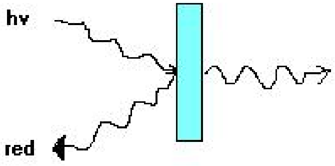
Emerging concepts in Memory Technology

Dr. A.Subrahmanyam

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



Semiconductor Laboratory, Dept. of Physics

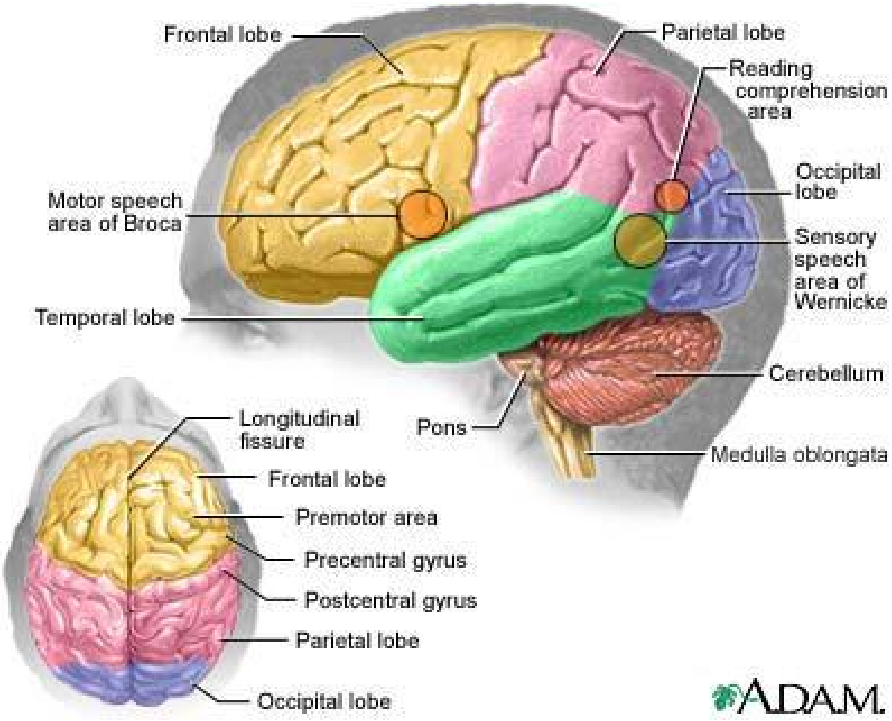
13 Oct 2006 SAMEER

Organization:

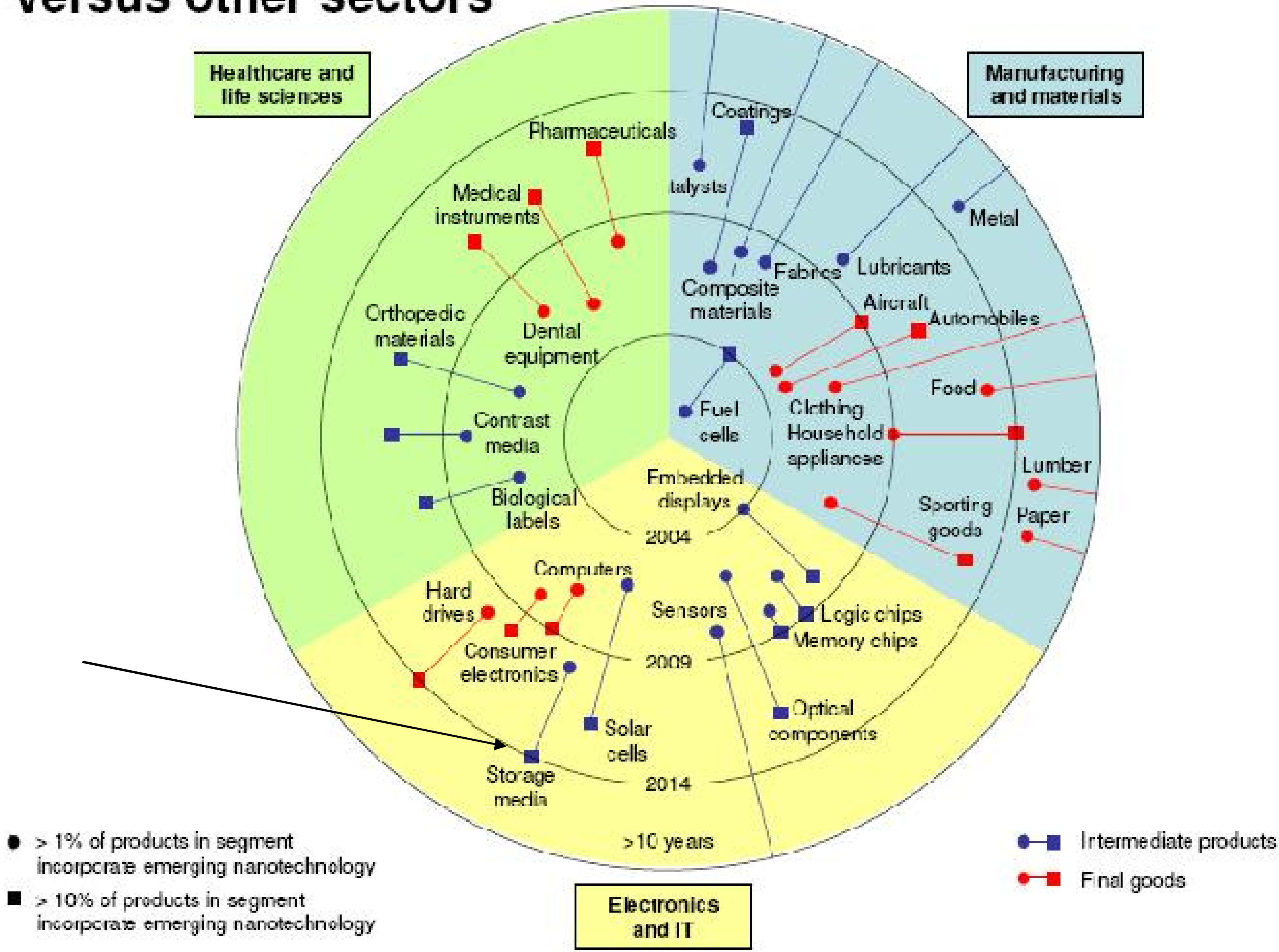
An Introduction to memories

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)

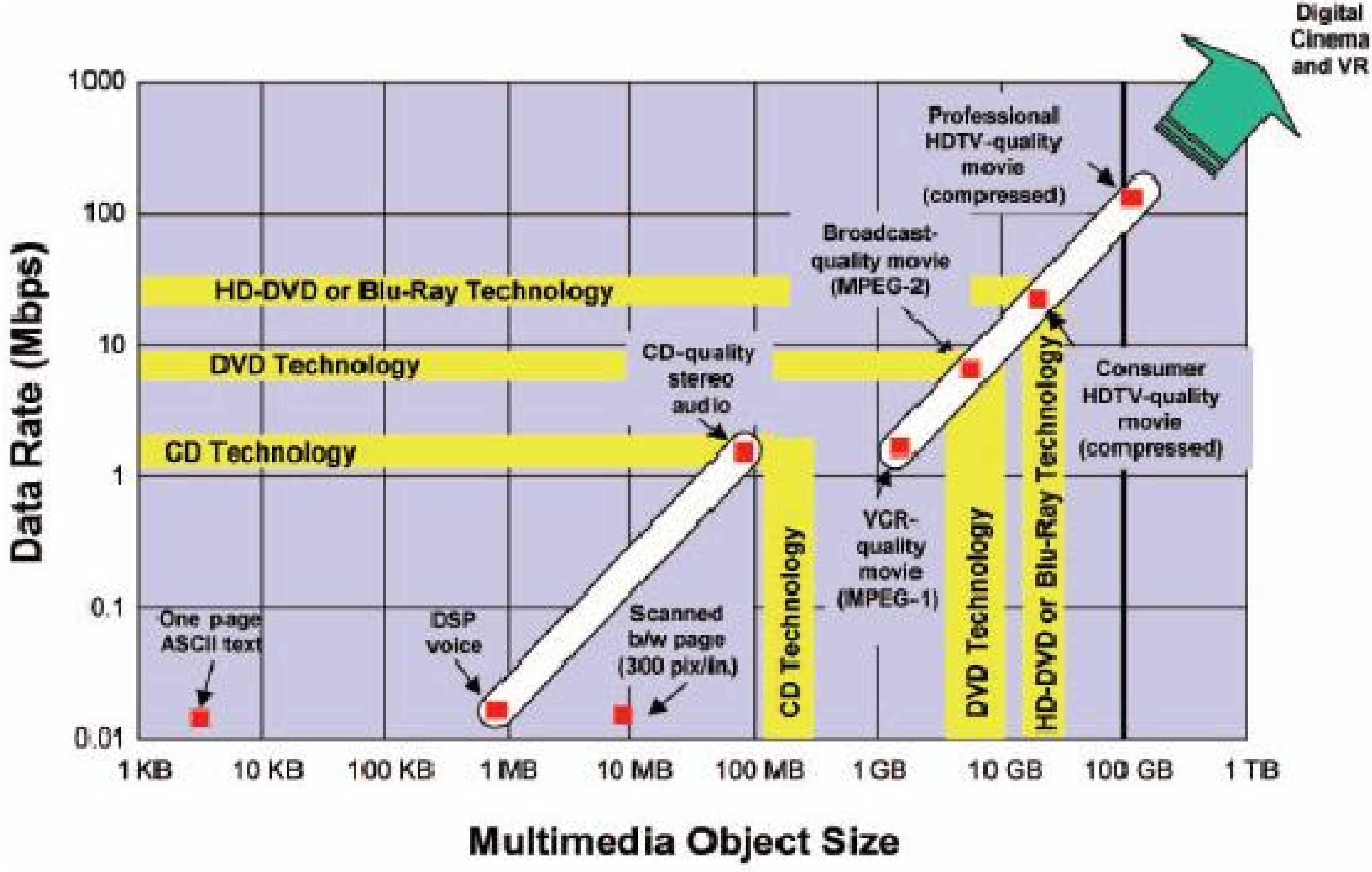
March 2-3, 2001 (Friday-Saturday)

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)
3. Surface Plasmon Assisted Fluorescence in Nano Silver
   (Dixon : Georgia, IIT Madras and Exter Univ, England))

External Memories:

1. Magnetic disk---Floppy disk, hard disk

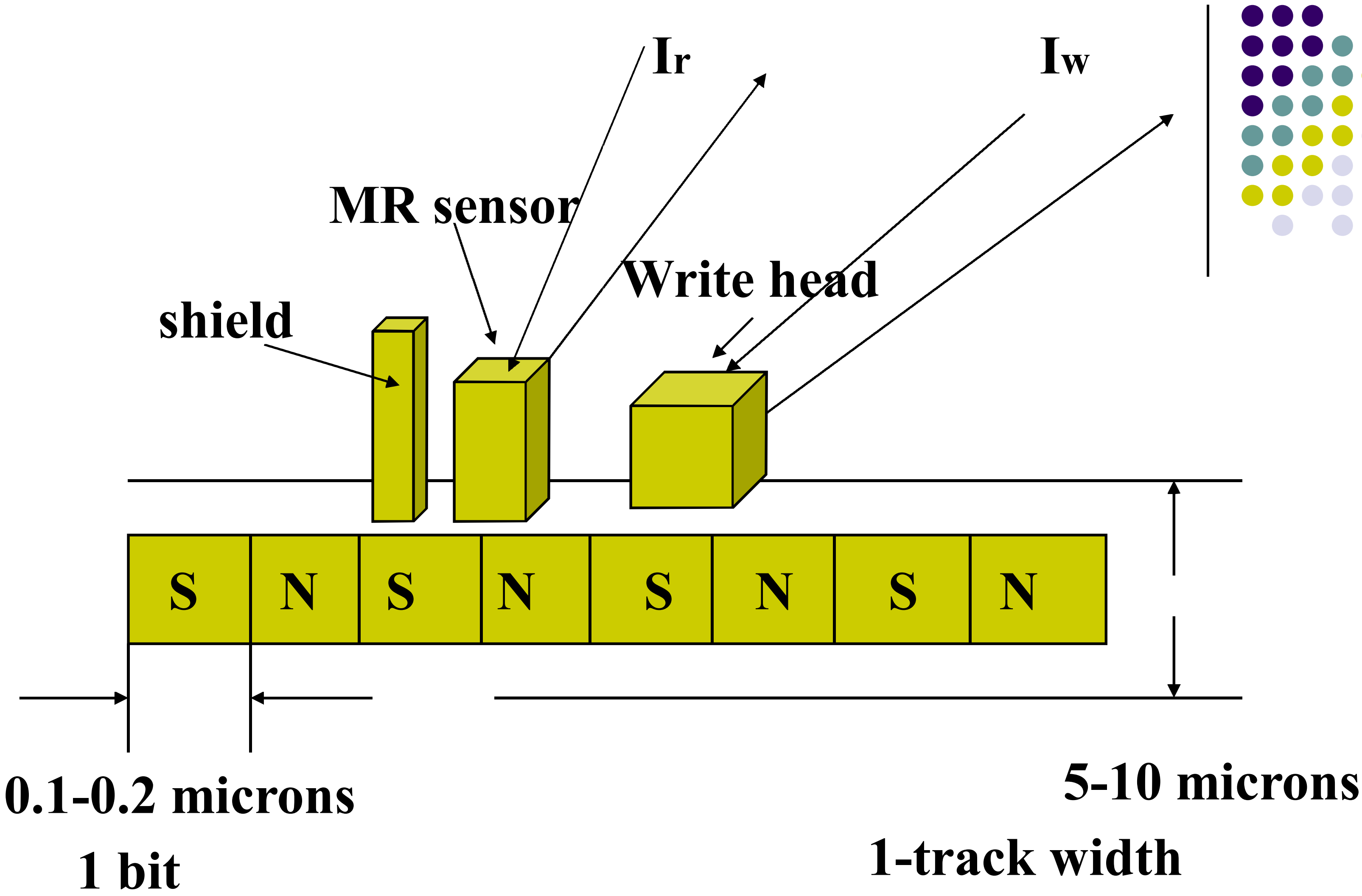
   magnetic materials based (Iron Oxide); magnetic sensing

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.



Magnetic disk (HD)

Magnetic Disks

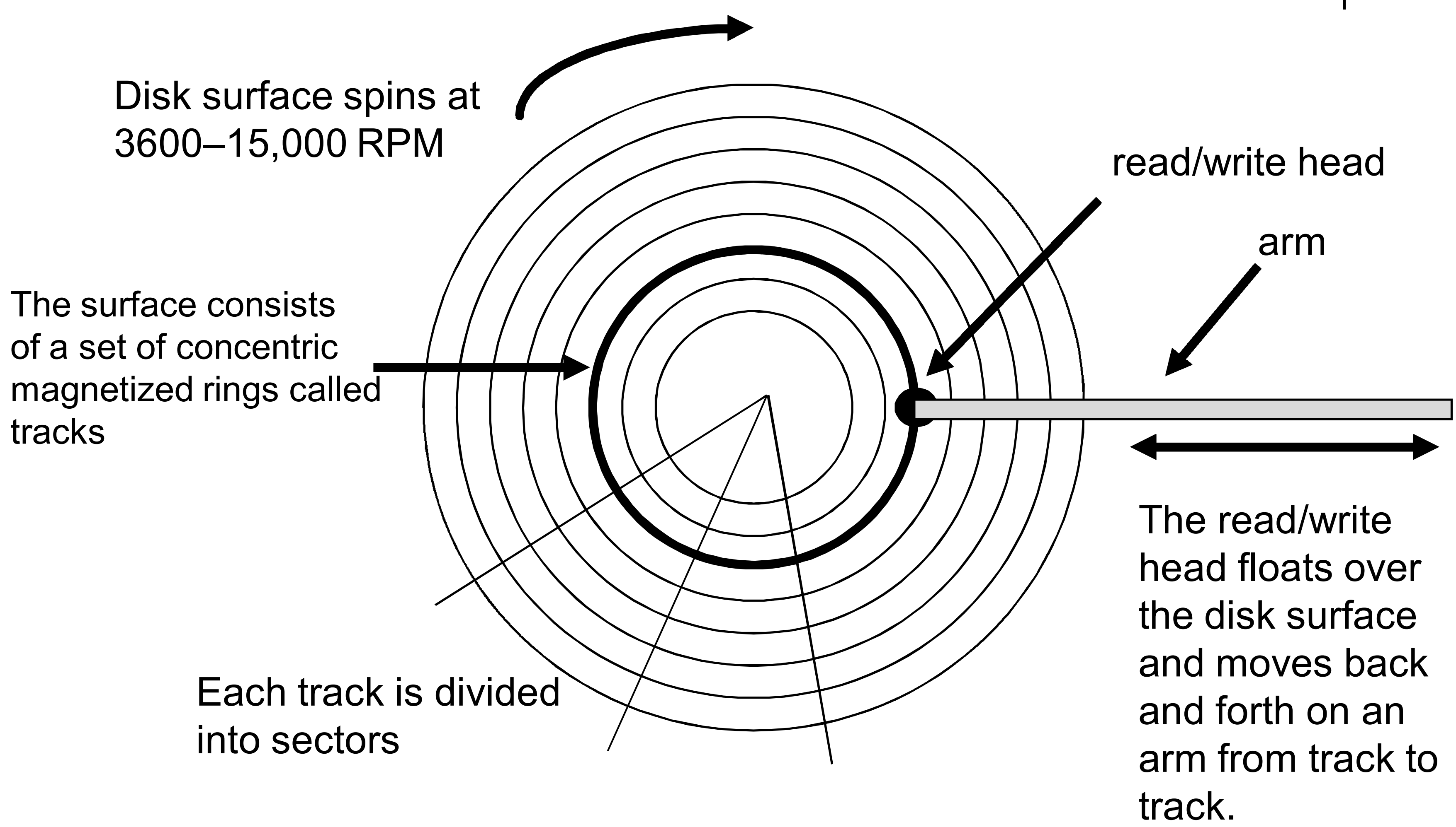


Table I: Parameters for Today's Digital Magnetic Tape Systems.

