Silver Oxide as an Optical Storage Medium

(Non-Thermal Recording Mechanisms)

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July 05

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Motivation:

- All current disk-based optical recording mechanisms thermally driven
- Thermal recording mechanisms impose the strict limits on energy spread to adjacent data cells
- Every increase in density challenges the thermal performance of the medium
- Optically driven electronic recording processes free from any of the above difficulties and faster and much more efficient in utilisation of laser energy.
- Continuing interest in using Silver Oxide as an active layer enhancing readout signal (CNR) from recording media.
- Continuing interest generally in fluorescent recording mechanisms

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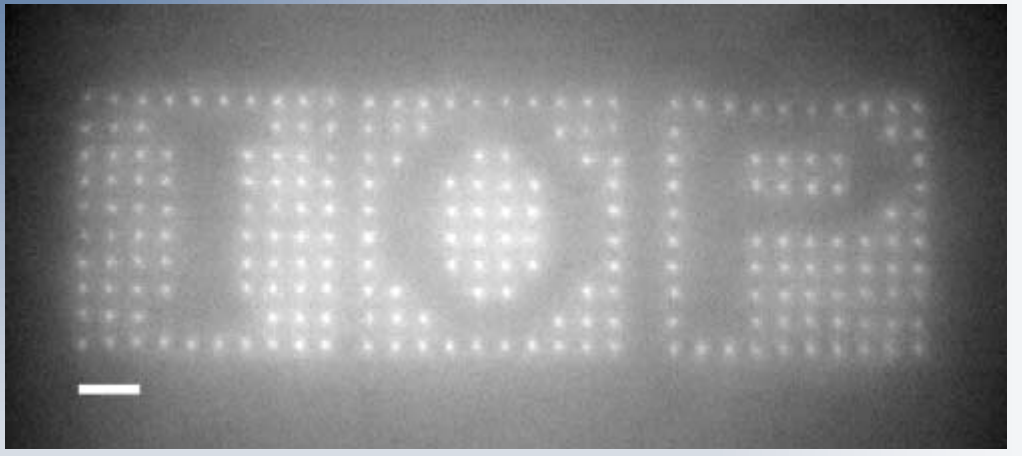
Optical Fluorescence Memory



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

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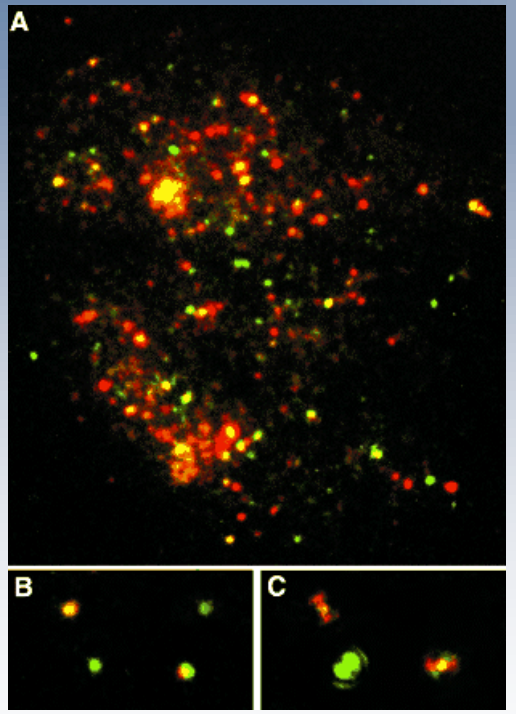
This work is prompted by a report of Peyser et al. who studied the fluorescence of Silver Oxide nano-particles prepared by both wet chemical and thermal evaporation processes



Fluorescence from a 16nm Ag/Ag_2O film excited at wavelength of 514.5nm.

