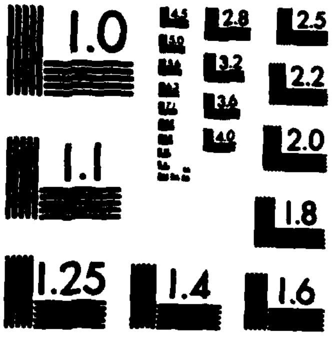
AD-A181 566 NEW MATERIALS FOR OPTICAL COMPUTATIONS PHASE 1 FEASIBILITY STUDY(U) QUANTEX CORP ROCKVILLE MD J LINDMAYER 1986 SDIO-86-11 N00014-86-C-0807 1/1

UNCLASSIFIED F/G 9/5 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

⑫

CONTRACT NUMBER N00014-86-C-0807

FINAL REPORT

NEW MATERIALS FOR OPTICAL COMPUTATIONS

PHASE I FEASIBILITY STUDY

SDIO Topic 86-11

PREPARED BY:

Joseph Lindmayer
Quantex Corporation
2 Research Court
Rockville, Maryland 20850
301-258-2701

SUBMITTED TO:

Scientific Officer
Office of Naval Research
ATTN: W. Miceli, Code 1111
800 North Quincy Street
Arlington, Virginia 22217-5000

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

LIMITED RIGHTS LEGEND

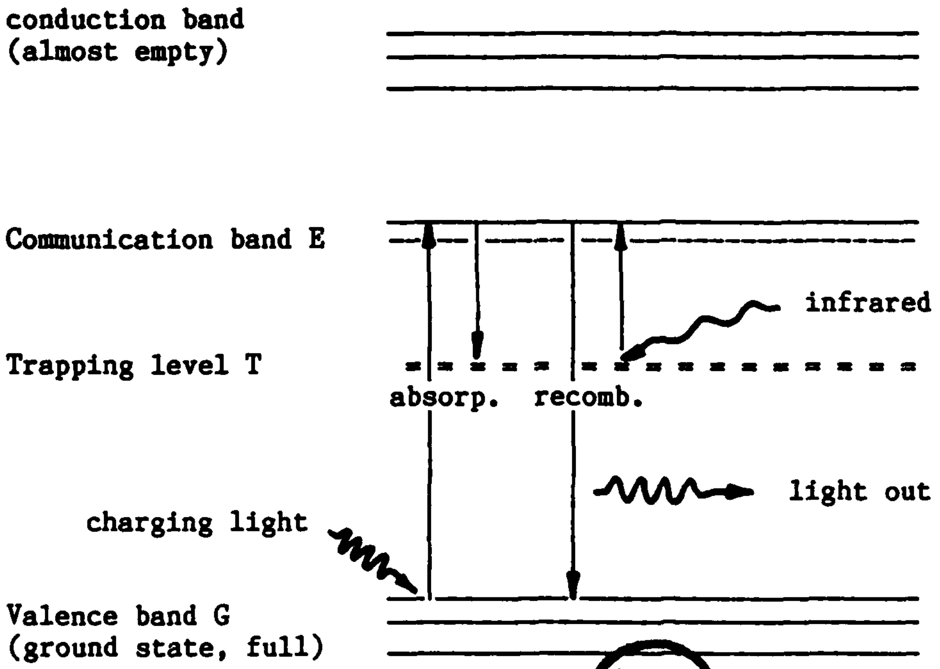
This technical data shall not, without the written permission of the above contractor, be either (A) used, released or disclosed in whole or in part outside the Government, (B) used in whole or in part by the Government for manufacture, or (C) used by a party other than the Govenrment. This legend shall be included on any reproduction of this data, in whole or in part.

I. OVERVIEW OF FINDINGS

It is generally accepted that ~~high~~ HIGH speed data processing by optical means is needed, ~~but the field is underdeveloped~~. Many hold the view that progress in optical memories and logic is determined by the availability ~~of new photonic materials~~. This Phase I feasibility study concentrated on the use of certain II-VI compounds that display unusual optical properties, offering new opportunities for the realization of erasable optical memories, processors and computers. ~~We believe that, within the confines of the Phase I work, significant progress was made.~~ The feasibility of the erasable memory function is well documented~~, and progress here was the greatest, particularly since some internal funds were also applied in parallel.~~ Optical processors and logic functions were also examined and the results to date show that, with application of larger resources, logic functions can be developed. (to page 3)

Before this study, Quantex had already discovered new compounds and technologies applicable to optical data processing that are unique and are not studied anywhere else at the present time. The new materials are now called "electron trapping" (ET) materials, because their operation depends on this basic function.