	System							
	Sun	**Sun**	**IBM**	**SONY**	**SDLT**	**HP**	**IBM**	**Sun**
Parameter	**T9840C**	**T9940B**	**3592**	**SAIT**	**600**	**LTO-3**	**TS1120**	**T10000**
Capacity (Gbyte)	40	200	300	500	300	400	500	500
Data rate (Mbytes/s)	30	30	41	30	39	80	100	120
No. of parallel data channels	16	16	8	6	16	16	16	32
Tape width (mm)	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7
Areal density (Gbit/in.^{2})	0.11	0.22	0.33	0.72	0.37	0.44	0.54	0.40
Volumetric density (Tbit/in.^{3})	0.25	0.48	0.82	2.08	0.804	1.05	1.43	1.20

**Note:* Areal and volumetric densities are estimates based on available information and modeling.

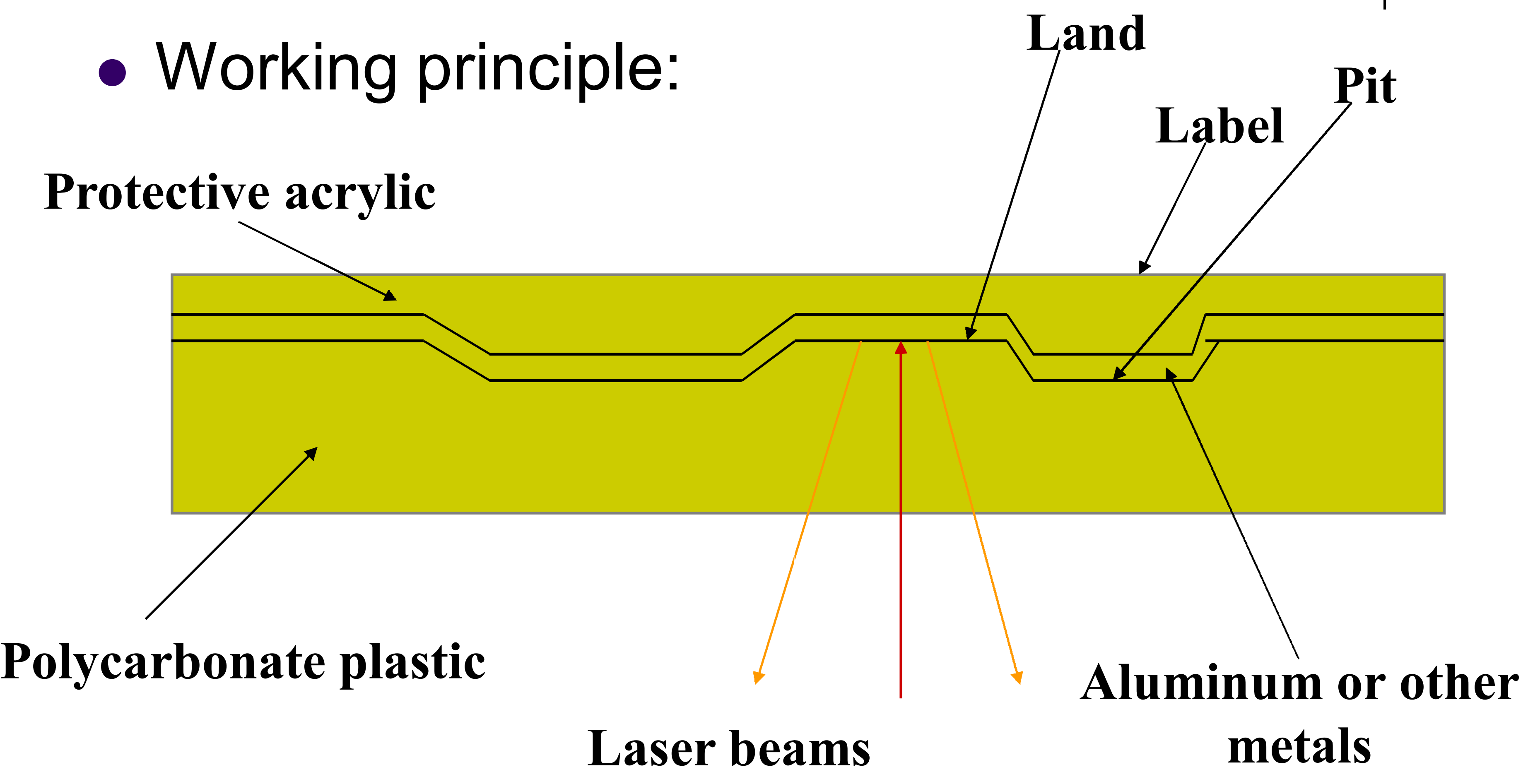
Table III: Hard-Disk-Drive Areal Density and Magnetic Parameters.

Reference	Areal Density (Gbit/in.^{2})	Linear Density (kbpi)[a]	Track Density (ktpi)[b]	Media $M_r t$ (milli-emu/cm^2)	H_c (Oe)	Spacing (nm)	Read Head	Shield Spacing (nm)
Tsang et al., 1990[5]	1	118	8.47	0.7	1800	51	MR SAL[c]	250
Tsang et al., 1996[6]	3	185	16.9	0.53	2000	80	MR SAL	200
Kanai et al., 1996[7]	5	257	19.5	0.44	2500	50	SV[d]	260
Tsang et al., 1999[8]	12	350	34.0	0.35	3000	40.6	SV	140
Liu et al., 2000[9]	36	511	70.4	0.32	3200	25	SV	120
Stoev et al., 2001[10]	63	600	105	0.39	3900	20	SV	100
Zhang et al., 2002[11]	101	680	149	0.4	5000	14.3	SV	...

[a] kbpi – kilobits per inch.
[b] ktpi – thousand tracks per inch.
[c] MR SAL – magnetoresistive soft adjacent layer bias.
[d] SV – spin valve.

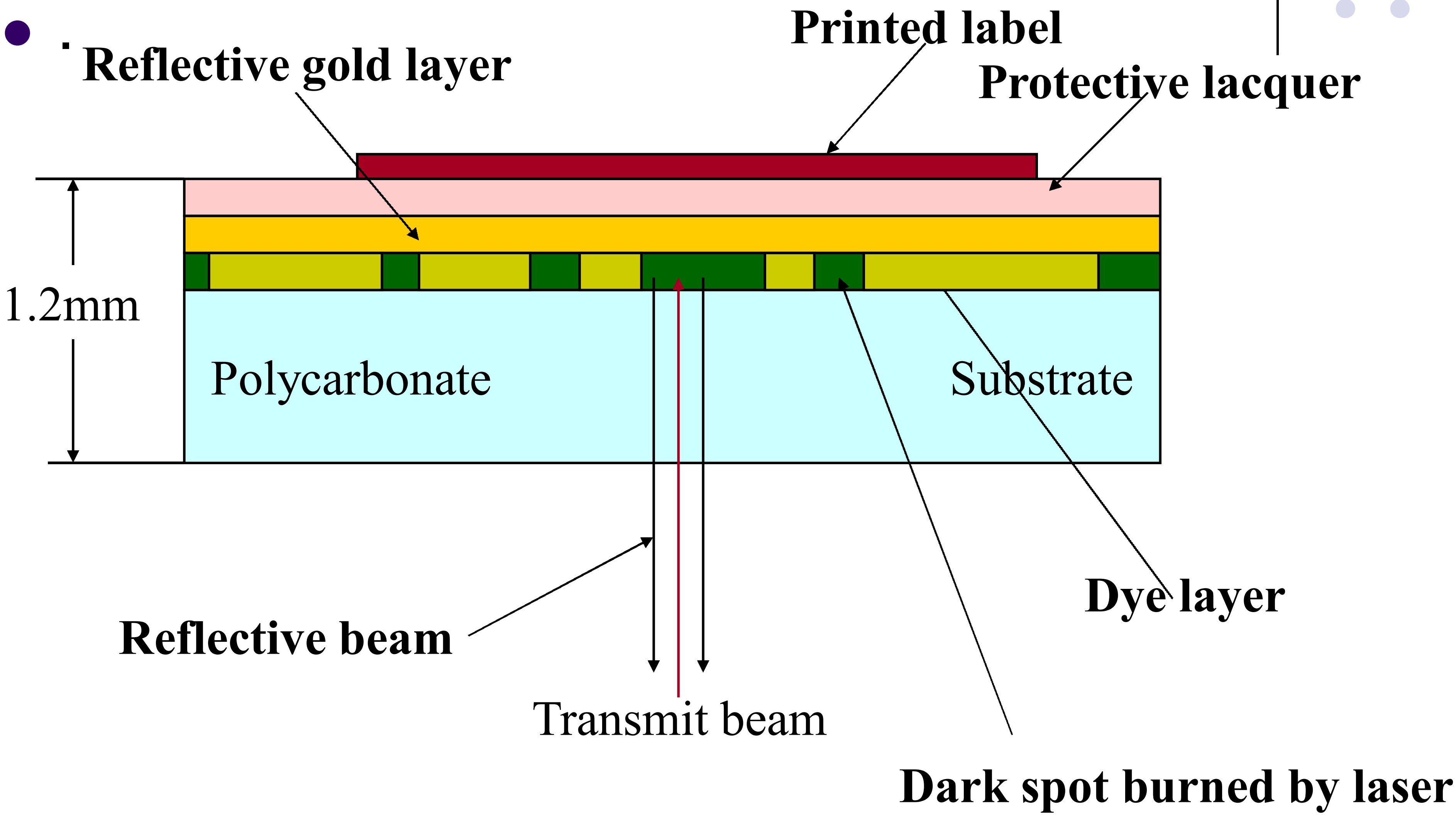
CD –ROMs

- Working principle:



Cross Section of CD-R

- .



Optical Disc Technology

CD-Technology **CD - Storage Capacity ca. 650 MB**

Prerecorded Information	Recordable	Rewritable
CD,CD-ROM	CD-R	CD-RW
Read Only Memory ROM	Write Once Read Many WORM	Write-Erase-ReWrite RW or RAM

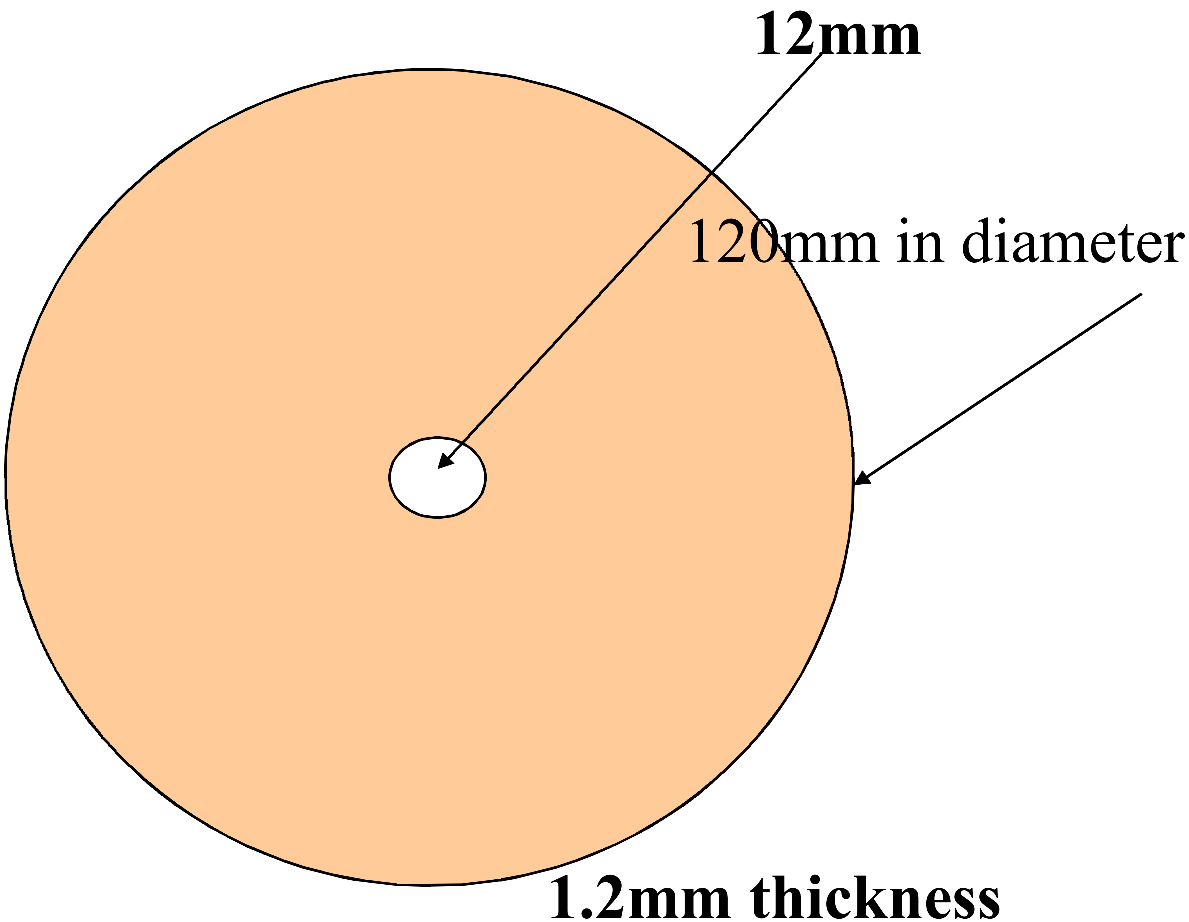
DVD-Technology **DVD - Storage Capacity max. 9,4 GB (18 GB)**

Prerecorded Information	Recordable	Rewritable
DVD-Video, DVD-ROM	DVD-R	DVD±RW, DVD-RAM
Read Only Memory ROM	Write Once Read Many WORM	Write-Erase-ReWrite RW or RAM

Blu Ray-Technology **Storage Capacity, 27 GB (2 x 25 GB)**

Prerecorded Information	Recordable	Rewritable
Read Only Memory ROM	Write Once Read Many WORM	Write-Erase-ReWrite RW or RAM

CD



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 75sectors/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).