Lynn A, Peyser, Amy E. Vinson, Andrew P. Bartko and Robert M. Dickson

Science Vol 291, 103-106 (2001)

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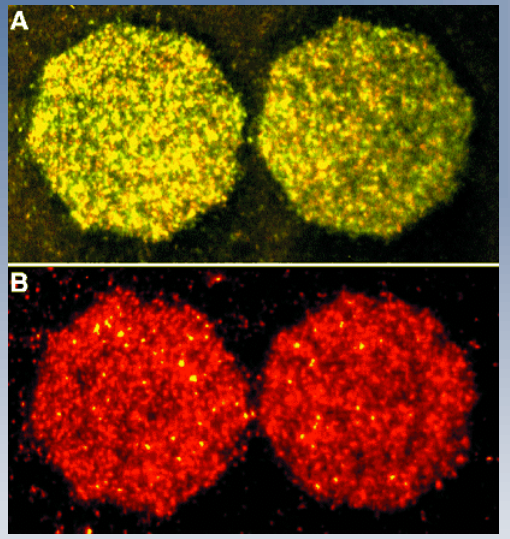

Also demonstrated recording possible – Apertures 35μm diameter exposed first to blue light (A) and subsequently read out via red fluorescence when exposed to green light .

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Aims:

- Investigate sputtering techniques for the preparation of high quality silver oxide films having controlled uniform structure on the nano-scale.

- Reproduce and improve on the work done in Atlanta and more rigorously study the sensitivity of the recording/erasure process.

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Preparation Techniques:

- Sputtering a series of Silver films followed by natural oxidation in air
- Reactively Sputtering a series of Silver Oxide films from a Silver target. Sputtering gas oxygen content set at 30% following ellipsometric studies of Buchel et al.
- A two stage process. In stage 1 precursor films of Silver are prepared. In stage 2 these are reactively back sputtered to develop the desired silver oxide nano-structure in a very controlled manner. Shutter isolates target from plasma during this stage preventing further deposition.

*For each technique studied films having thicknesses in the range 2nm to 24nm were prepared.

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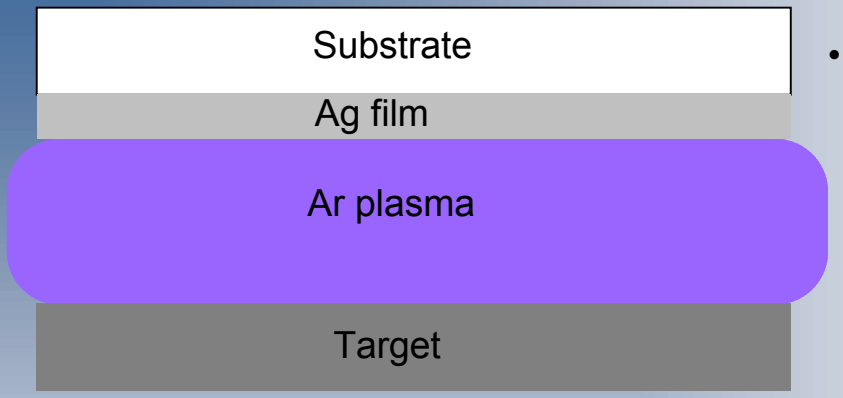
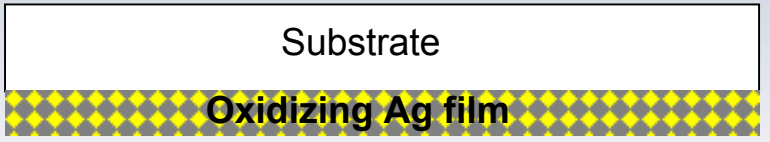


- **Sputter Silver Films of different thicknesses.**



Silver film Oxidise naturally in air to Silver Oxide with thickness dependent structure.

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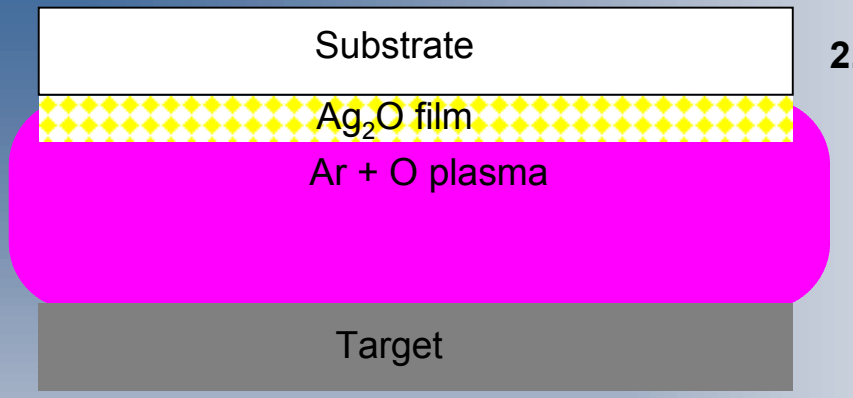
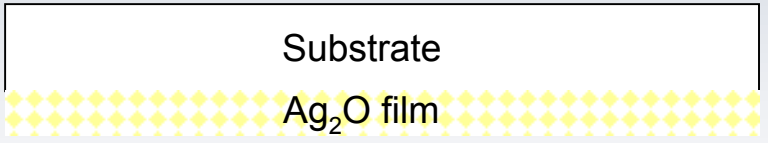


