12.7</td>
</tr>
<tr>
<td>Areal density (Gbit/in.²)</td>
<td>0.11</td>
<td>0.22</td>
<td>0.33</td>
<td>0.72</td>
<td>0.37</td>
<td>0.44</td>
<td>0.54</td>
<td>0.40</td>
</tr>
<tr>
<td>Volumetric density (Tbit/in.³)</td>
<td>0.25</td>
<td>0.48</td>
<td>0.82</td>
<td>2.08</td>
<td>0.804</td>
<td>1.05</td>
<td>1.43</td>
<td>1.20</td>
</tr>
</tbody>
</table>

*Note: Areal and volumetric densities are estimates based on available information and modeling.*
<table>
<thead>
<tr>
<th>Reference</th>
<th>Areal Density (Gbit/in.²)</th>
<th>Linear Density (kbpi)ᵃ</th>
<th>Track Density (ktpi)ᵇ</th>
<th>Media $M_s t$ (milli-emu/cm²)</th>
<th>$H_c$ (Oe)</th>
<th>Spacing (nm)</th>
<th>Read Head</th>
<th>Shield Spacing (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tsang et al., 1990⁵</td>
<td>1</td>
<td>118</td>
<td>8.47</td>
<td>0.7</td>
<td>1800</td>
<td>51</td>
<td>MR SAL⁶</td>
<td>250</td>
</tr>
<tr>
<td>Tsang et al., 1996⁶</td>
<td>3</td>
<td>185</td>
<td>16.9</td>
<td>0.53</td>
<td>2000</td>
<td>80</td>
<td>MR SAL</td>
<td>200</td>
</tr>
<tr>
<td>Kanai et al., 1996⁷</td>
<td>5</td>
<td>257</td>
<td>19.5</td>
<td>0.44</td>
<td>2500</td>
<td>50</td>
<td>SV⁸</td>
<td>260</td>
</tr>
<tr>
<td>Tsang et al., 1999⁹</td>
<td>12</td>
<td>350</td>
<td>34.0</td>
<td>0.35</td>
<td>3000</td>
<td>40.6</td>
<td>SV</td>
<td>140</td>
</tr>
<tr>
<td>Liu et al., 2000⁹</td>
<td>36</td>
<td>511</td>
<td>70.4</td>
<td>0.32</td>
<td>3200</td>
<td>25</td>
<td>SV</td>
<td>120</td>
</tr>
<tr>
<td>Stoev et al., 2001¹⁰</td>
<td>63</td>
<td>600</td>
<td>105</td>
<td>0.39</td>
<td>3900</td>
<td>20</td>
<td>SV</td>
<td>100</td>
</tr>
<tr>
<td>Zhang et al., 2002¹¹</td>
<td>101</td>
<td>680</td>
<td>149</td>
<td>0.4</td>
<td>6000</td>
<td>14.3</td>
<td>SV</td>
<td>…</td>
</tr>
</tbody>
</table>

ᵃ kbpi — kilobits per inch.
ᵇ ktpi — thousand tracks per inch.
⁶ MR SAL — magnetoresistive soft adjacent layer bias.
⁸ SV — spin valve.
**CD –ROMs**

- **Working principle:**
  - Protective acrylic
  - Polycarbonate plastic
  - Laser beams
  - Land
  - Label
  - Pit
  - Aluminum or other metals
Cross Section of CD-R

- Reflective gold layer
- Printed label
- Protective lacquer
- Polycarbonate
- Substrate
- Dye layer
- Reflective beam
- Transmit beam
- Dark spot burned by laser

1.2mm
## Optical Disc Technology

<table>
<thead>
<tr>
<th>CD-Technology</th>
<th>CD - Storage Capacity ca. 650 MB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prerecorded Information</td>
<td>Recordable</td>
</tr>
<tr>
<td>CD, CD-ROM</td>
<td>CD-R</td>
</tr>
<tr>
<td>Read Only Memory ROM</td>
<td>Write Once Read Many WORM</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DVD-Technology</th>
<th>DVD - Storage Capacity max. 9.4 GB (18 GB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prerecorded Information</td>
<td>Recordable</td>
</tr>
<tr>
<td>DVD-Video, DVD-ROM</td>
<td>DVD-R</td>
</tr>
<tr>
<td>Read Only Memory ROM</td>
<td>Write Once Read Many WORM</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Blu Ray-Technology</th>
<th>Storage Capacity, 27 GB (2 x 25 GB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prerecorded Information</td>
<td>Recordable</td>
</tr>
<tr>
<td>Read Only Memory ROM</td>
<td>Write Once Read Many WORM</td>
</tr>
</tbody>
</table>
CD

120mm in diameter

12mm

1.2mm thickness
**Information on the CD disks**

- Data are written in series form and are read in series fashion, too.