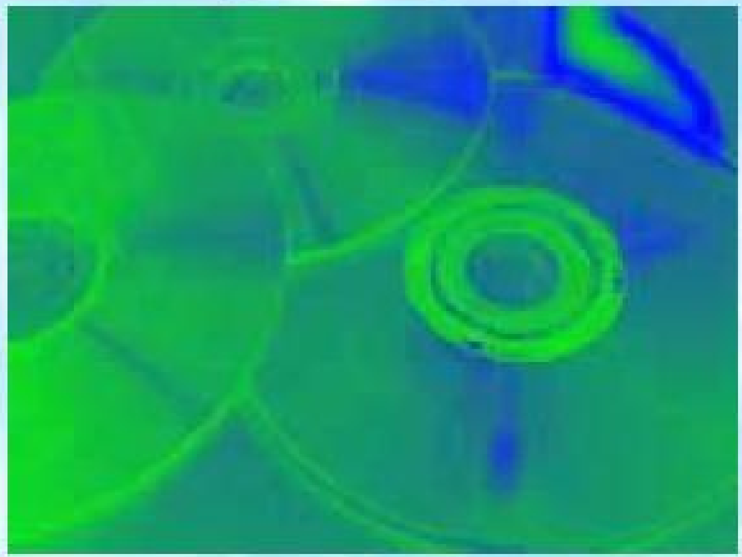
The Blu-ray Disc Alliance:

- 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

Blu-ray Disc



Application: Digital High Definition TV

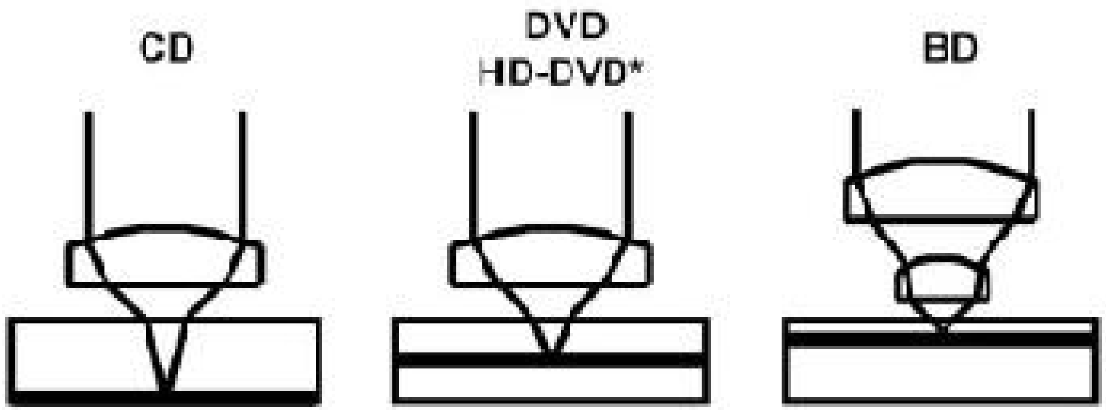
An out line of the Physics / Optics of the CD / DVD / Blue Ray

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

The Optics



	CD	DVD / HD-DVD*	BD
λ (nm)	780	650/405*	405
NA	0.45	0.60/0.65*	0.85
d (mm)	1.2	0.60	0.10 (cover layer
Capacity (Gbyte)	0.65	4.7/15*	25

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, λ – 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.

Format	λ (nm)	NA	d (nm)	Storage Capacity (Gbyte)	Δz (µm)	Δd (mm)	α (mrad)	Δn_{rz} (nm/mm)
CD	780	0.45	1.2	0.65	1.87	0.100	10.0	500[1]
DVD	650	0.60	0.6	4.7	0.88	0.026	7.0	750[1]
HD-DVD	405	0.65	0.6	15	0.46	0.012	3.4	640[2]
BD	405	0.85	0.1	25	0.27	0.004	9.2	2240[2]

[1]Typical measured value.
[2]Scaled value with DVD as reference.
Symbols and abbreviations: λ = laser wavelength, NA = numerical aperture, d = substrate thickness, Δz = defocus distance, Δd = substrate thickness variation, α = degree of tilt, Δn_{rz} = vertical birefringence, CD = compact disc, DVD = digital versatile disc, HD-DVD = high-definition DVD, and BD = Blu-ray disc.

The anatomical statistics:

Table I: Key Parameters for Three Generations of Optical Disc Systems.

	1st Generation	2nd Generation	3rd Generation	
	CD	DVD	HD-DVD	BD
Wavelength	780 nm	658 nm	405 nm	405 nm
Numerical aperture (NA)	0.45	0.60	0.65	0.85
Capacity (single-layer disc)	650 Mbyte	4.7 Gbyte	15–20 Gbyte	25 Gbyte

The material for Multiple Write / Read CD (Blue ray DVD):

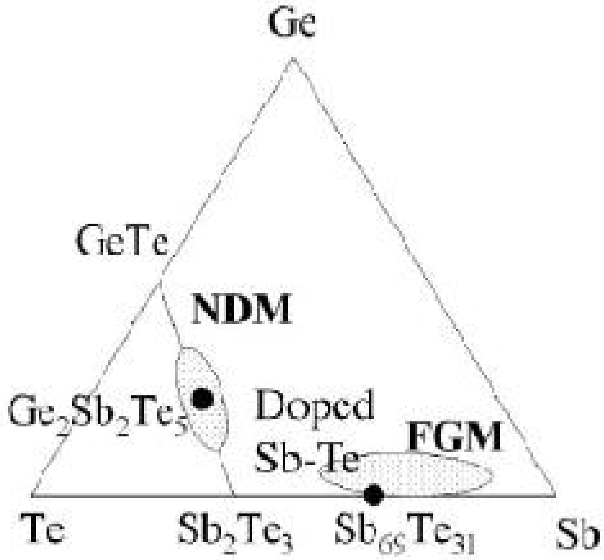
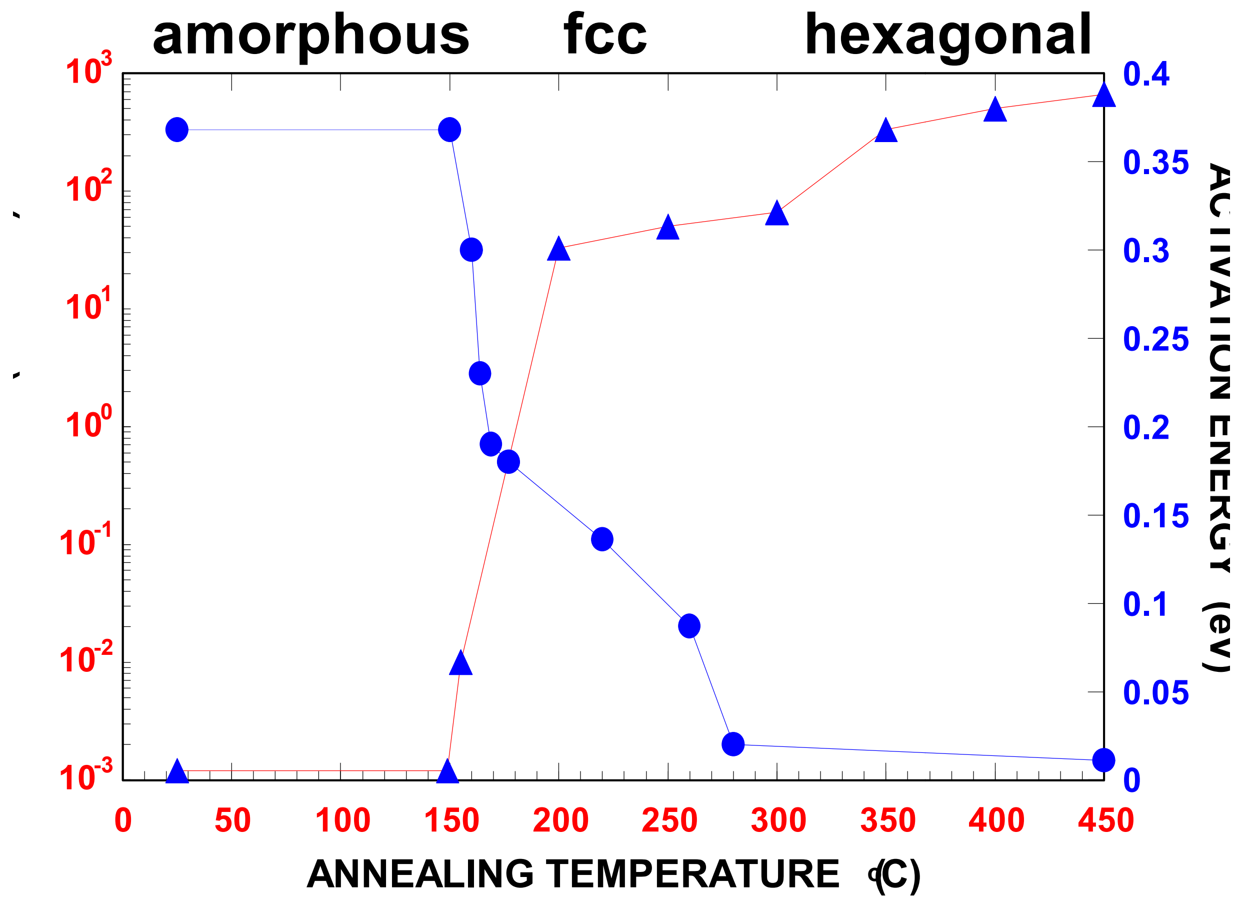
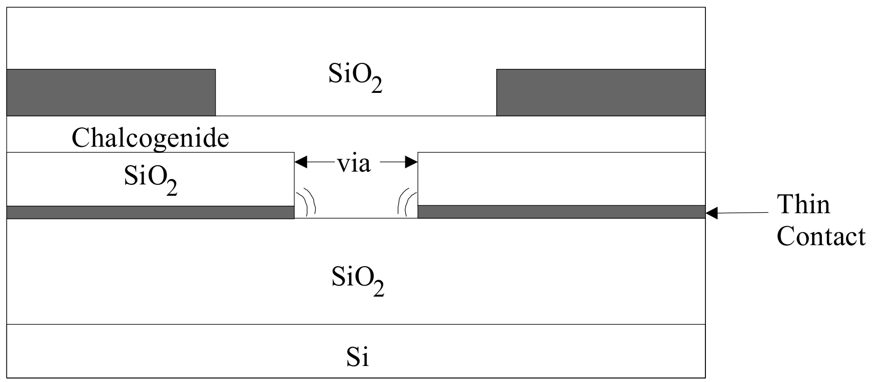


Figure 2. Composition triangle for Ge, Sb, and Te. Fast-growth material (FGM) (e.g., doped Sb-Te) and nucleation-dominated material (NDM) (e.g., $Ge_2Sb_2Te_5$) are indicated.


amorphous
fcc
hexagonal
ACTIVATION ENERGY (eV)
ANNEALING TEMPERATURE (°C)


SiO2
Chalcogenide
via
SiO2
Thin Contact
SiO2
Si

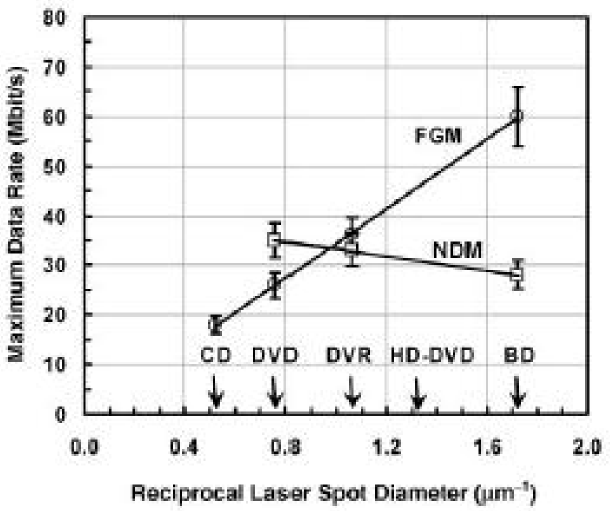


Figure 4. Maximum user data rate as a function of the reciprocal laser spot diameter of four consecutive optical recording systems for a nucleation-dominated $Ge_2Sb_2Te_5$ composition (NDM) and a growth-dominated doped Sb_2Te composition (FGM). DVR refers to the high-numerical-aperture system (NA = 0.85) based on a red laser.[12] 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.

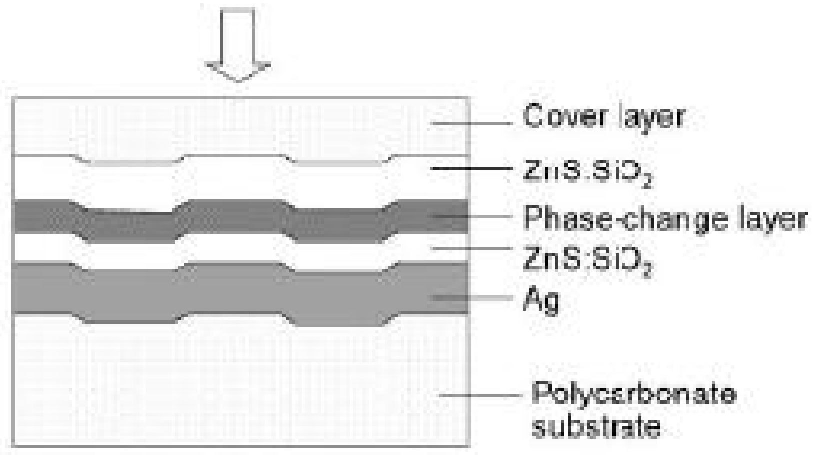


Figure 1. Schematic illustration of a phase-change stack for blue recording.

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.[9] 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 λ = 0.55 μm 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.

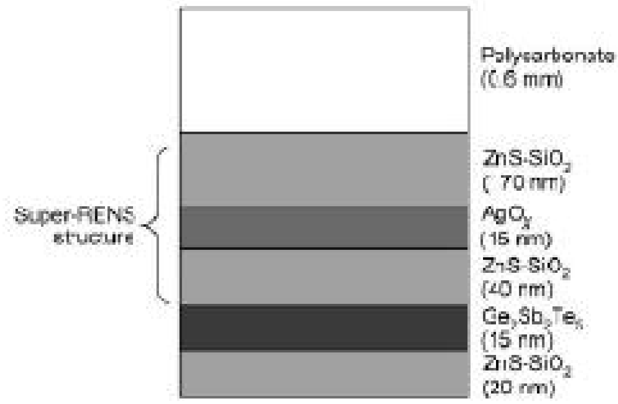


Figure 4. AgO_x super-resolution near-field structure (super-RENS) with a GeSbTe recording layer.

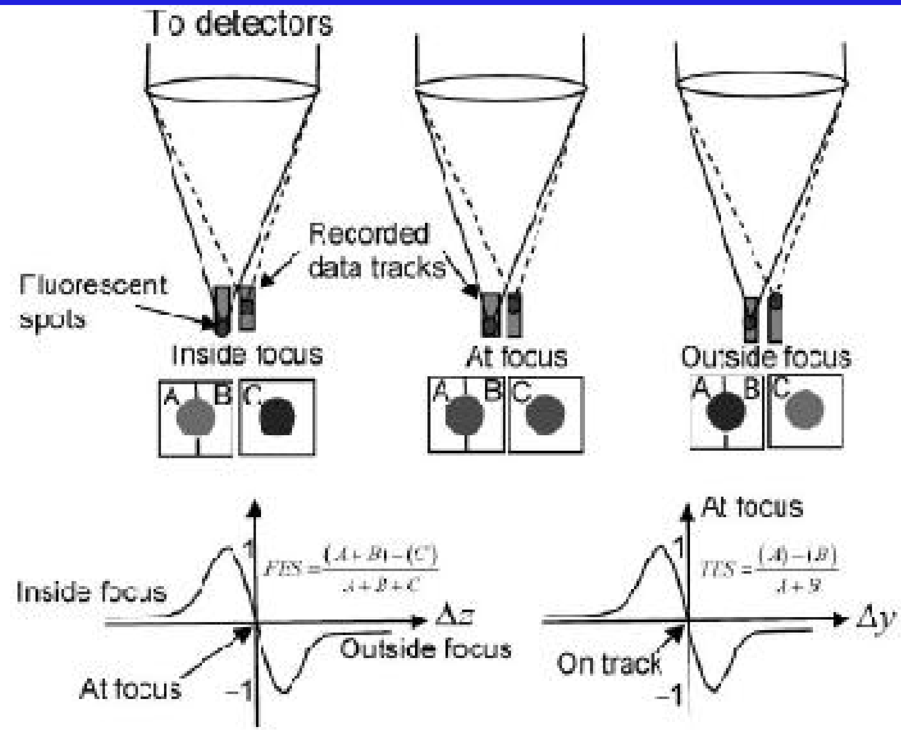


Figure 6. A two-fluorescent-spot servo technique suggested by Walker[23] for fluorescent material. Both tracking error signal (TES) and focus error signal (FES) (y axis variables in two bottom graphs) can be generated by combinations of currents from the three detectors.