2. Reactively Sputter Silver Oxide Films of different thicknesses.



Silver Oxide films with thickness dependent Structure

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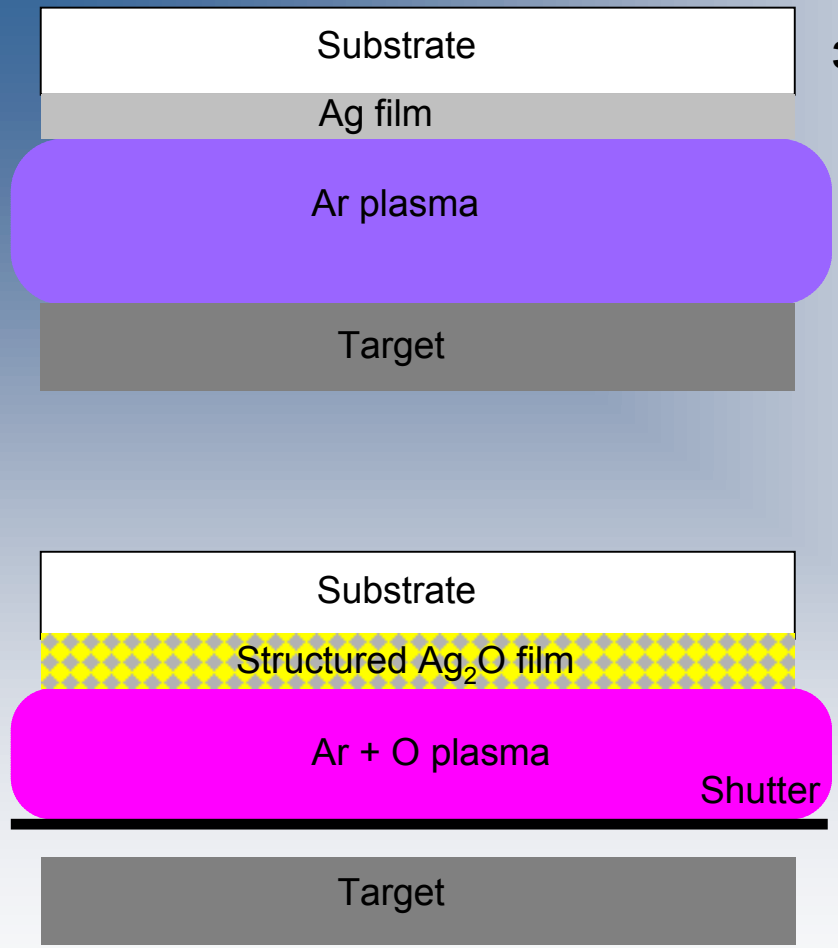

3. **Sputter Silver Oxide Films of different thicknesses.**

Isolate plasma from target and reactively back sputter Silver to Silver Oxide film with thickness dependent Structure

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- A Perkin-Elmer LS-50 Fluorescence Spectrometer was used to characterise the fluorescence performance of each of the many samples produced by the different fabrication techniques.
- Blue excitation wavelengths of 450, 465 & 485nm were used whilst scanning over emission output.
- The majority of samples displayed a strong emission peak centred on 660nm with a FWHM of about 30nm.
- Best excitation was obtained at the 485nm wavelength.
- Large differences in the fluorescence output were recorded for films fabricated by the different techniques and output was very dependent on thickness.