- The disks have to rotate with a constant linear velocity for CD-music.

- Single-speed CD-ROM drives operate at 75 sectors/sec---153,600 bytes/sec in mode 1 and 175,200 bytes/sec in mode 2.

- The difference between 1 and 2 is between music and video mode or data mode.
Blue-Ray

- digital dubbing between the hard drive, DVDs, and Blu-ray Discs, including the ability to dub five DVDs (4.7GB) onto a single Blue-ray Disc (25GB).

- The recorder also features an HDMI output jack, enabling users to enjoy full-digital high-definition video and high-fidelity audio with no signal deterioration by outputting recorded high-definition video (HDTV) to a compatible monitor for playback.

- The BD-HD100 will begin selling in Japan next month for about 320,000 yen ($2,991).
The Blu-ray Disc Alliance:
- Sony
- Philips
- Pioneer
- Matsushita (Panasonic)
- Samsung
- Sharp
- Hitachi
- LG
- Thomson

27 Gigabyte Storage Capacity
- Single Layer

50 Gigabyte (2 x 25) Storage Capacity
- Dual Layer

Application: Digital High Definition TV
Two important points:

1. Write by High power Laser to ablate the material on the Disk (in CD)
2. Read by the reflections coming out of the pits created during writing
3. For DVD and Multi Write / Read CDs, the property of Phase change of Material during heating and reheating

Technology: Focusing on to a Pixel: Near and far field optics
Space resolution in focusing an optical beam:
wavelength of the beam: Blue ray Technology
Figure 1. Roadmap of optical data storage and its key parameters. CD – compact disc, DVD – digital versatile disc, HD-DVD – high-definition digital versatile disc, BD – Blu-ray disc, \( \lambda \) – wavelength of the laser light, NA – numerical aperture of the objective lens, and \( d \) – thickness of substrate or cover layer.
The Fundamentals of Optics and the CD limits:

Table I: Some Calculated System Margins According to the Approximated Aberration Formulas Stated in the Text.

<table>
<thead>
<tr>
<th>Format</th>
<th>$\lambda$ (nm)</th>
<th>NA</th>
<th>d (nm)</th>
<th>Storage Capacity (Gbyte)</th>
<th>$\Delta z$ (μm)</th>
<th>$\Delta d'$ (mm)</th>
<th>$\alpha$ (mrad)</th>
<th>$\Delta n_{rz}$ (nm/mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CD</td>
<td>780</td>
<td>0.45</td>
<td>1.2</td>
<td>0.65</td>
<td>1.87</td>
<td>0.100</td>
<td>10.0</td>
<td>500$^1$</td>
</tr>
<tr>
<td>DVD</td>
<td>650</td>
<td>0.60</td>
<td>0.6</td>
<td>4.7</td>
<td>0.88</td>
<td>0.026</td>
<td>7.0</td>
<td>750$^1$</td>
</tr>
<tr>
<td>HD-DVD</td>
<td>405</td>
<td>0.65</td>
<td>0.6</td>
<td>15</td>
<td>0.46</td>
<td>0.012</td>
<td>3.4</td>
<td>640$^2$</td>
</tr>
<tr>
<td>BD</td>
<td>405</td>
<td>0.85</td>
<td>0.1</td>
<td>25</td>
<td>0.27</td>
<td>0.004</td>
<td>9.2</td>
<td>2240$^2$</td>
</tr>
</tbody>
</table>

$^1$Typical measured value.
$^2$Scaled value with DVD as reference.