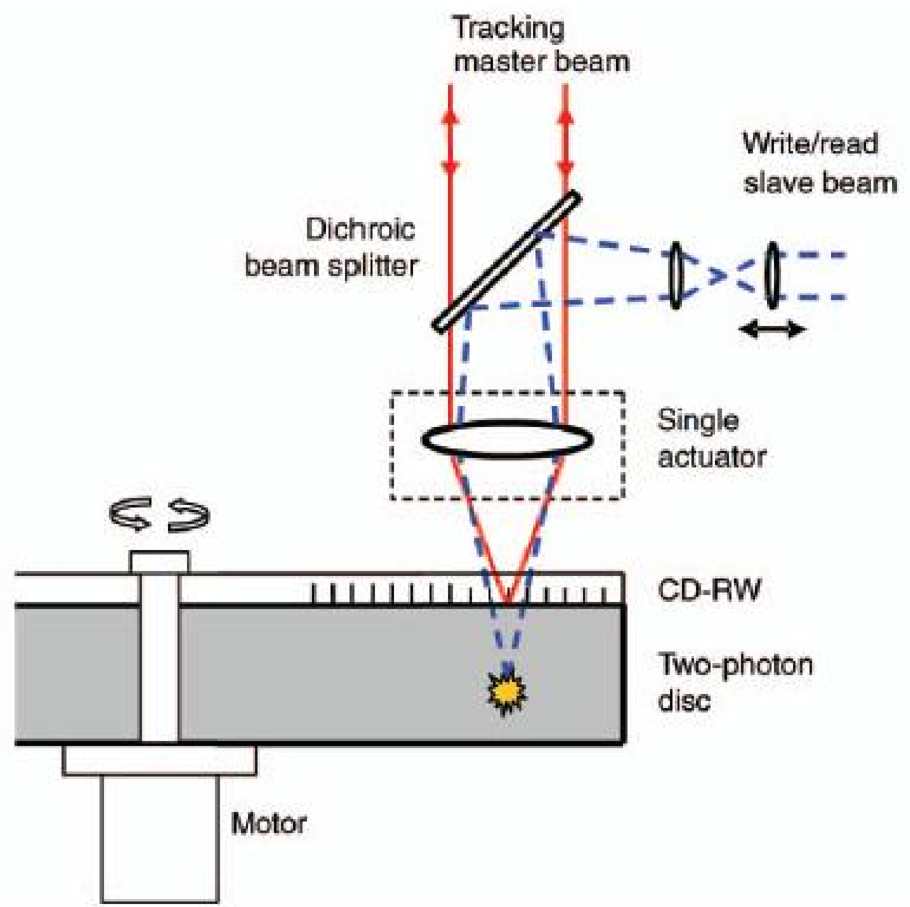


Figure 7. A master/slave servo technique combines the master beam and the slave beam into a single path. The write/read slave beam is focused deep inside the volumetric disc. The master beam used to generate the reference signals is focused on tracks of a conventional rewritable compact disc (CD-RW) bonded to the volumetric disc.

Holographic memories:

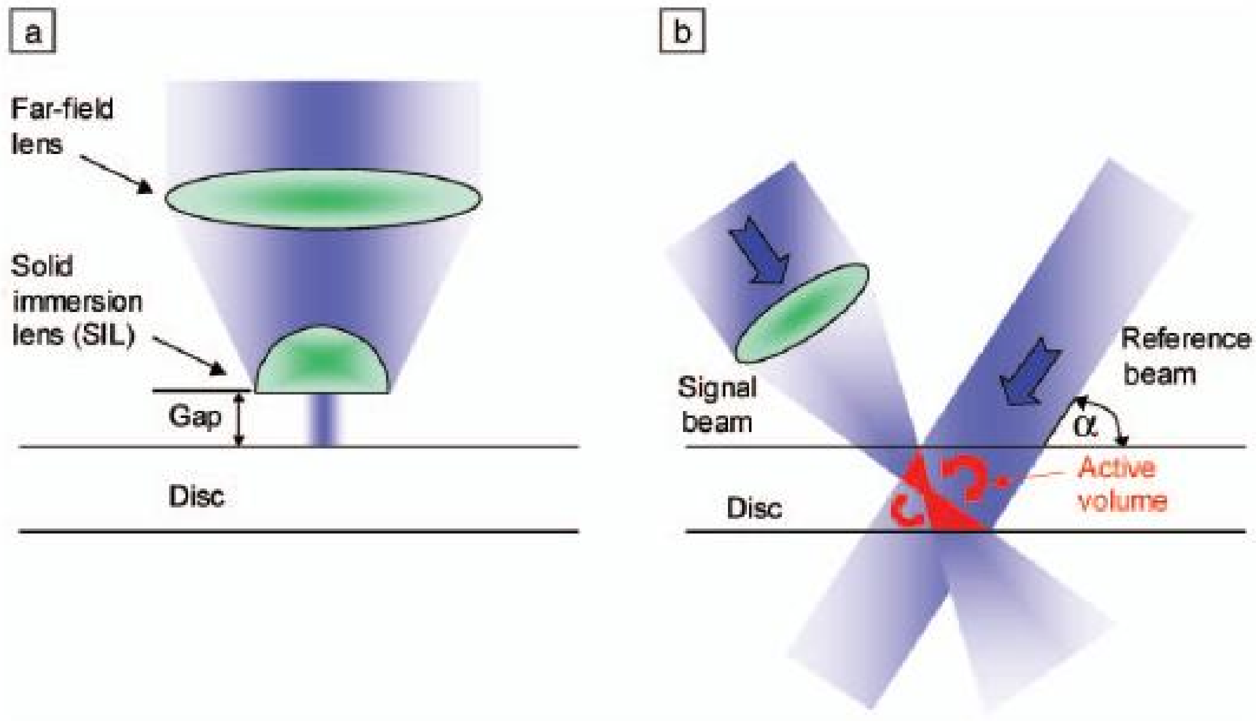


Figure 10. (a) Near-field optics readout system for an optical disc. (b) Holography with angular multiplexing. "Active volume" means only this volume is used for a particular angle.

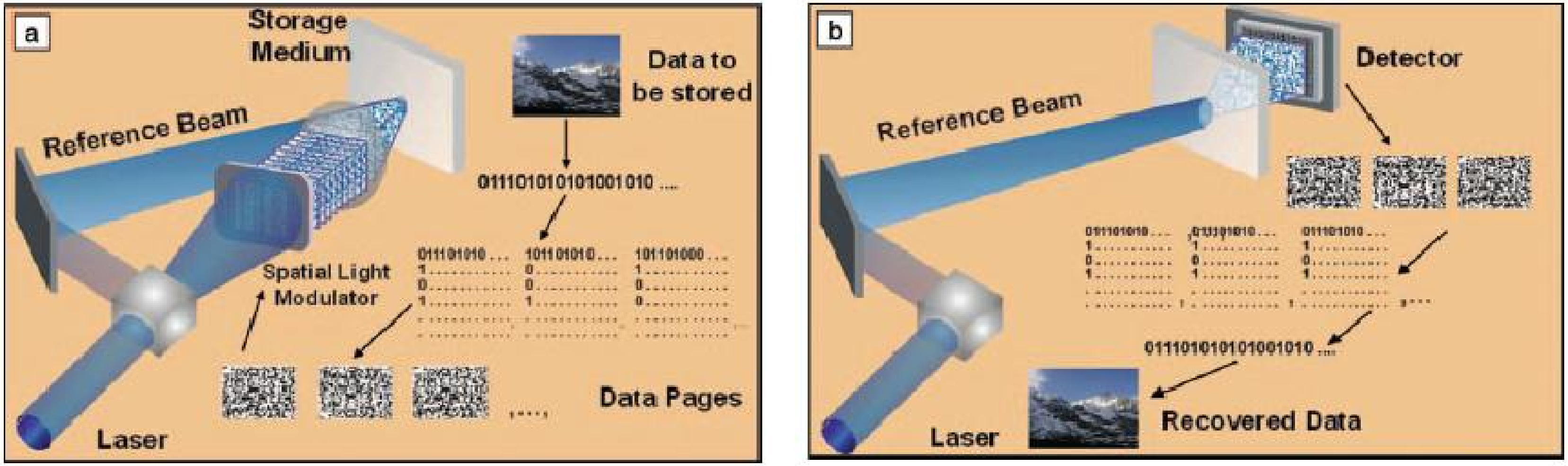


Figure 1. Schematic illustrations of (a) the recording process in holographic storage and (b) the readout process in holographic storage.

Table I: Requirements for Recording Media for Holographic Storage.	
Material Parameters	**Requirements**
Optical flatness	$<\sim\lambda/2$ per cm
Optical scatter	$<\sim 10^{-5}$ of reference beam power
Thickness of media	>500 µm
Dynamic range ($M/\#^a$)	≥ 10
Photosensitivity (in the visible to near-infrared)	100–1000 mJ/cm^2 to achieve full dynamic range, or $M/\#$
Dimensional stability	<0.2%
Processing for readout	Solvent/heat-free
Readout	Nonvolatile

[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 (Δn)*(thickness of medium), where Δn 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 η_i is the diffraction efficiency of each hologram.[20]

	Standard MRAM (90 nm)[a]	DRAM (90 nm)[b]	SRAM (90 nm)[b]	SMT MRAM (90 nm)[a]	Flash (90 nm)[b]	Flash (32 nm)[b]	SMT MRAM (32 nm)[a]
Cell Size (μm^2)	0.25	0.25	1–1.3	0.12	0.1	0.02	0.01
	256 Mbit/cm	256 Mbit/cm	64 Mbit/cm	512 Mbit/cm	512 Mbit/cm	2.5 Gbit/cm	5 Gbit/cm
Read Time	10 ns	10 ns	1.1 ns	10 ns	10–50 ns	10–50 ns	1 ns
Program Time	5–20 ns	10 ns	1.1 ns	10 ns	0.1–100 ms	0.1–100 ms	1 ns
Program Energy/Bit	120 pJ	5 pJ	5 pJ	0.4 pJ	30–120 nJ	10 nJ	0.02 pJ
	Needs refresh						
Endurance	$>10^{15}$	$>10^{15}$	$>10^{15}$	$>10^{15}$	$>10^{15}$ read, $>10^{6}$ write	$>10^{15}$ read, $>10^{6}$ write	$>10^{15}$
Nonvolatility	Yes	No	No	Yes	Yes	Yes	Yes

Table I: Projected Performance of MRAM, SMT MRAM, and Conventional Semiconducting Memories.

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.

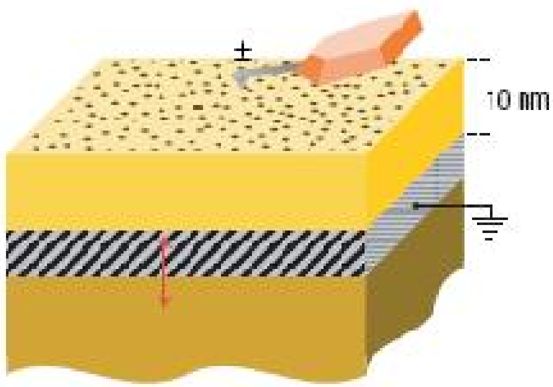
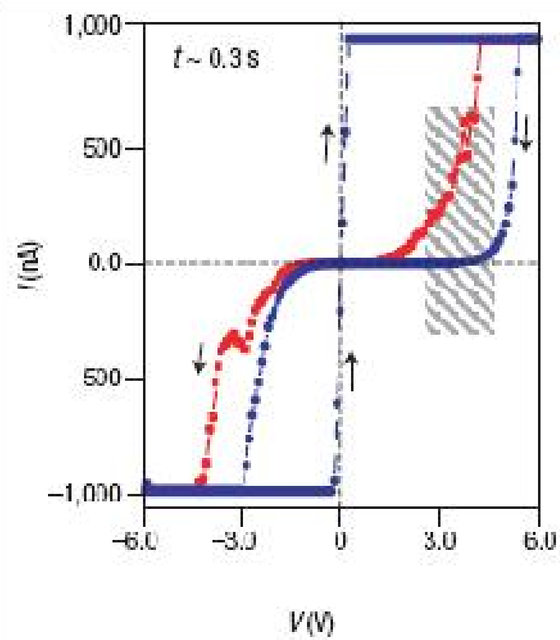


Figure 1 Switching of single dislocations. ***a***, The dislocations (dark spots) are individually addressed by an atomic force microscope with a conductive cantilever. **b**, The current–voltage characteristics clearly show bistable switching. (Reproduced from ref. 1.)