The basic physics of the approach is described below in terms of the energy relations in ET materials. The electron trapping effects can also be viewed as an electronic quantum state change induced by photons. This phenomenon, explored in detail for the first time, offers the new opportunities.



A wide bandgap host lattice creates the original valence and conduction bands. Energy levels E and T are introduced by two selected impurities. The narrow band of energy levels, E, is now called (by us) the "communication" band, since interaction of electrons is allowed there. Trap sites at level T are non-communicating (electrons do not interact). In the first approximation, excitation of electrons from the ground state requires a minimum of E-G photon energies. After the charging excitation is stopped, the trapping sites remain filled and it can be said that the material is "charged" or "energized" as the electrons remain in a higher energy state (practically indefinitely). Later exposure to infrared that can supply E-T energies kicks electrons from the traps up to band E. In the communications band, E, the electrons interact, because it is a band, and start recombining with ground states in band G. The resulting light emission is characterized by a narrow band of wavelengths associated with the E-G energy differences.

The depth of the traps is normally much higher than the thermal energy and, therefore, the electrons cannot be displaced by thermal agitation (the depth of the traps in the materials is about 1.2 eV). For a controlled trap density which cuts off tunneling interchange, the trapped electrons cannot communicate with each other, cutting off the possibility of recombination with ground state electrons. Then, in the energized state, the traps are filled, band E is empty and recombination from T to G is nonexistent. The storage times become enormous. The stage is set to receive infrared photons, and to emit higher energy photons. This basic phenomenon leads to photonic memory and optical computing functions.

P

Much progress ~~was~~ has been made in the erasable optical memory area employing the above phenomenon. Clearly, information can be written by a visible light source, which is then retained in the form of the spatial distribution of trapped electrons. It has been demonstrated that both digital and analog information can be stored this way. Reading is accomplished by a "gentle" infrared beam that partially discharges the traps in the process of reconstructing the information. While each reading reduces the trapped electron density, many readings can be made and the information is easily rewritten. We have found that the material in its thin film form has a speed faster than 5 nanoseconds (equipment limited) and the resolution is at least 0.6 micron.

Erasable optical memories are not yet available, in spite of the extensive effort by large organizations using magneto-optic, dye-polymer and phase-change materials; they generally get "tired" after certain limited numbers of write/erase cycles. ET memory is entirely electronic and, therefore, the write/erase cycles are unlimited. This new memory media also displays superior high speeds and a linearity which allows for analog or multilevel recording as well. These are unique properties that are not available in any of the competing approaches at the present time.

In the area of optical computing, the focus was on improving and characterizing thin film layers of ET materials. While Quantex uses crystallites (powders) for less critical commercial applications (such as IR sensor cards), it has succeeded in the laboratory to form surface crystallized layers a few microns thick on various substrates. This earlier breakthrough leads to the possibility of forming microphotonic circuits with ET materials through the adaptation of microelectronic technologies, such as photolithography. In addition, the high resolution offered by the thin film can also be useful in certain parallel optical processing schemes.

The essence of the Phase I work in optical processing was to take the first steps toward a planar microphotonic circuit. At the present state of development, it is now known that such an approach is realistic. The techniques available to modern VLSI microelectronic fabrication would obviously be key ingredients in microphotonics development for computers.

Thin film ET materials could form active photonic devices, which are required for optical logic functions. It is expected that planar optical waveguides can be formed readily on a substrate so that the light can be sent around without difficulty. (This replaces the interconnection wiring in microcircuits. As an interesting fact, note that light beams crossing each other do not pose a short circuit.) The heart of the optical circuit is the active ET device, which must be in the thin film form. Much experimentation took place in forming such islands and to form thin films on metal layers which would be one side of the parallel plane waveguide. For efficient operation, the light should be confined in the waveguide and not allowed to escape into space. Progress was made in the newly defined optical microcircuit area that would look similar to electronic microcircuits, but operate entirely by light on the surface plane of a substrate. Of course, the Phase I funding was insufficient to develop these approaches fully, nevertheless, technological feasibility is apparent.

The breakthrough development of ET materials offers other possibilities of constructing fast and efficient parallel optical computing devices such as Spatial Light Modulators, Optical Crossbar Switches and Optical Correlators. Current understanding of the material indicates the possibility of sub-nanosecond speeds and resolution in the sub-micron range.

The need for resources in furthering this complex field became very apparent during the Phase I work. As time progressed, it became clear that the new ET materials offer the basic parameters needed. Now it is established that only electronic processes are involved, high speed is available, submicron resolution is at hand and that the electrons will stay in their high energy state for very long times.

The next block diagram outlines the position of the Phase I work in a field that could move rapidly to sophisticated applications, if the resources are available.