Symbols and abbreviations: $\lambda$ = laser wavelength, NA = numerical aperture, d = substrate thickness, $\Delta z$ = defocus distance, $\Delta d$ = substrate thickness variation, $\alpha$ = degree of tilt, $\Delta n_{rz}$ = vertical birefringence, CD = compact disc, DVD = digital versatile disc, HD-DVD = high-definition DVD, and BD = Blu-ray disc.
The anatomical statistics:

<table>
<thead>
<tr>
<th></th>
<th>1st Generation</th>
<th>2nd Generation</th>
<th>3rd Generation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CD</td>
<td>DVD</td>
<td>HD-DVD</td>
</tr>
<tr>
<td>Wavelength</td>
<td>780 nm</td>
<td>658 nm</td>
<td>405 nm</td>
</tr>
<tr>
<td>Numerical aperture (NA)</td>
<td>0.45</td>
<td>0.60</td>
<td>0.65</td>
</tr>
<tr>
<td>Capacity (single-layer disc)</td>
<td>650 Mbyte</td>
<td>4.7 Gbyte</td>
<td>15–20 Gbyte</td>
</tr>
</tbody>
</table>
The material for Multiple Write / Read CD (Blue ray DVD):

![Composition triangle for Ge, Sb, and Te. Fast-growth material (FGM) (e.g., doped Sb-Te) and nucleation-dominated material (NDM) (e.g., Ge$_2$Sb$_2$Te$_5$) are indicated.](image)
Figure 4. Maximum user data rate as a function of the reciprocal laser spot diameter of four consecutive optical recording systems for a nucleation-dominated Ge$_2$Sb$_2$Te$_5$ composition (NDM) and a growth-dominated doped Sb$_2$Te composition (FGM). DVR refers to the high-numerical-aperture system (NA = 0.85) based on a red laser. The arrows identify the spot diameters of the various disc formats. CD is compact disc, DVD is digital versatile disc, HD-DVD is high-definition DVD, and BD is Blu-ray disc.
Figure 1. Schematic illustration of a phase-change stack for blue recording.
The Next generation Technology uses Fluorescence as the tool:

**Fluorescent Materials**

The second category for multilayer media is fluorescent materials, which was first proposed as a volumetric bitwise data storage medium by Parthenopoulos. He presented the principles for a 3D bitwise optical memory device by using two forms of spirobenzopyran, which is a photochromic dye, embedded in PMMA. The PMMA can also serve as the substrate for the recording device, thus enabling reasonable manufacturing costs. This photochromic molecule, initially in the spiropyran form, absorbs two photons at the same time via a 2P excitation when illuminated by a tightly focused laser beam with \( \lambda = 0.55 \, \mu m \) and yields the merocyanine form via heterolytic cleavage. Thus, the molecular structure is changed into a new “written” form, and a data bit is generated.
Figure 4. AgOx super-resolution near-field structure (super-RENS) with a GeSbTe recording layer.
Figure 6. A two-fluorescent-spot servo technique suggested by Walker for fluorescent material. Both tracking error signal (TES) and focus error signal (FES) (y axis variables in two bottom graphs) can be generated by combinations of currents from the three detectors.
Figure 7. A master/slave servo technique combines the master beam and the slave beam into a single path. The write/read slave beam is focused deep inside the volumetric disc. The master beam used to generate the reference signals is focused on tracks of a conventional rewritable compact disc (CD-RW) bonded to the volumetric disc.
Holographic memories:

Figure 10. (a) Near-field optics readout system for an optical disc. (b) Holography with angular multiplexing. "Active volume" means only this volume is used for a particular angle.
Figure 1. Schematic illustrations of (a) the recording process in holographic storage and (b) the readout process in holographic storage.
## Table 1: Requirements for Recording Media for Holographic Storage.

<table>
<thead>
<tr>
<th>Material Parameters</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optical flatness</td>
<td>$&lt; \sim \lambda/2$ per cm</td>
</tr>
<tr>
<td>Optical scatter</td>
<td>$&lt; \sim 10^{-6}$ of reference beam power</td>
</tr>
<tr>
<td>Thickness of media</td>
<td>$&gt;500$ μm</td>
</tr>
<tr>
<td>Dynamic range (M/#\textsuperscript{a})</td>
<td>$\geq 10$</td>
</tr>
<tr>
<td>Photosensitivity (in the visible to near-infrared)</td>
<td>100–1000 mJ/cm(^2) to achieve full dynamic range, or M/#</td>
</tr>
<tr>
<td>Dimensional stability</td>
<td>$&lt; 0.2%$</td>
</tr>
<tr>
<td>Processing for readout</td>
<td>Solvent/heat-free</td>
</tr>
<tr>
<td>Readout</td>
<td>Nonvolatile</td>
</tr>
</tbody>
</table>