Concept from Angus Kingon, NCSU, Raleigh, USA

IBM

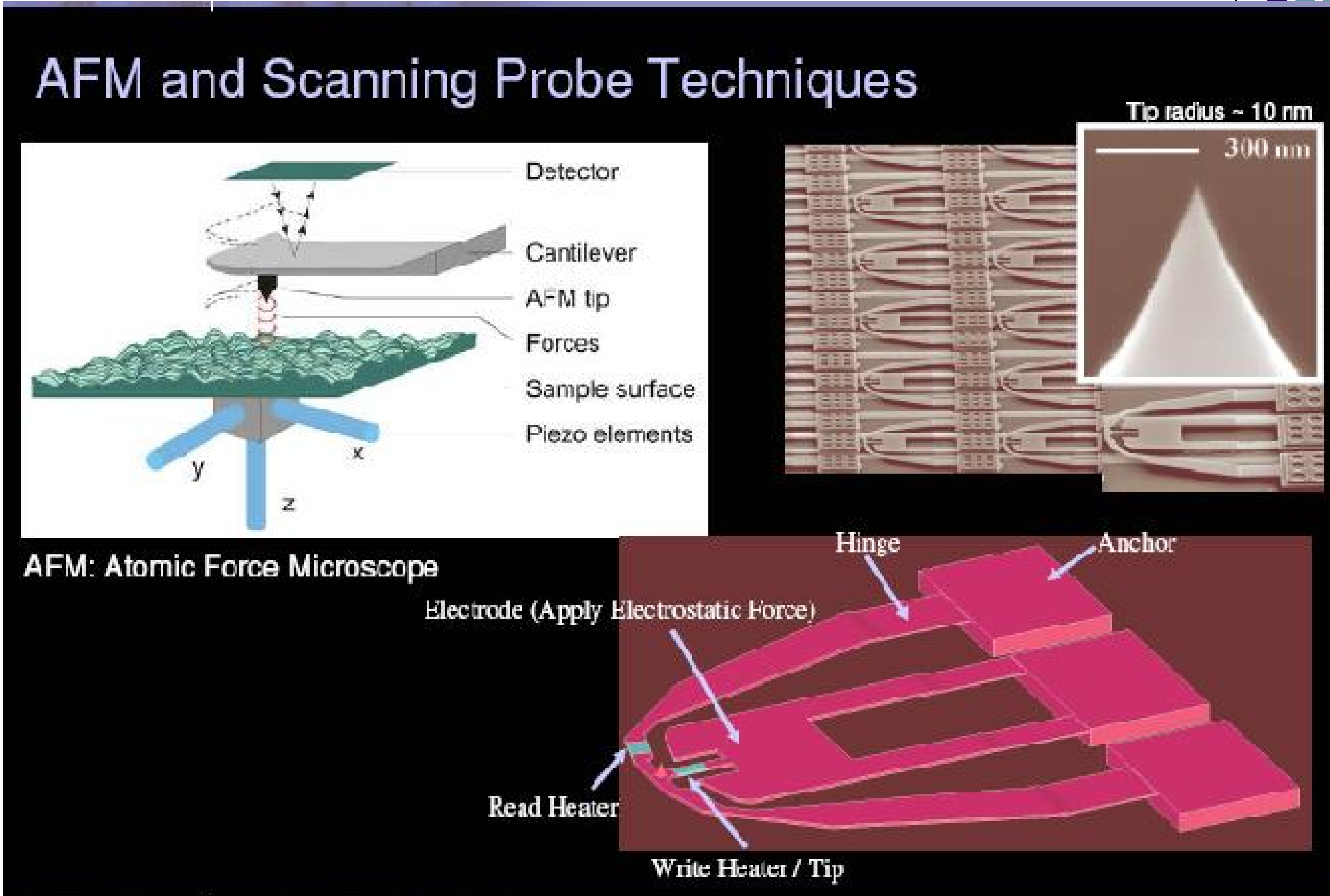
Zurich Research Laboratory

Scanning Probes Entering Data Storage: From Promise to Reality

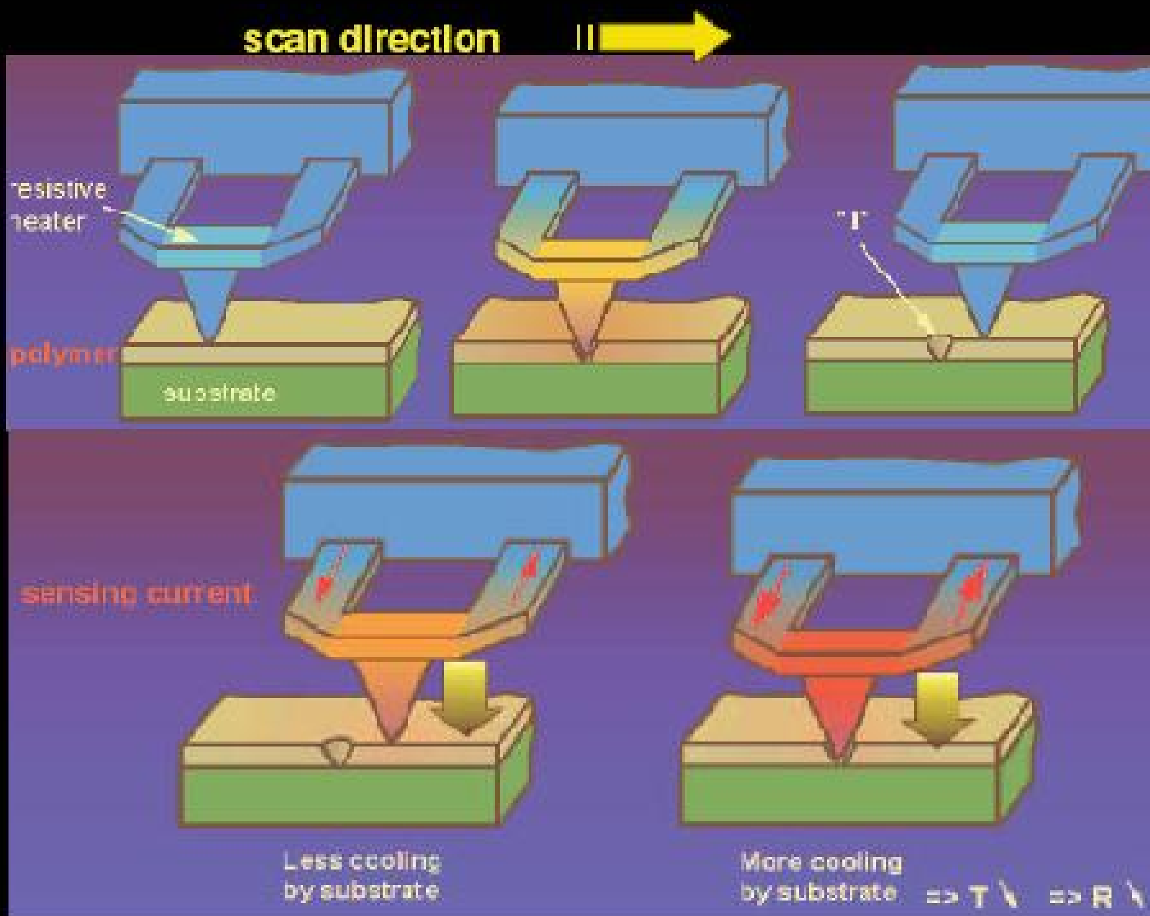
Haralampos Pozidis

January 11, 2006

www.zurich.ibm.com


AFM and Scanning Probe Techniques
Detector
Cantilever
AFM tip
Forces
Sample surface
Piezo elements
y
x
z
AFM: Atomic Force Microscope
Tip radius ~ 10 nm
300 nm
Hinge
Anchor
Electrode (Apply Electrostatic Force)
Read Heater
Write Heater / Tip

Thermomechanical Writing and Reading Concepts



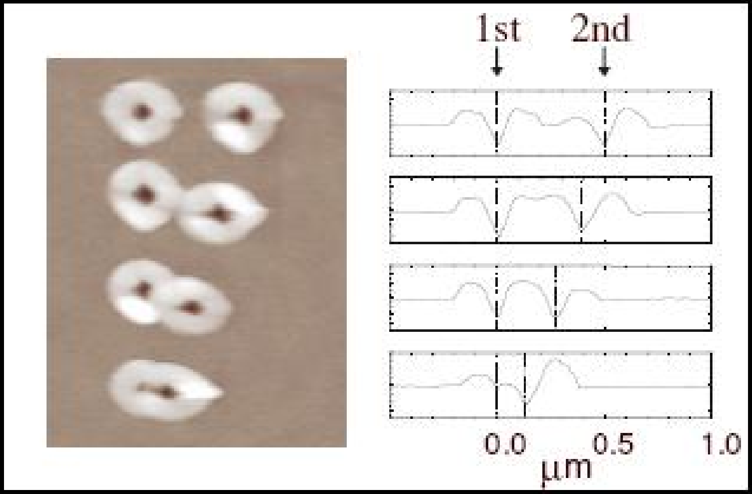
Writing Concept

Reading Concept

Read Sensitivity
$\Delta R/R \sim 10^{-4}$ / nm

Thermomechanical Erasing

Erasure: Indentation Crowding



- Probe storage technology offers unprecedented data storage density
  - >1 Terabit / in^2 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
  - 2^{nd} 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:

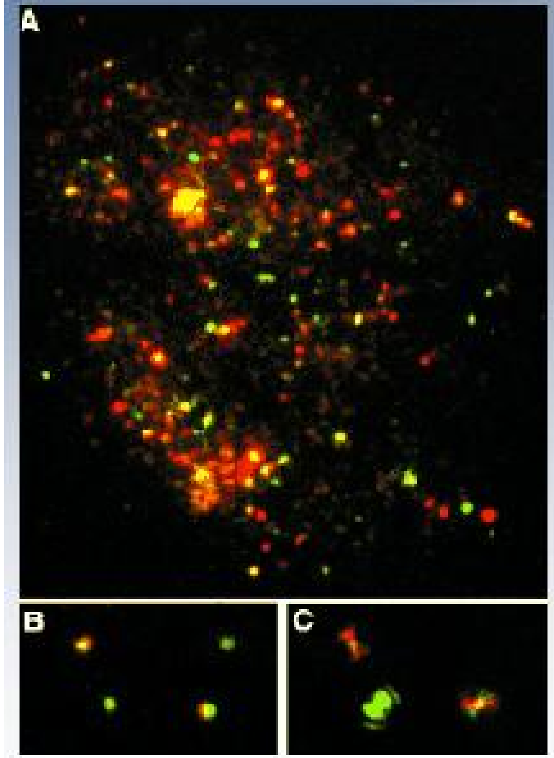
Proposed by Dickson group at Georgia Tech (2001)

- L.A. Peyser, A.E. Vinson, A.P. Bartko and R.M. Dickson. “Photoactivated Fluorescence from Individual Silver Nanoclusters”. Science, 291, pp103-106 (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_2O film excited at wavelength of 514.5nm..

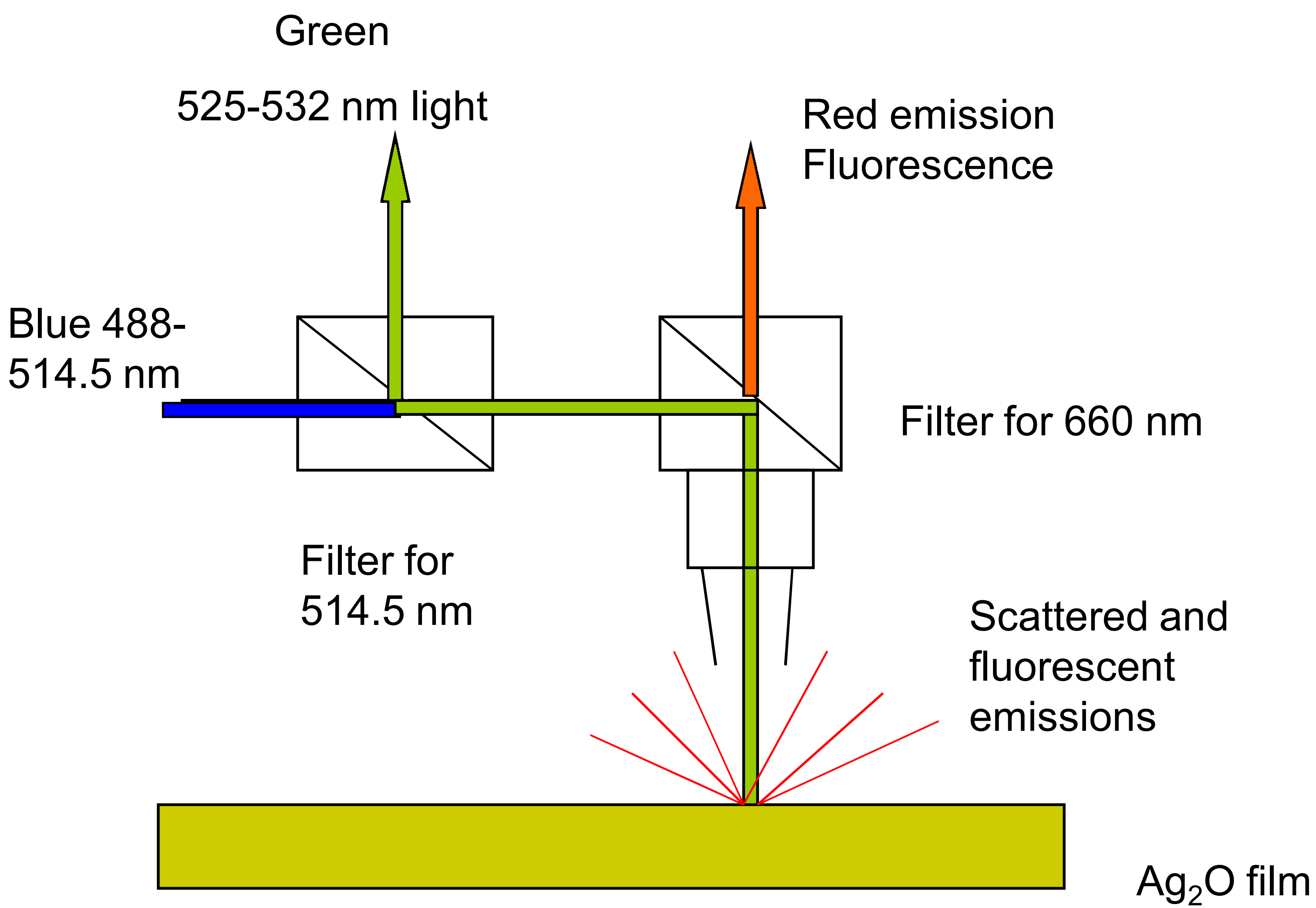
Read Mechanism:

When these silver nano clusters are irradiated with a longer wavelength, emit FLUORESCENCE (> 600 nm).

This Fluorescence emission is the read mechanism

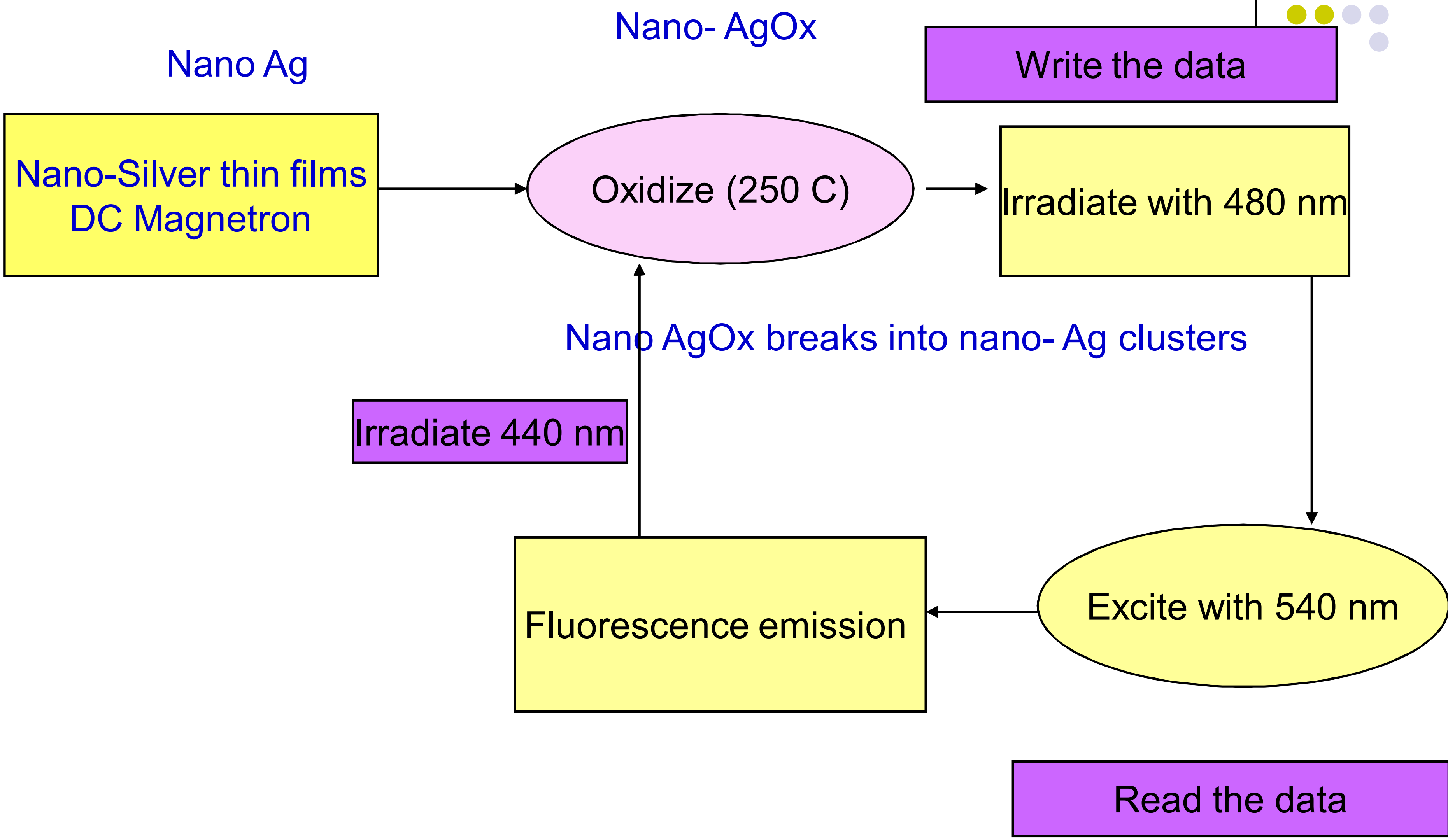
In ONE Square inch, you can have one Tera Byte memory!!