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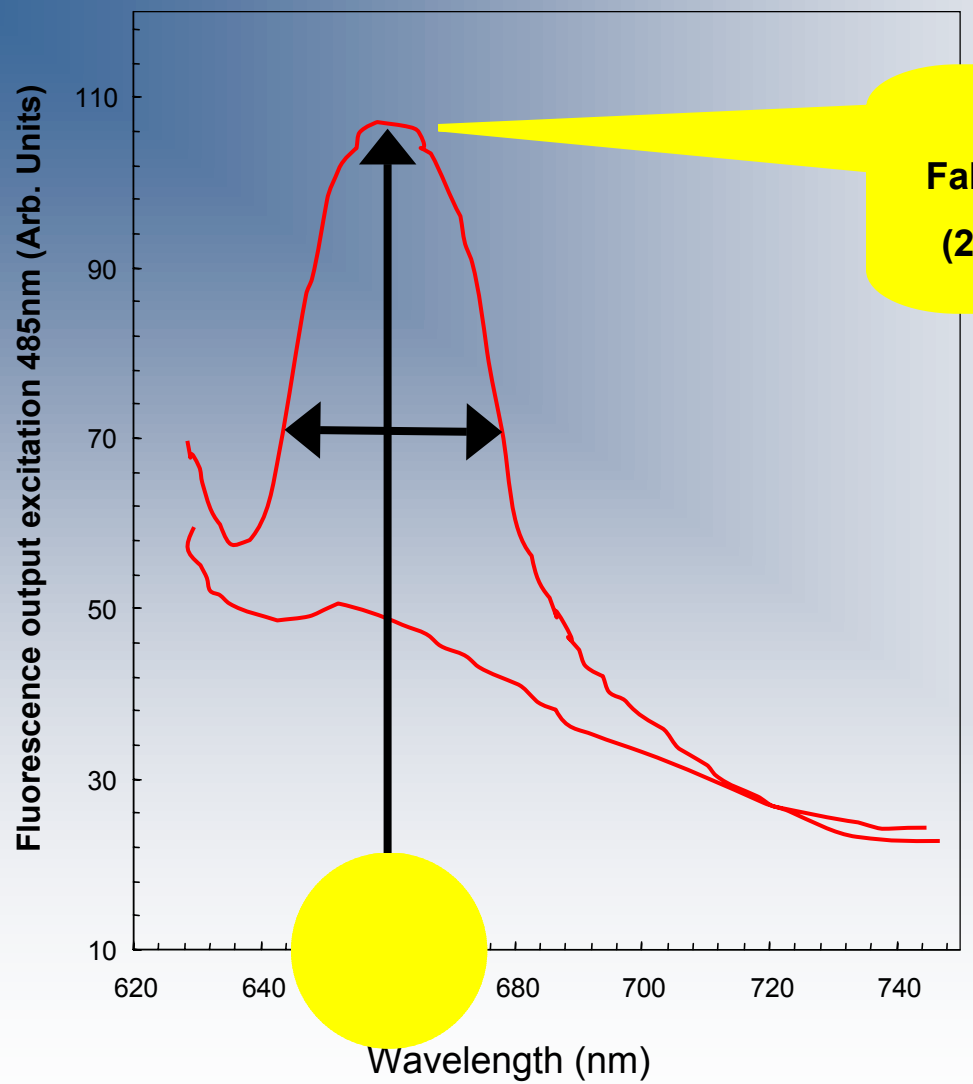

Best output from Fabrication technique 3

(23nm Precursor film)

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Recording Experiments:

- ❑ All subsequent work refers to work conducted on samples 23nm thick fabricated by technique 3.
- ❑ To facilitate recording experiments optical fibres were fed into the LS-50 spectrometer. These carried more intense radiation than available from the xenon flash tube in the instrument.
- ❑ The write fibre carried the 514nm wavelength from an argon ion laser.
- ❑ The readout fibre carried the 532nm wavelength from a frequency doubled CW YAG laser.
- ❑ Both lasers were directed on to a masked area of sample 5mm diameter producing power densities of approximately 250mW/cm^2 and 65mW/cm^2 respectively.
- ❑ The spectrometers photomultiplier and counting system was retained to detect sample fluorescence at 660nm.

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- It was immediately discovered that in contrast with the results of Peyser et al. where the samples were fabricated in darkness, all samples produced by either techniques 2 or 3 were fabricated in the “written” state.
- This was attributed to the intense blue colour of the sputtering plasma whose spectrum obviously contained much more optical energy below the critical 520nm wavelength boundary between recoding and readout processes than above it.