\textsuperscript{a}M/# is a measure of the number of holograms of a certain diffraction efficiency that can be multiplexed in a volume of the recording medium. $M/#$ is proportional to $(\Delta n)^2$ (thickness of medium), where $\Delta n$ is the refractive index contrast of the material. $M/# = \sum_{i=1}^{N} \sqrt{\eta_i}$, where $N$ is the number of holograms multiplexed in the same volume of material and $\eta_i$ is the diffraction efficiency of each hologram.\textsuperscript{20}
<table>
<thead>
<tr>
<th></th>
<th>Standard MRAM (90 nm)(^a)</th>
<th>DRAM (90 nm)(^b)</th>
<th>SRAM (90 nm)(^b)</th>
<th>SMT MRAM (90 nm)(^a)</th>
<th>Flash (90 nm)(^b)</th>
<th>Flash (32 nm)(^b)</th>
<th>SMT MRAM (32 nm)(^a)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cell Size (μm(^2))</strong></td>
<td>0.25</td>
<td>0.25</td>
<td>1–1.3</td>
<td>0.12</td>
<td>0.1</td>
<td>0.02</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>256 Mbit/cm</td>
<td>256 Mbit/cm</td>
<td>64 Mbit/cm</td>
<td>512 Mbit/cm</td>
<td>512 Mbit/cm</td>
<td>2.5 Gbit/cm</td>
<td>5 Gbit/cm</td>
</tr>
<tr>
<td><strong>Read Time</strong></td>
<td>10 ns</td>
<td>10 ns</td>
<td>1.1 ns</td>
<td>10 ns</td>
<td>10–50 ns</td>
<td>10–50 ns</td>
<td>1 ns</td>
</tr>
<tr>
<td><strong>Program Time</strong></td>
<td>5–20 ns</td>
<td>10 ns</td>
<td>1.1 ns</td>
<td>10 ns</td>
<td>0.1–100 ms</td>
<td>0.1–100 ms</td>
<td>1 ns</td>
</tr>
<tr>
<td><strong>Program Energy/Bit</strong></td>
<td>120 pJ</td>
<td>5 pJ</td>
<td>5 pJ</td>
<td>0.4 pJ</td>
<td>30–120 nJ</td>
<td>10 nJ</td>
<td>0.02 pJ</td>
</tr>
<tr>
<td></td>
<td>Needs refresh</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Endurance</strong></td>
<td>&gt;10(^{15})</td>
<td>&gt;10(^{15})</td>
<td>&gt;10(^{15})</td>
<td>&gt;10(^{15})</td>
<td>&gt;10(^{15}) read</td>
<td>&gt;10(^{15}) read</td>
<td>&gt;10(^{15})</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&gt;10(^{6}) write</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Nonvolatility</strong></td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Notes: MRAM = magnetic random-access memory. SMT = spin momentum transfer. DRAM = dynamic random-access memory. SRAM = static random-access memory.
\(^a\) MRAM values as projected by the authors.
\(^b\) These values are from the International Technology Roadmap for Semiconductors.
New Concept of Switching Dislocations in Oxides

With silicon microelectronics approaching fundamental limits, new concepts for high-density memory devices are sought. The individual switching of dislocations in oxides may offer just the right alternative.

Figure 1 Switching of single dislocations. a. The dislocations (dark spots) are individually addressed by an atomic force microscope with a conductive cantilever. b. The current-voltage characteristics clearly show bistable switching. (Reproduced from ref. 1.)

Concept from Angus Kingon, NCSU, Raleigh, USA
Scanning Probes Entering Data Storage: From Promise to Reality

Haralampos Pozidis

January 11, 2006
AFM and Scanning Probe Techniques

AFM: Atomic Force Microscope
Thermomechanical Writing and Reading Concepts

Writing Concept

Reading Concept

Read Sensitivity
\[ \Delta R/R \sim 10^{-4} / \text{nm} \]
Thermomechanical Erasing

Erasure: Indentation Crowding

![Image of indentation crowding with plots and graphs showing changes in nanometers (nm).](image-url)
- Probe storage technology offers unprecedented data storage density
  - >1 Terabit/in² shown
  - Future density growth prospects appear better than flash or magnetic recording
  - Fundamental limits may occur at molecular dimensions