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 660 nm
Filter for
514.5 nm
Scattered and
fluorescent
emissions
Ag_2O film

The Process:


Nano Ag
Nano- AgOx
Write the data
Nano-Silver thin films
DC Magnetron
Oxidize (250 C)
Irradiate with 480 nm
Nano AgOx breaks into nano- Ag clusters
Irradiate 440 nm
Fluorescence emission
Excite with 540 nm
Read the data

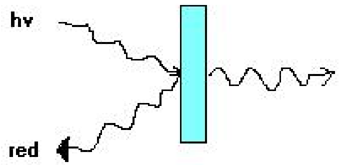
Nano Silver Thin films have been prepared by :

- DC Magnetron Sputtering Technique

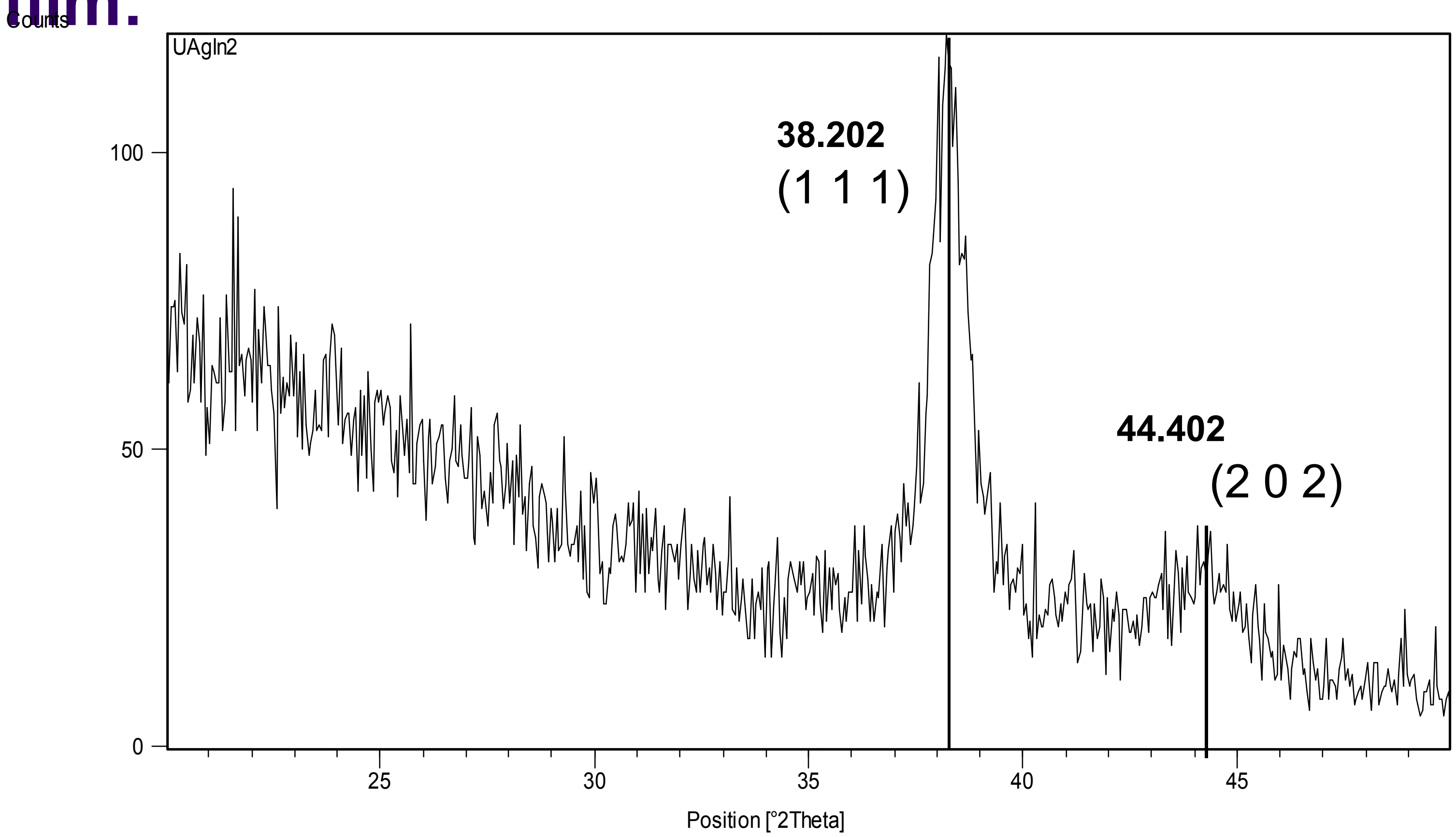
  - Industrially viable
  - Can control the growth parameters precisely

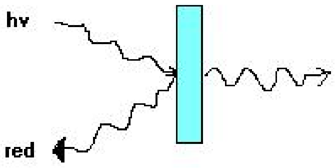
These nano-Silver is oxidized to form Silver oxide

Dickson’s Group has reported on chemical methods

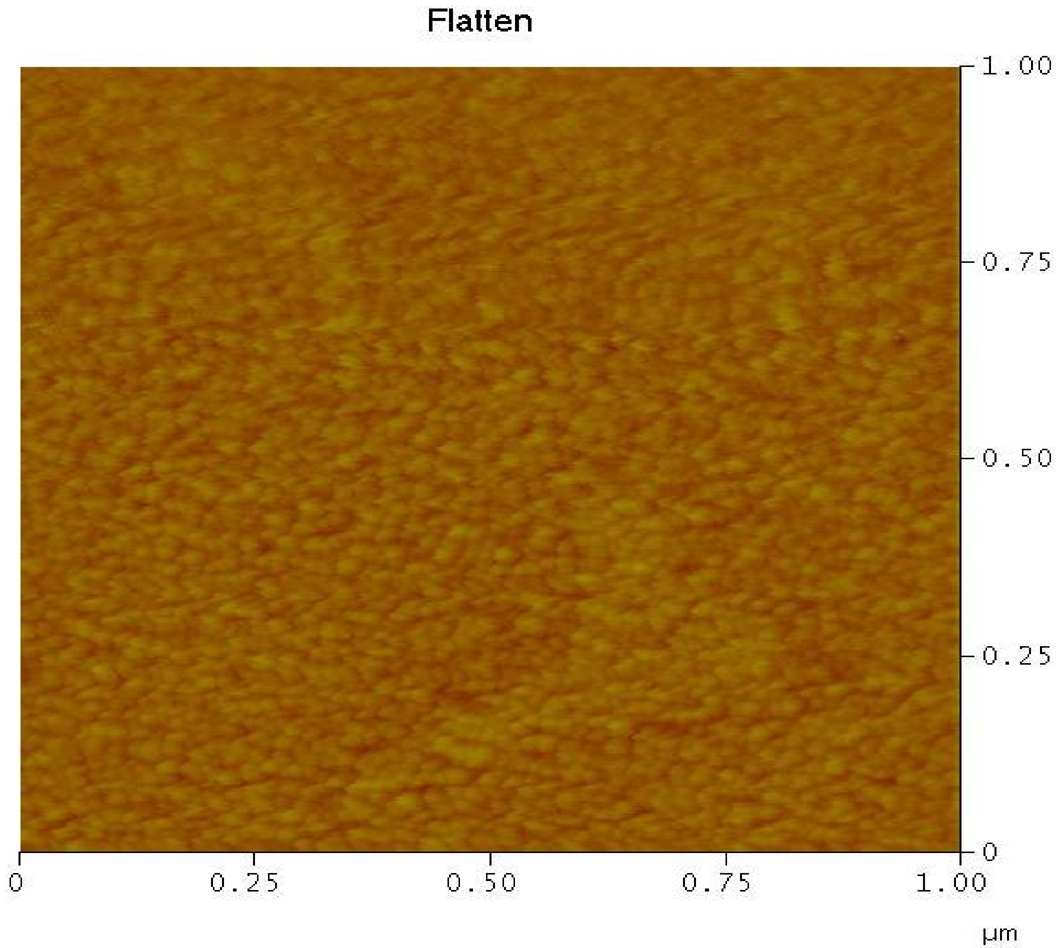


XRD Spectrum obtained from metallic Silver film:

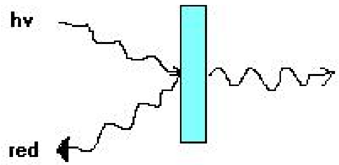




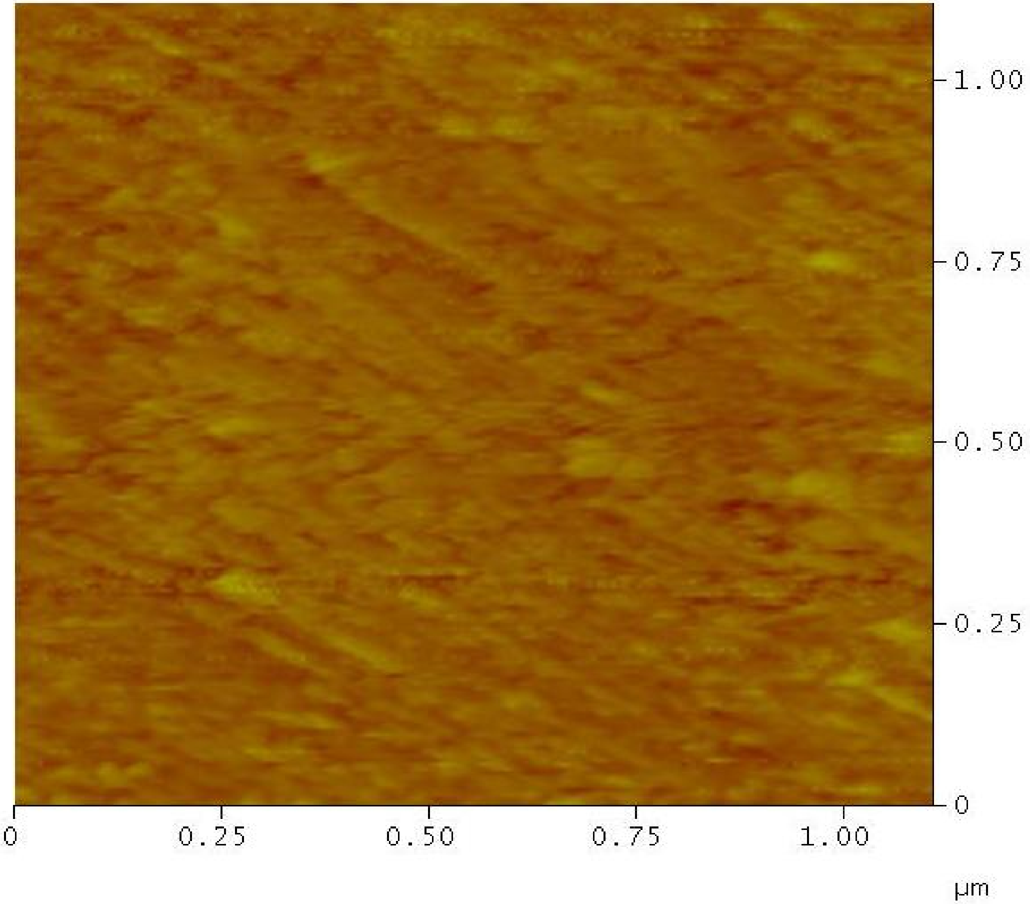
AFM image of the metallic silver film before oxidation:



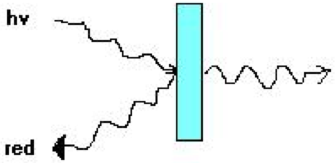
Grain size ~ 28 nm



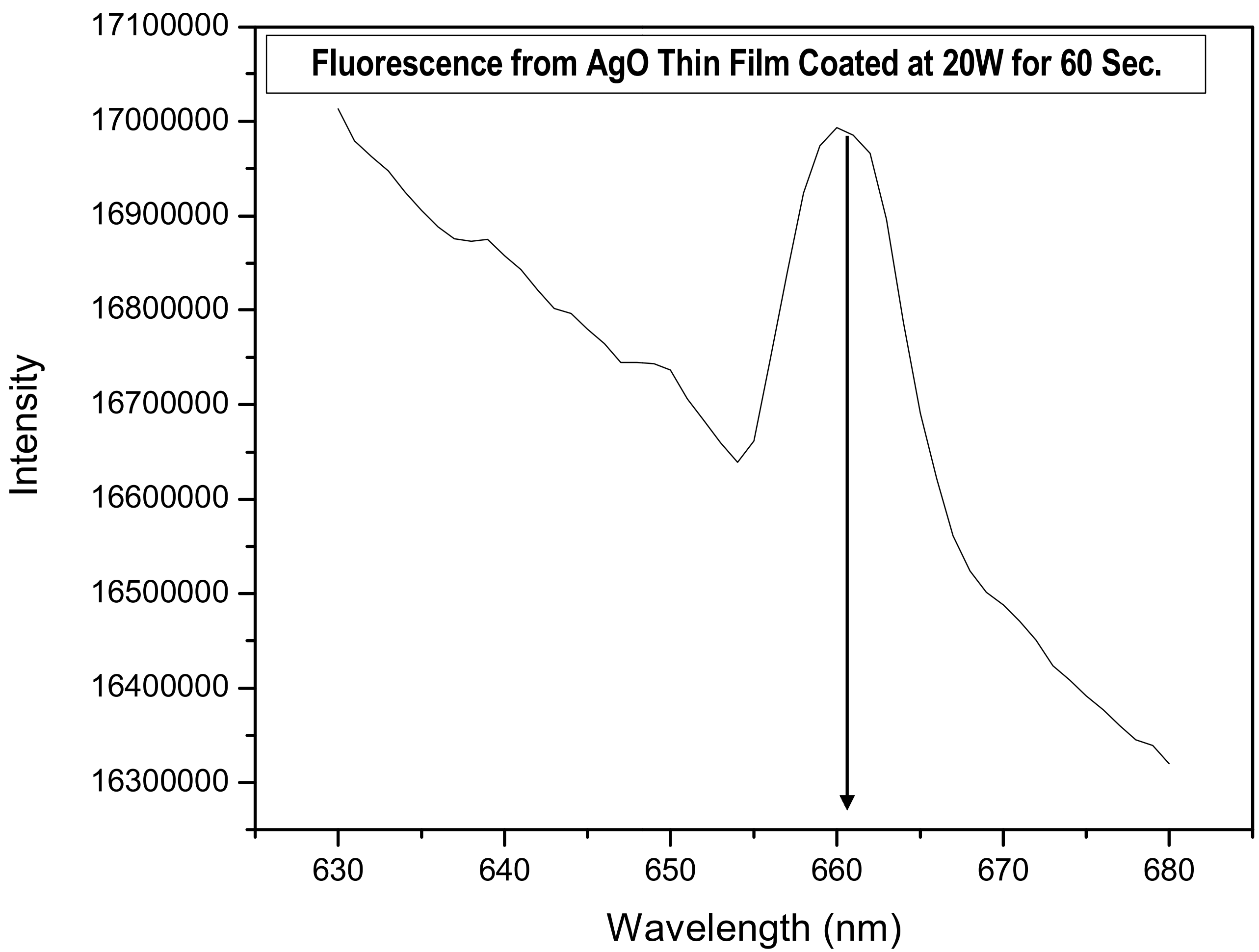
AFM image of the silver oxide film after oxidation of metallic silver:

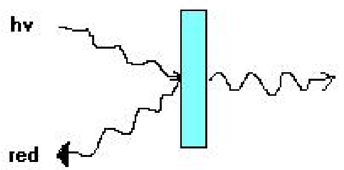


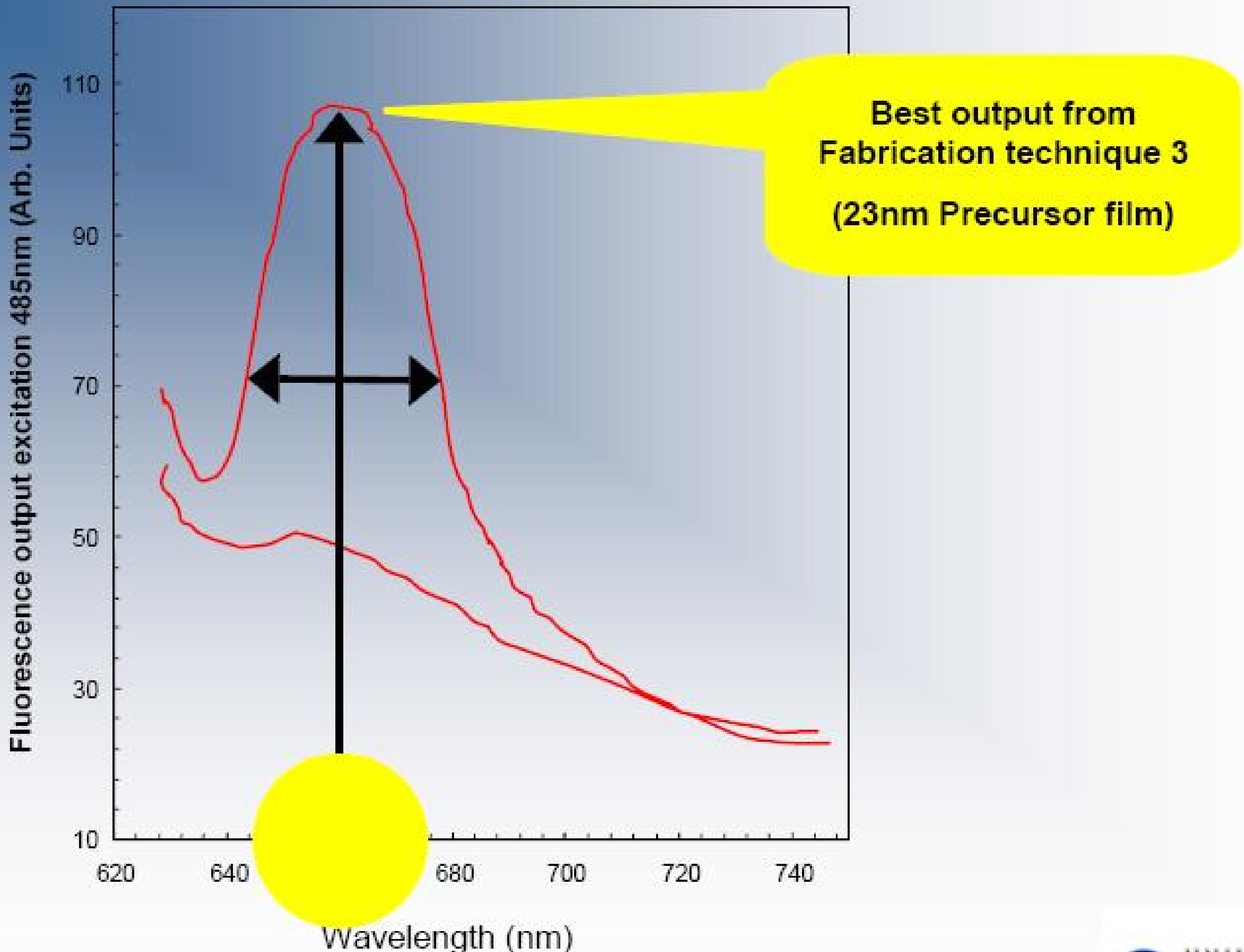
Grain size :~ 40 nm



Fluorescence spectra of nano silver oxide coated at 20W for 60 seconds:







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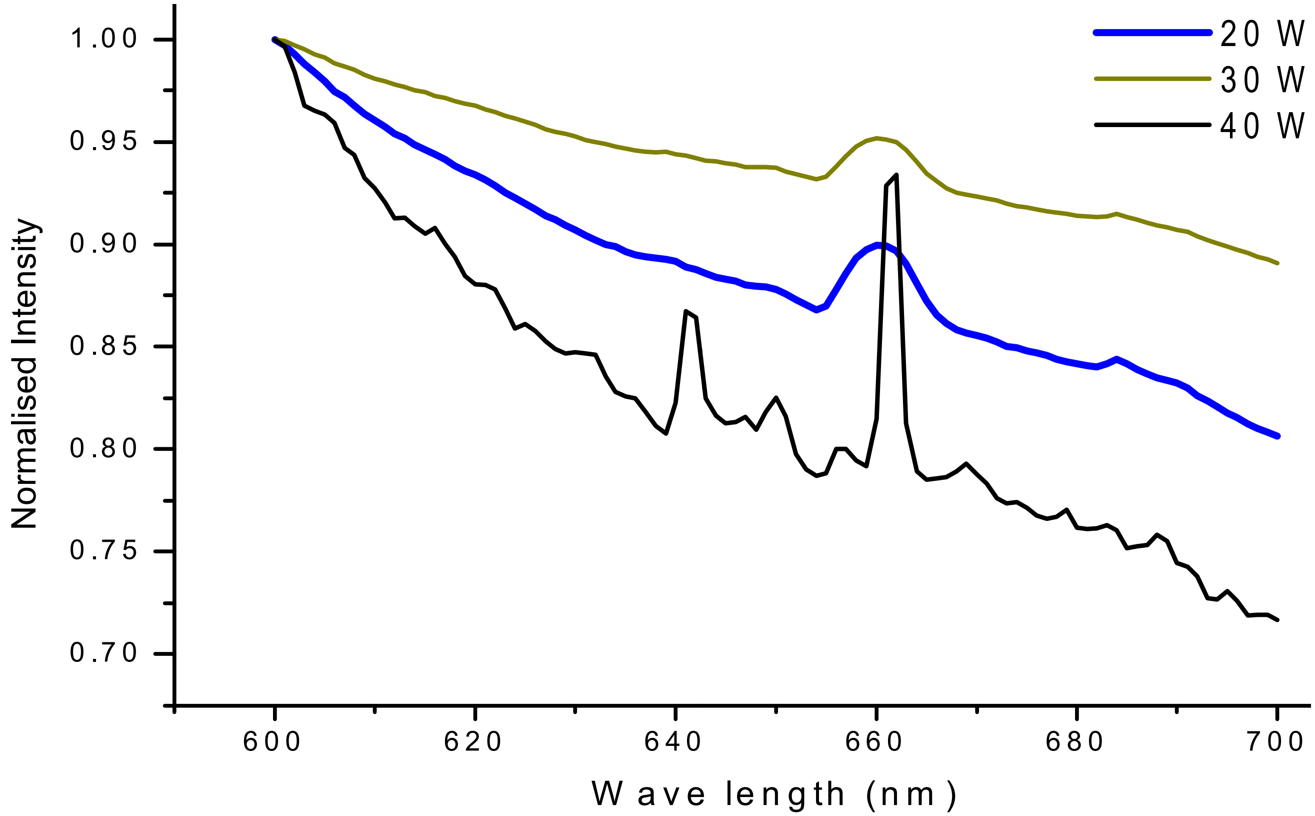
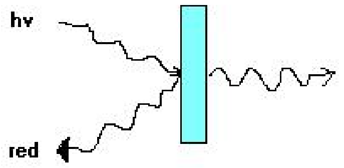
Comparison of Fluorescence spectra coated at different sputtering rates:





We are also evaluated the films for Electrical resistivity

Sputtering Power	Thickness of the film (in Å)	Resistivity measured (Ω cm)	Hall Coefficient (cm^3/coloumb)
20 Watt	100	6.51×10^{-5}	-1.9×10^{-4}
30 Watt	250	7.14×10^{-5}	-6.8×10^{-4}
40 Watt	450	1.9×10^{-5}	-2.8×10^{-4}

Summary of results:

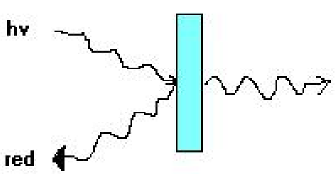
1. We could prepare the nano silver and silver oxide clusters

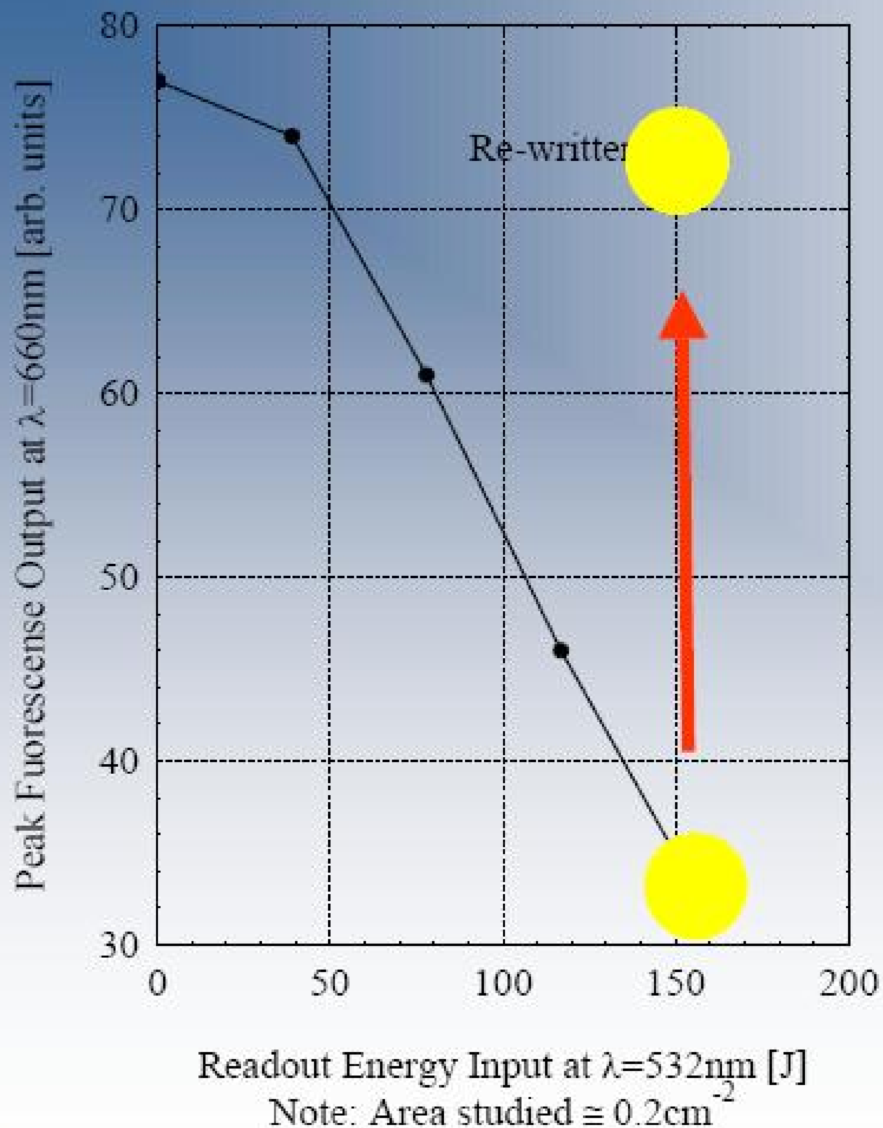
2. Good fluorescence spectra show that the concept works with DC Magnetron sputtering technique

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

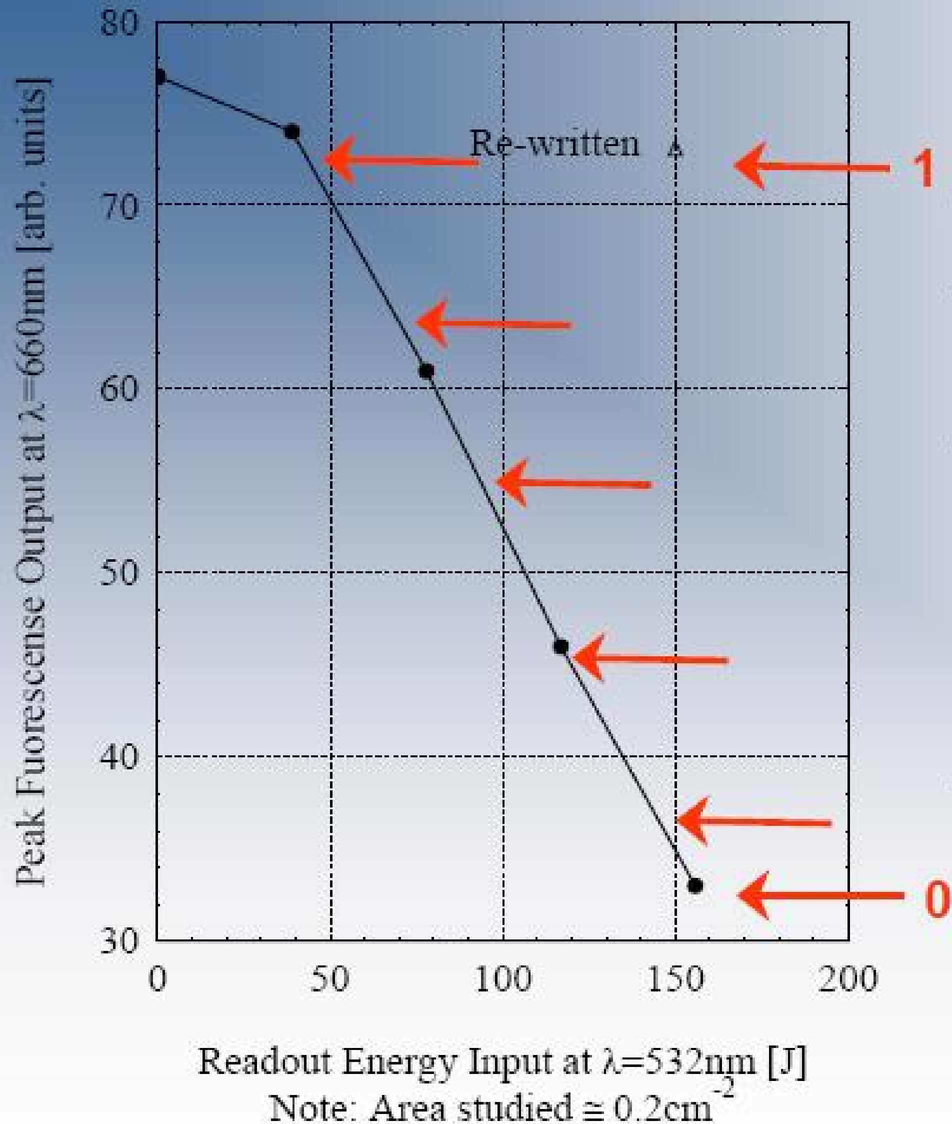
We are also carrying out the work with PLD.





Expressing the recording/erasure processes in terms of their energy requirements it is seen that:-

- ❑ Approximately 150J of optical energy at ? = 532nm is required to completely exhaust the 660nm fluorescence.
- ❑ An equivalent amount of energy is required at λ = 514nm 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

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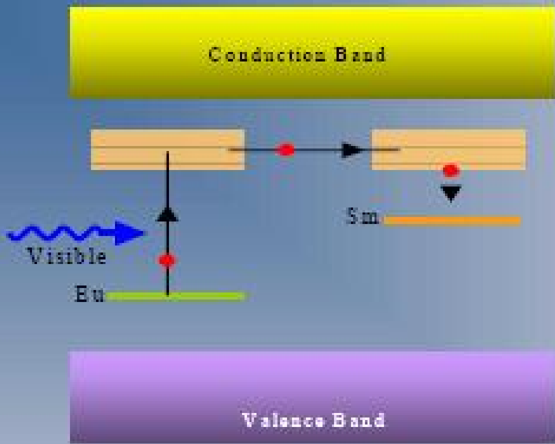
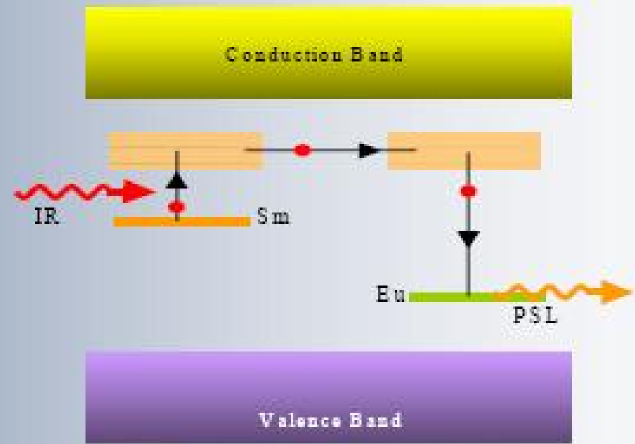
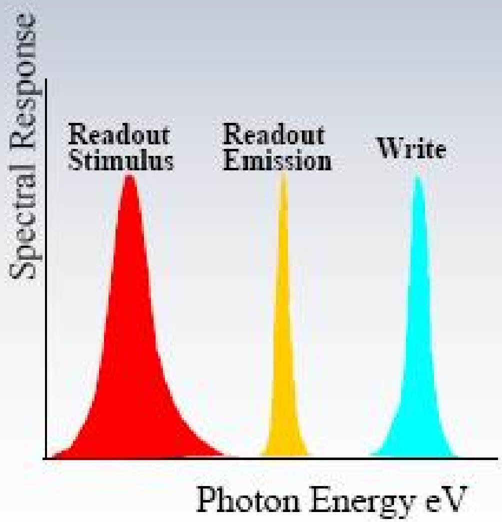
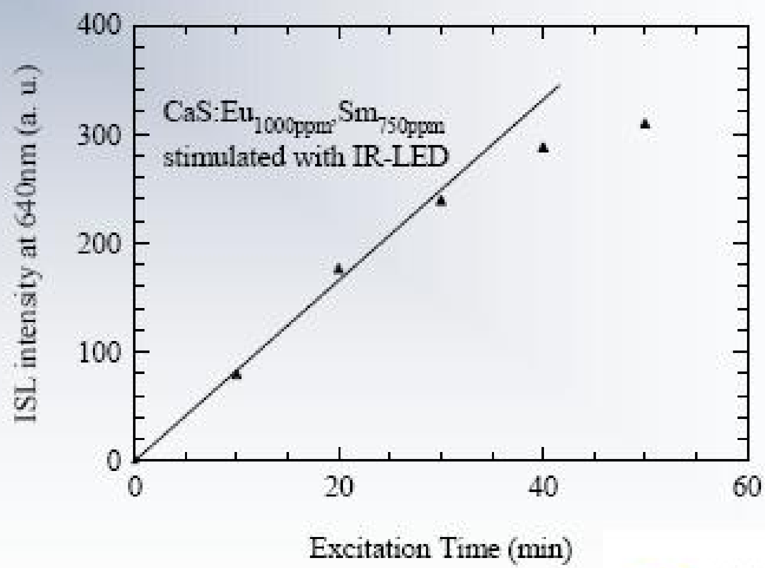
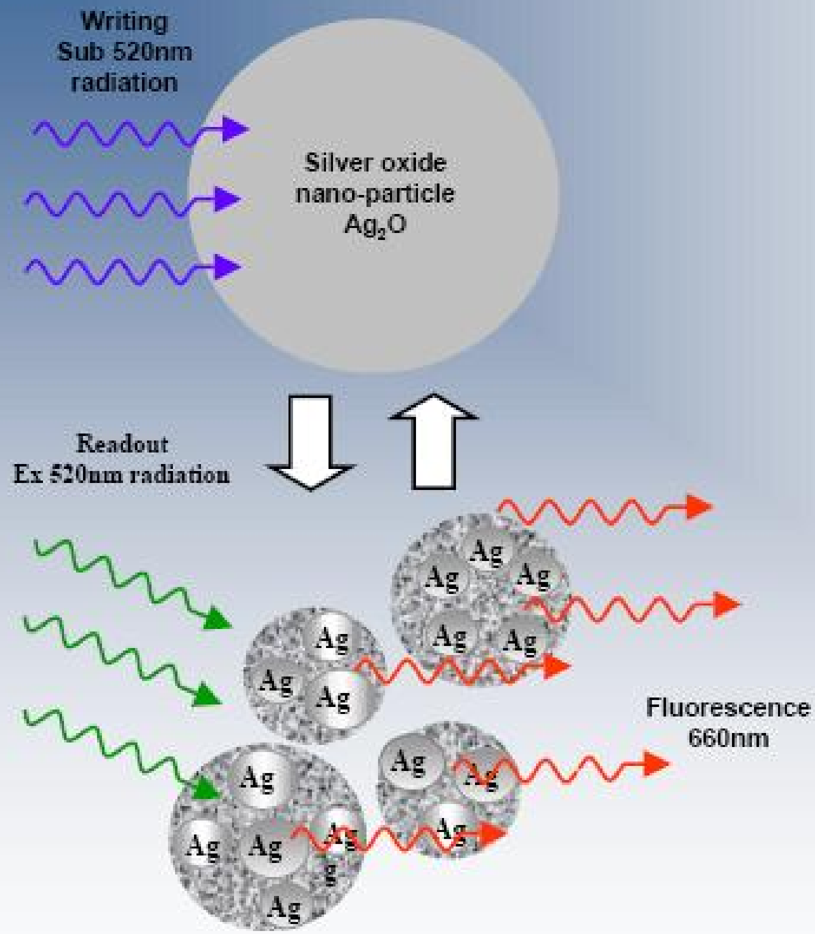