Outline of Technical Progress

ET Materials
(available)

Thin film (microns)
ET on substrate
(working)

Thin film on memory disk substrate	ET material on sapphire or glass substrate
Demonstrate speed and resolution (static mode)	Small area ET on sapphire and planar opt. guide

END OF PHASE I

Produce prototype of real disk	Demonstrate logic functions
Dynamic testing Drive issues	Optical Processor (e.g. multiplier)
Overall testing	Multiple logic functions on chip
PROTOTYPES	PROTOTYPES

In general, the control and reproducibility of ET materials is very good. In order to put this statement in perspective, a comparison can be made to established semiconductor technologies. Consider the following:

- * While semiconductors require extremely high purity, ET materials do not. This arises from the fact that the doping levels are very high in ET materials; orders of magnitude higher than in a typical semiconductor.

- * While semiconductor operation needs single crystals in order to transport electrons at high mobility, ET materials do not depend on electron transport. In ET materials, electrons are merely raised to a higher energy state at about the same location and returned to their ground state also at the same general location. Accordingly, only small crystals are required. As far as grain boundaries are concerned, they can represent a barrier against electron flow, but have very small effect on photon movement.

- * Semiconductors devices require many electrical contacts in their operation - a constant problem area. Photons are transmitted and sent around without electrical contacts, a very desirous situation.

As a result of impurity tolerance, not requiring perfect crystals and not having electrical contacts, the ET technology will be less capital intensive than semiconductor technology.

The payoff of continued development will be found in the possibility of realizing a superior high-speed, high-resolution erasable memory system, laying the foundations of optical integrated circuits and parallel optical processors. The memory approach has been compared to the performance of the magneto-optic and phase-change approaches and the superiority of the ET memory is clear. The optical microcircuit approach pursued here is unique in that ET materials allow for the use of photolithographic techniques, similar to present microcircuits, for establishing high function densities. Furthermore, it appears that ET materials are certainly applicable to parallel optical processing. In these latter areas, however, work had to be limited during Phase I.

(Further insight can be given to this fast developing technological situation by the results obtained from parallel efforts under internal funds. Just as this report was being written, active specular films were obtained.)

II. PROJECT SUMMARY

A. Purpose

This Phase I SBIR effort was performed to demonstrate the feasibility of utilizing Quantex electron trapping (ET) materials as a new media for erasable optical mass data storage applications and optical processing.

B. Description of the Work Performed

The Phase I activities consisted of the preparation and evaluation of experimental thin-film and thick-film samples of the ET materials, generation and submission of a Summary Abstract and generation of this Final Report. Detailed measurements of erasable electron trapping optical memory and optical processing properties were performed, including the following:

1. WRITE input, READ input, and READ output spectra.
2. WRITE and ERASE input energy density requirements.
3. Response times of the output signal.
4. Output signal as a function of infrared input intensity.
5. Temperature sensitivity of the various optical spectra.
6. Minimum bit location size (optical interaction resolution or "photonic radius").
7. Evaluation of conditions and technologies required for planar optical computational devices.
8. Evaluation of results for use in parallel optical processors.

III. DESCRIPTION OF THE WORK PERFORMED

The following is a description of the work performed during the Phase I feasibility evaluation efforts.

A. Sample Preparation

A number of bulk samples of different Quantex ET material formulations were prepared. These were: a) ground to fine powders, sieved to size ranges, sprayed on sapphire substrates to obtain thick films of uniform thickness and fired at an elevated temperature to produce excellent adherence between the ET material powders and substrates, and b) evaporated as thin films onto sapphire substrates to thicknesses of 4-8 microns and appropriately crystallized.

B. Measurements

A number of different measurements were carried out in order to quantify the characteristics of the ET materials in both thick-film and thin-film form.

It is obvious that the material could perform as all-optical memory media. The WRITE operation is accomplished by visible light, with the result that energetic electrons are stored in the media at geometric locations defined by the WRITE beams. The infrared light, then, serves both READ and ERASE functions, with the integrated input energy determining whether the media is read or erased.

To be a viable media for mass data storage and optical processing, it is necessary that the media have low volatility, very rapid function speeds, lower power density requirements, high resolution and indefinite cycle life for very large numbers of operations. In evaluating these issues, a number of different measurements were performed on several formulations of the Quantex ET materials, as follows:

1. Throughput Rate - The temporal response of the visible output pulse (READ output) to the infrared input pulse (READ input) was investigated extensively. Measurements of both the rise and fall times of the output pulse were made in response to high speed, infrared laser pulses (see Figure 1 for the measurement configuration).