- Technical progress is on track
  - Key subsystems have been demonstrated
  - 2nd generation of complete storage system prototype integrating all subsystems demonstrated
  - Performance and reliability of read/write process being critically evaluated

- Application to Storage for Handheld Devices (phones, PDAs, cameras, portable A/V)
  - Small form factor: Flash type format (SD, MMC, CF)
  - High capacity: potential for several 10's GB
  - Potential for low-cost, all-silicon batch fabrication
  - Low power consumption at mobile speed
  - Variable speed vs power consumption option
New Emerging concepts in Optical memories

Silver nano particles:

Proposed by Dickson group at Georgia Tech (2001)


Write mechanism:

A nano crystalline silver is oxidized to form silver oxide. These Silver oxide nano clusters decompose into metallic silver when exposed to shorter wavelengths (< 520 nm) : NO LASER
This work is prompted by a report of Peyser et al. who studied the fluorescence of Silver Oxide nano-particles prepared by both wet chemical and thermal evaporation processes.

Fluorescence from a 16nm Ag/Ag$_2$O film excited at wavelength of 514.5nm.
Read Mechanism:
When these silver nano clusters are irradiated with a longer wavelength, emit FLUORESCENCE (> 600 nm).

This Fluorescence emission is the read mechanism

In ONE Square inch, you can have one Tera Byte memory!!

The Read / Write can be as many times as we can convert silver to silver oxide and silver oxide to silver
Green
525-532 nm light

Red emission
Fluorescence

Blue 488-514.5 nm

Filter for 514.5 nm

Filter for 660 nm

Scattered and fluorescent emissions

Ag$_2$O film
The Process:

Nano-Silver thin films
DC Magnetron

Nano Ag

Nano AgOx

Oxidize (250 C)

Irradiate 440 nm

Nano AgOx breaks into nano-Ag clusters

Write the data

Irradiate with 480 nm

Excite with 540 nm

Fluorescence emission

Read the data
Nano Silver Thin films have been prepared by:

- DC Magnetron Sputtering Technique
  - Industrially viable
  - Can control the growth parameters precisely

These nano-Silver is oxidized to form Silver oxide.

Dickson’s Group has reported on chemical methods.
XRD Spectrum obtained from metallic Silver film:

Position [°2Theta]

Counts

38.202
(1 1 1)

44.402
(2 0 2)
AFM image of the **metallic silver** film before oxidation:

Grain size \( \sim 28 \text{ nm} \)
AFM image of the silver oxide film after oxidation of metallic silver:

Grain size: \(\sim 40\) nm
Fluorescence spectra of nano silver oxide coated at 20W for 60 seconds:
Best output from Fabrication technique 3 (23nm Precursor film)
Comparison of Fluorescence spectra coated at different sputtering rates:

![Graph showing Fluorescence spectra](image)

- Normalised Intensity
- Wave length (nm)

- 20 W
- 30 W
- 40 W
We are also evaluated the films for Electrical resistivity.

<table>
<thead>
<tr>
<th>Sputtering Power</th>
<th>Thickness of the film (in Å)</th>
<th>Resistivity measured (Ω cm)</th>
<th>Hall Coefficient (cm³/coloumb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 Watt</td>
<td>100</td>
<td>$6.51 \times 10^{-5}$</td>
<td>$-1.9 \times 10^{-4}$</td>
</tr>
<tr>
<td>30 Watt</td>
<td>250</td>
<td>$7.14 \times 10^{-5}$</td>
<td>$-6.8 \times 10^{-4}$</td>
</tr>
<tr>
<td>40 Watt</td>
<td>450</td>
<td>$1.9 \times 10^{-5}$</td>
<td>$-2.8 \times 10^{-4}$</td>
</tr>
</tbody>
</table>
Summary of results:

1. We could prepare the nano silver and silver oxide clusters

2. Good fluorescence spectra show that the concept works with DC Magnetron sputtering technique

Future work:

1. How to get uniform size of the clusters
2. The sharpness of the Fluorescence lines (nearest neighbor interactions to be minimized)
3. The factors / growth parameters that influence the clusters
4. Resolution of the cluster sizes

We are also carrying out the work with PLD.
Expressing the recording/erasure processes in terms of their energy requirements it is seen that:

- Approximately 150J of optical energy at \( \lambda = 532 \text{nm} \) is required to completely exhaust the 660nm fluorescence.
- An equivalent amount of energy is required at \( \lambda = 514 \text{nm} \) to re-establish the fully written state.
Can either
- Use whole of output range to obtain high SNR
- Readout semi non-destructively many times until fluorescence output drops below that to produce adequate SNR.
- Implement multi-level rather than digital storage. Number of storage levels determined by SNR

Note: Area studied $\approx 0.2 \text{cm}^2$
Schematic Photo-Physics/Chemistry:

- Write radiation (sub 520nm) partially photo-reduces Ag₂O to AgO and silver particles.
- Some energy absorbed by the Ag₂O is transferred to the silver clusters raising them to stable excited states.
- Readout using longer wavelength radiation releases this energy in fluorescence (660nm) and drives the reversal process.
- Fluorescence wavelengths determined by size of silver particles.
Amorphous Phase

Scale: 0.2 microns

Crystalline Phase

Electron Diffraction Patterns

Short Range Atomic Order
Low Free Electron Density
High Activation Energy
High Resistivity

Long Range Atomic Order
High Free Electron Density
Low Activation Energy
Low Resistivity

Material Characteristics
Summary:

- Nano-scale silver oxide appears to have potential as a material capable of supporting non-thermal recording mechanisms.
- Oxidative re-sputtering is the most efficient fabrication technique and 23nm films exhibit optimum performance at wavelengths studied.

Questions:

- Stability under ambient light conditions?
- Impact of protective overcoat?
- Fabrication in thicker film form whilst retaining essential structure and characteristics?
- Can more precise frequency selectivity be obtained through better control of particle size?
Thanks to:

- The support of Dept of Information Technology, Govt of India

  Technical support of Mr Jeeva, Mr Suman, Mr C.Suresh Kumar

Also Thanks to ALL my students who teach me every day.

Thanks for your kind attention
Hierarchy in optical near-fields and its application to memory retrieval

Makoto Naruse, Takashi Yatsui, Wataru Nomura, Nobuaki Hirose, and Motoichi Ohtsu

Optics Express, Vol. 13, Iss. 23 -- November 2005
• pp: 9265-9271
Plasmon enhanced optical near-field probing of metal nanoaperture surface emitting laser

Jiro Hashizume and Fumio Koyama
Microsystem Research Center, Tokyo Institute of Technology,
4259-RI-22 Nagatsuta, Midori-ku, Yokohama 226-8503, Japan
j.hashizume13@mz.pt.titech.ac.jp

Fig. 3. Measurement setup for signal voltage and optical near-field intensity.

Fig. 4. Measured surface topography (a), optical near-field intensity (b), and voltage change (c) of nano-aperture VCSEL with metal nano-particle.
Nanofocusing probe limitations for a ultra-high density optical memory

I D Nikolov

Optics and Spectroscopy Department, University of Sofia, 5A James Bourcher Boulevard, Sofia BG-1164, Bulgaria

Nanofocusing recording probe for an optical disk memory

I D Nikolov\(^1,4\), K Goto\(^2,3\), S Mitsugi\(^2,3\), Y J Kim\(^2,3\) and V I Kavardjikov\(^2,3\)

\(^1\) Optics and Spectroscopy Department, University of Sofia, Sofia, BG-1164, Bulgaria
\(^2\) School of High Technology for Human Welfare, Tokai University, Nishino 317, Numazu-city, Shizuoka 410-0395, Japan
\(^3\) Institute of Mechanics, Bulgarian Academy of Sciences, Sofia, BG-1113, Bulgaria

E-mail: ivandn@intech.bg
Research Theme 1: Ultradense Memory

Desired Attributes:
- **Objective:**
  To explore technologies that promise ultra-dense, low-power, on-chip memory.

- **Projects:**
  - molecular switch memory
  - optical memory

- **Approach:**
  - electronic memory
  - optical memory

![molecular memory element](image)

![Optical Media](image)
Nanodiode-Based Optical Storage

Objective: Demonstrate nanoscale LEDs and photodiodes for applications in ultra-dense near-field storage
Optical Fluorescence Memory

Three-dimensional optical memory using a human fingernail

Akihiro Takita, Hirotugu Yamamoto, Yoshio Hayasaki, and Nobuo Nishida,

The University of Tokushima; Hiroaki Misawa, Hokkaido University

Optics Express Vol. 13, No. 12 June 13, 2005 Page: 4560 - 4567