Conduction Band
Visible
Eu
Sm
Valence Band


Conduction Band
IR
Sm
Eu
PSL
Valence Band


Spectral Response
Readout Stimulus
Readout Emission
Write
Photon Energy eV


CaS:Eu1000ppm,Sm750ppm
stimulated with IR-LED
ISL intensity at 640nm (a. u.)
Excitation Time (min)
0
100
200
300
400
0
20
40
60

Schematic Photo-Physics/Chemistry:



- ❑ Write radiation (sub 520nm) partially photo-reduces Ag_2O to AgO and silver particles.
- ❑ Some energy absorbed by the Ag_2O 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

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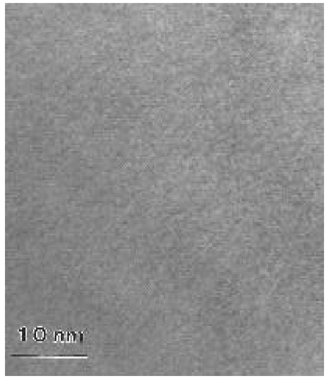
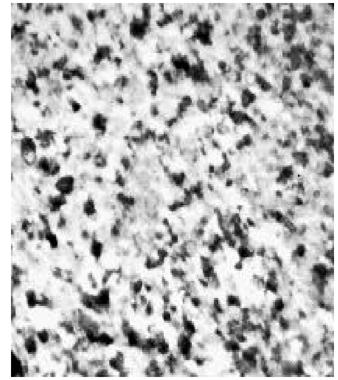
Amorphous
Phase



Scale:

0.2 microns



Crystalline
Phase

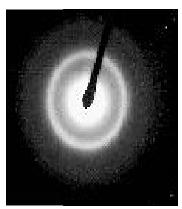
Electron Diffraction Patterns

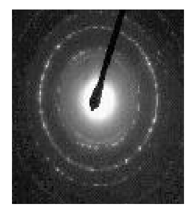
Short Range Atomic Order

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?

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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-R2-22 Nagatsuta, Midori-ku, Yokohama 226-8503, Japan
j-hashizume33@ms.pi.titech.ac.jp

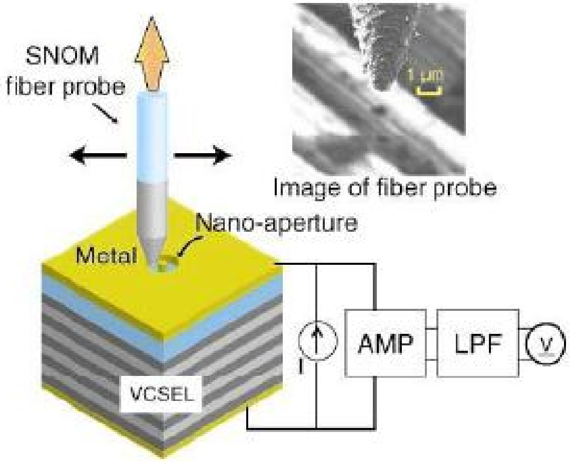
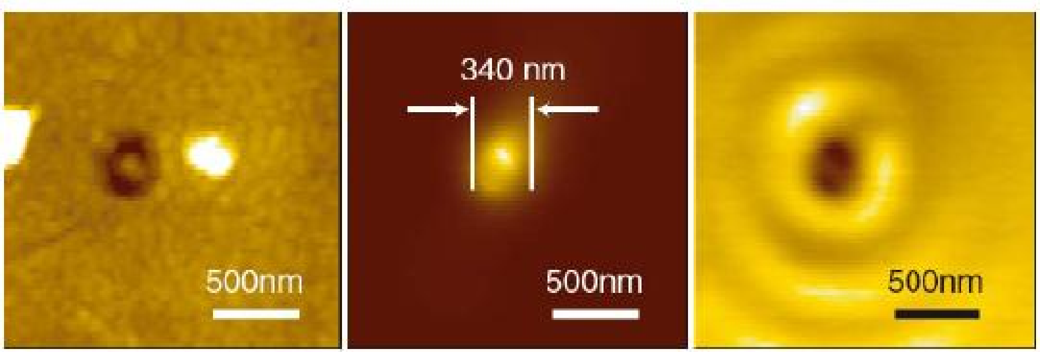


Fig. 3. Measurement setup for signal voltage and optical near-field intensity.



(a) (b) (c)

Fig. 4. Measured surface topography (a), optical near-field intensity (b), and voltage change (c) of nano-aperture VCSEL with metal nano-particle.

Institute of Physics Publishing Nanotechnology
Nanotechnology 15 (2004) 1076–1083 PII: S0957-4484(04)79716-0

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

Institute of Physics Publishing Nanotechnology
Nanotechnology 13 (2002) 471–477 PII: S0957-4484(02)32718

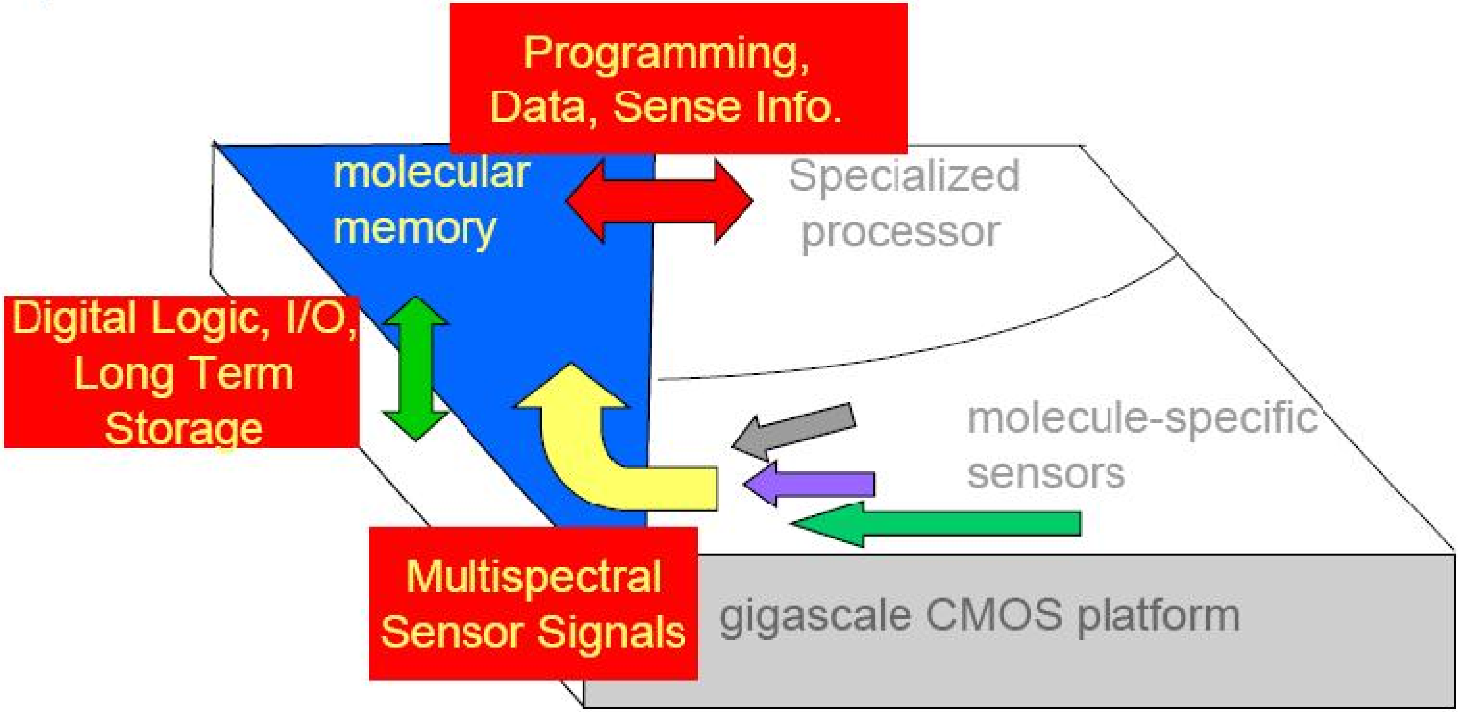
Nanofocusing recording probe for an optical disk memory

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

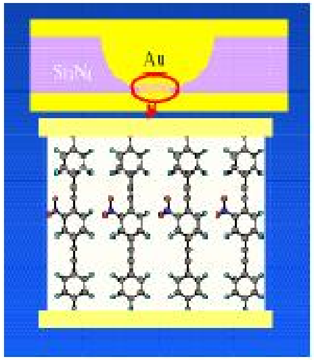


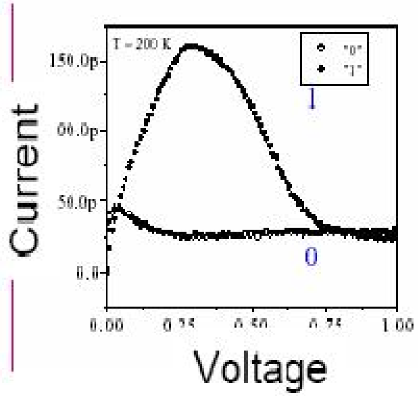
Desired Attributes:

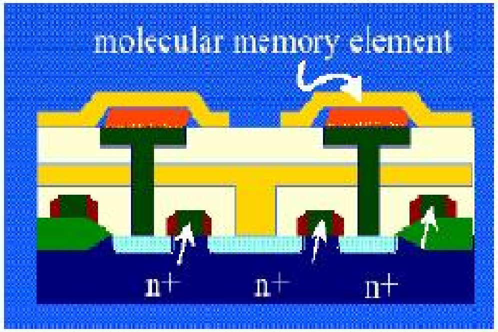
- *Objective:*
  To explore technologies that promise ultra-dense, low-power, on-chip memory.

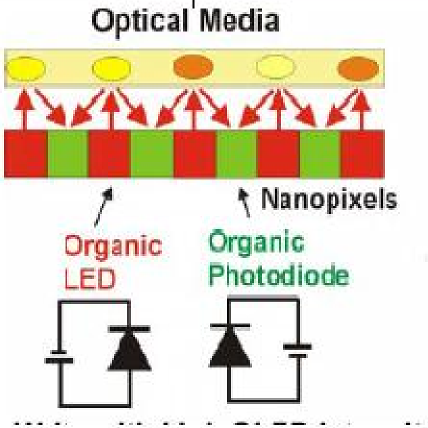
- *Projects:*
  -molecular switch memory
  -optical memory

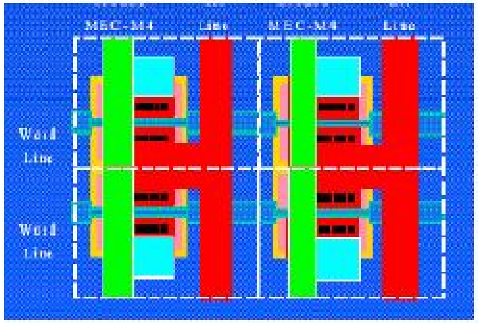
- *Approach:*
  -electronic memory
  -optical memory







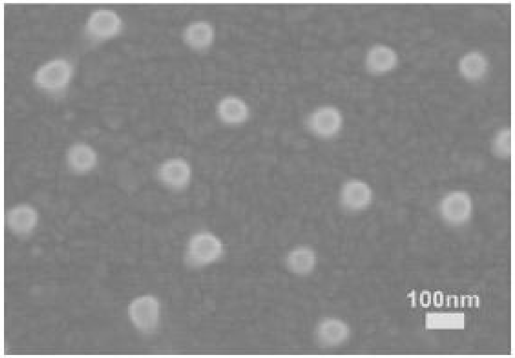




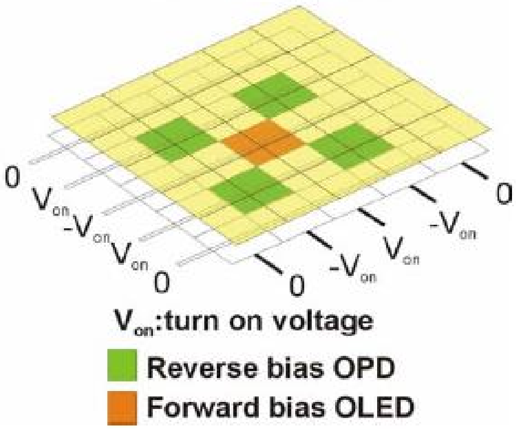
Nanodiode-Based Optical Storage

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

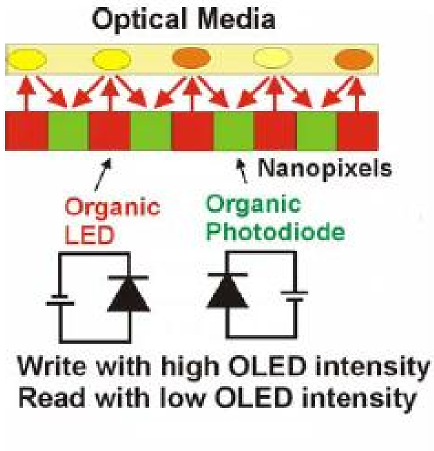
SEM of 90 nm nanodiode array



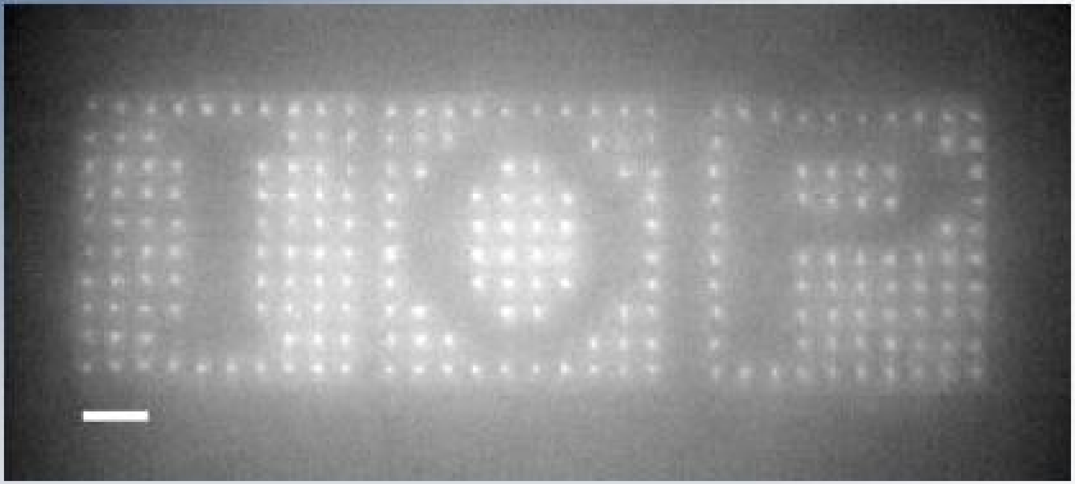
Addressing scheme



Read-write scheme



Optical Fluorescence Memory



Three-dimensional optical memory using a human fingernail

Akihiro Takita, Hirotsugu 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