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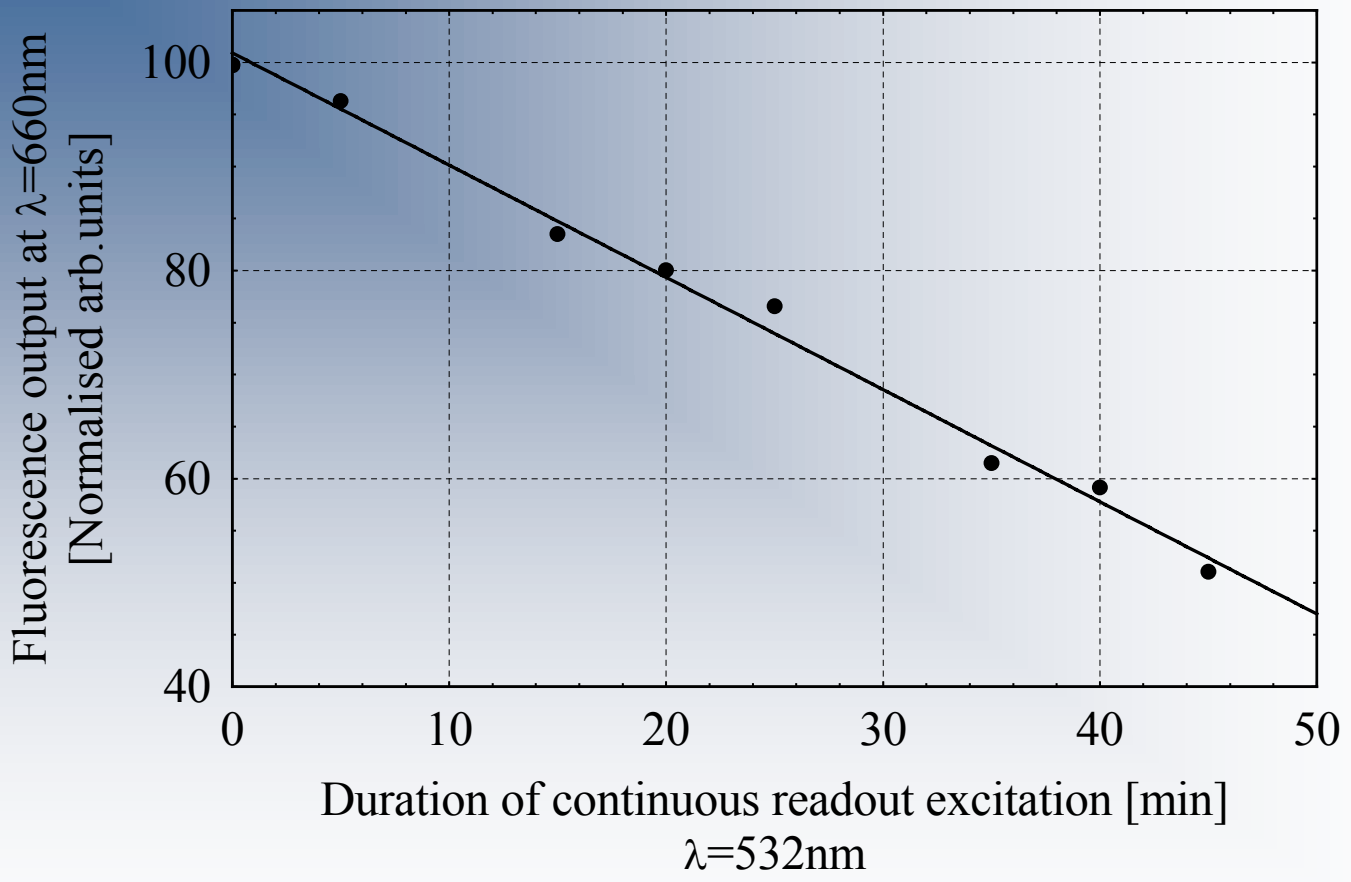
Exhaustion of the Fabricated state



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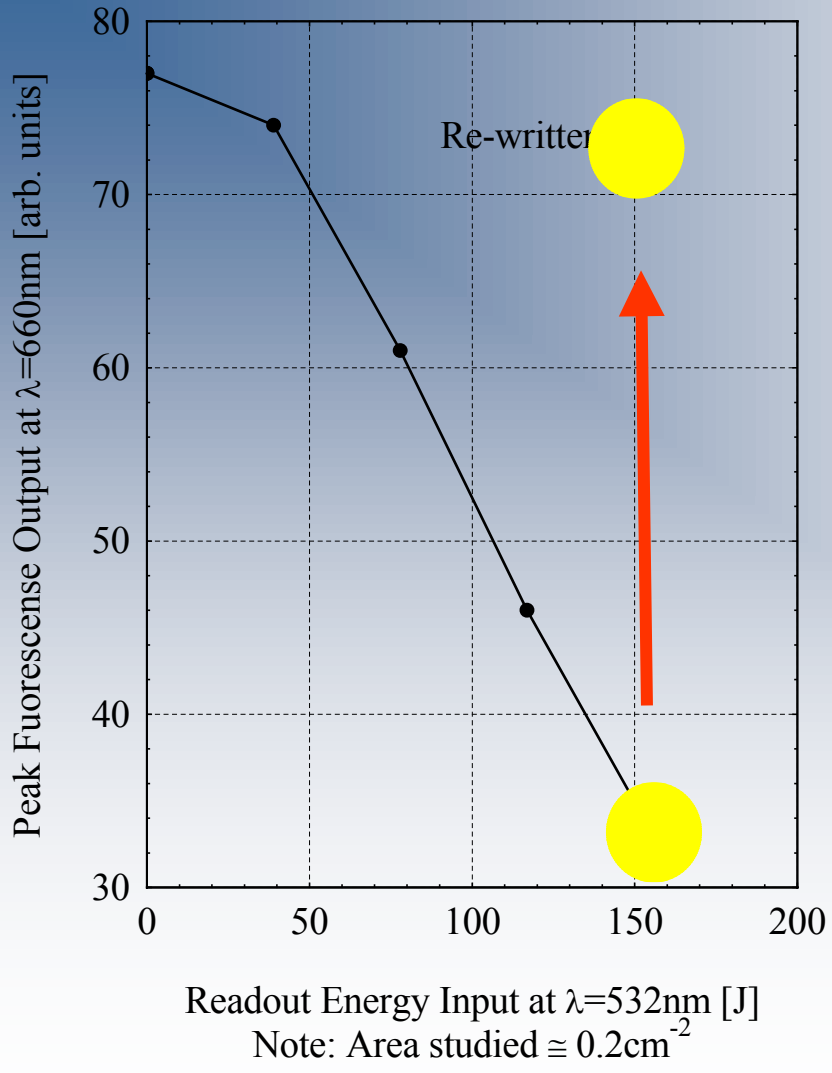

Expressing the recording/erasure processes in terms of their energy requirements it is seen that:-

- 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

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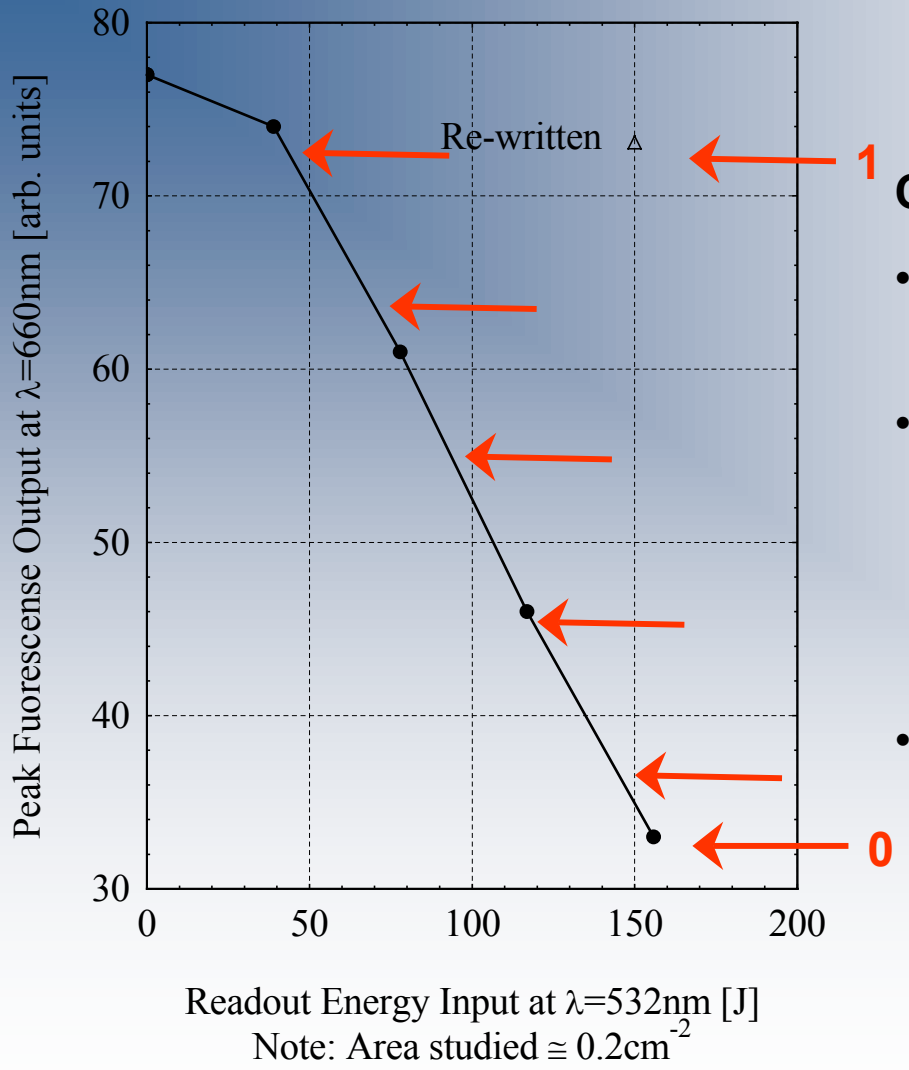

Can either

- 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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Comments:

- Recording mechanism linear over the dynamic range between Saturation and Exhaustion levels.

- Energy per unit area required to reverse the state of the best films in either direction is ~ $750 Jcm^{-2}$ ($150J/0.2cm^2$).

These samples are approximately 25 times more efficient than those produced by Peyser et al.

- At the bit level i.e in a focussed diffraction limited spot the energy required to produce complete reversal in either direction is of the order of $1 \times 10^{-6} J$. Therefore lasers delivering a few Watts appear to be required for recording at MHz rates.

However current samples are only of monolayer thickness and because of their structure intercept a small fraction of incident energy. It is necessary to be able to produce them in much thicker form whilst retaining the nano-particulate structure essential to the recording mechanism.

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Concept is in fact very similar to optical memory based on electron trapping in doped wide band-gap semiconductor materials studied previously.

Efficiency appears to be similar or better and films are easier to fabricate at least in monolayer form.

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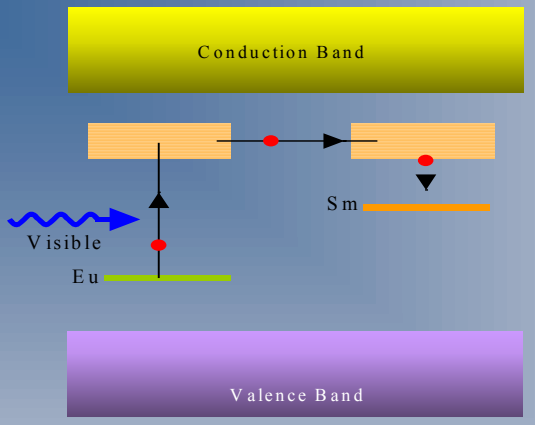

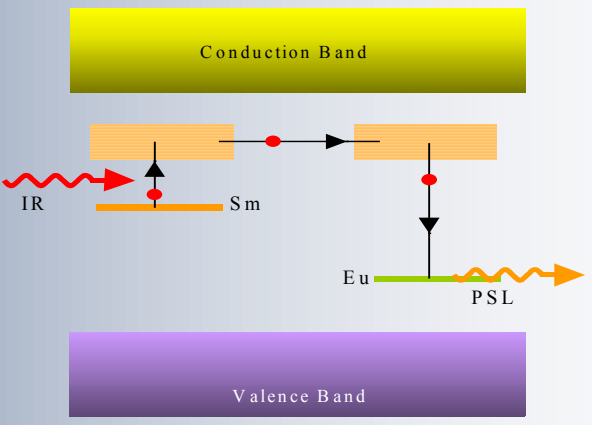

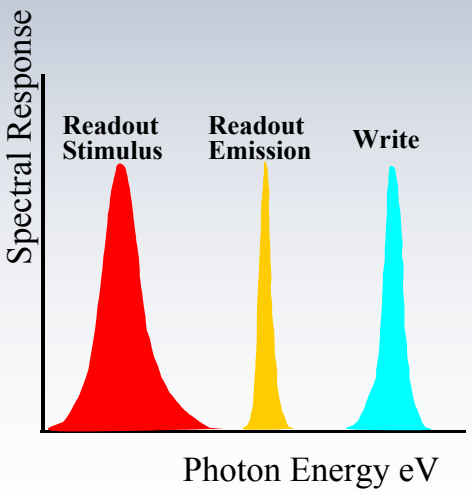

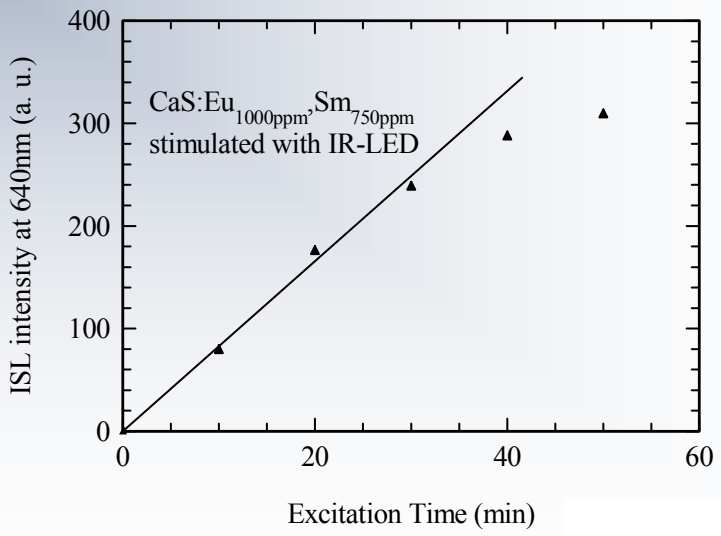

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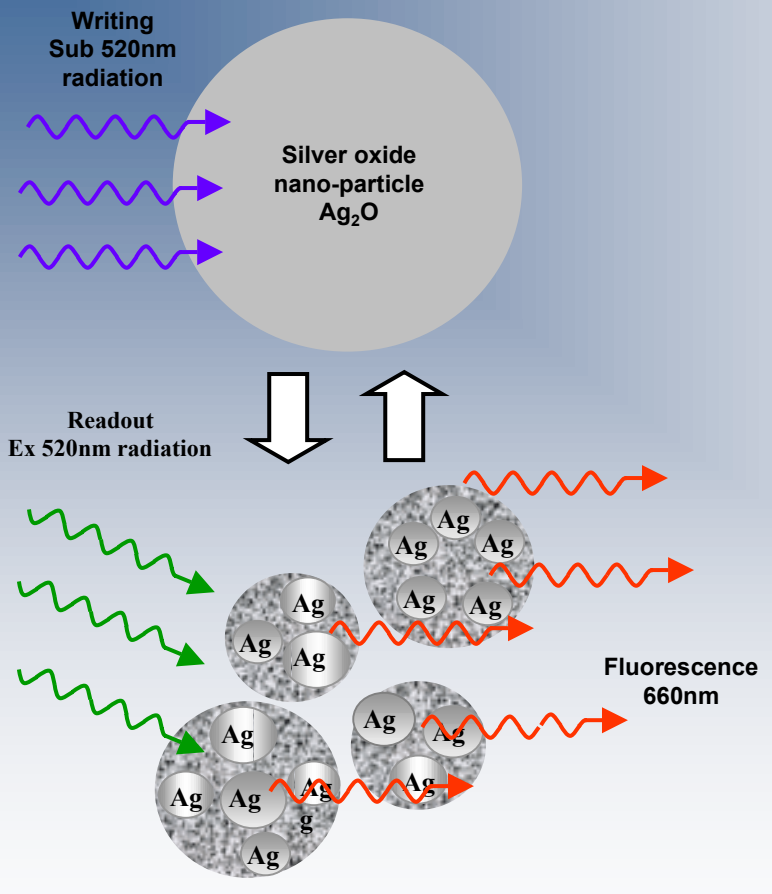
Schematic Photo-Physics/Chemistry:



- 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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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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