2. Retention - Experimental samples were exposed to visible wavelength light (WRITE input) energy sufficient that the electron traps became saturated. After the WRITE input was terminated, the media was left in the dark, at a known temperature. The intensity of the READ output was sampled from time to time. The experiments were run at various temperatures, e.g., 20°C, 50°C, and 80°C. The initial results indicated very long times for retention even at the elevated temperatures and, therefore, it was concluded that a project beyond the timeframe of Phase I would be required to accurately characterize long term volatility.

3. Output Radiance - After the electron traps were saturated by the WRITE input, the READ output was measured as a function of the READ input intensity. Specifically, for each value of the READ input level, the initial value of the READ output was recorded. (Only relative values of the READ output were measured, because the isotropic emission of the output light would require development of an optical system or selective mirror coatings for absolute measurements far beyond the scope of the Phase I feasibility effort.)

4. Erasure - Electron traps in the media were filled by the WRITE input and, within a second after the WRITE input was switched off, the ERASE input commenced. The output was monitored over an extended period of time, i.e., until the output signal had decreased to approximately 0.1% of its initial value. The experimental set-up was arranged as seen in Figure 2.

5. Wavelength Sensitivity - A fixed number of visible photons per unit area, at each WRITE wavelength, were used to excite and trap electrons in the ET media samples. Within a second after the WRITE input signal was terminated, the READ input signal commenced. The output was recorded for each wavelength of the WRITE input signal. At the WRITE wavelength of peak efficiency, the energy required to saturate the electron traps was determined.

6. Temperature Stability - The measurements were conducted as in (5) above, except that the sample temperature was varied. A thermoelectrically controlled block, on which the sample was mounted, was used to control the temperature in the range of -10°C to +80°C.

7. Resolution - Samples were exposed to a WRITE input signal through a photolithographic mask containing lines with line widths as small as 0.6 micrometers. After the WRITE signal was switched off, the sample was exposed to infrared light and the pattern was observed through magnifying optics. A photograph of the resolution pattern employed is shown in Figure 3.

8. Technology Related to Device Geometry - Formation of active islands of thin film ET materials was investigated experimentally. Figure 4 shows experimental geometries generated with precision shadow masks.

9. Integration with Optical Waveguide - In order to test the potential of forming active thin film ET islands inside of plane parallel optical waveguides, films were deposited on evaporated metal layers. This was done in order to evaluate the feasibility of forming crystalline layers in conjunction with reflecting surfaces. Figure 5 shows a photomicrograph of a thin film ET material deposited on a thin film metal substrate.

IV. RESULTS AND DISCUSSION

A. Throughput Rate

Both the rise and fall times of the output signal were found to be limited by the response speed of the available pulsed infrared sources and instrumentation available to measure the response. Because of this, it can only be stated that the rise and fall times are both less than 5 nanoseconds. It is expected that they are much less than 5 nanoseconds.

B. Retention

As was indicated before, no detailed study of volatility was made during the short Phase I time frame. However, we have observed that patterns of visible light projected onto ET materials remained after months of storage in the dark, when interrogated by infrared. As can be concluded, electrons remain trapped for very extended periods of time.

C. Output Radiance

Once an electron population in the traps has been set by a WRITE signal, one can determine the functional dependence of the READ output signal on the READ input. Figure 6 shows the measured luminescence emission (READ output) as a function of infrared irradiance (READ input). The dependence was measured to be linear over at least three orders of magnitude. In addition, Figure 7 shows the luminescent output for a fixed infrared input as a function of deposited WRITE energy over many orders of magnitude up to saturation. The results strongly support the feasibility of analog or multilevel digital storage in these electron trapping materials. In addition, since the visible output is the product of the visible and infrared inputs, a parallel multiplier is obviously feasible in a two-dimensional processor.

D. Erasure

A typical erasure curve is seen in Figure 8. The relative visible output intensity is plotted as a function of time while the sample is illuminated with low intensity (for ease of measurement) infrared. The energy density for erasure has typically been found to be 30 mJ/cm^2 for 250 micron thick samples on sapphire (1.2 J/cm^3). As would be expected, the input energy density for erasure was very dependent on the thickness and morphology of the samples.

Experiments also showed that the trade-off between the intensity of the ERASE signal and the duration had little effect on the total energy density required for erasure.

From these results, we have calculated that only about 1.5 pJ will be required for bit erasure of a one square micron area of a 1 to 2 micron thick film.

E. Wavelength Sensitivity

The relative sensitivity for trapping electrons as a function of wavelength is seen in Figure 9. The most efficient wavelength for the samples employed was at 450 nanometers. At this wavelength, for example, 10 mJ/cm^2 of energy was required to saturate the electron traps in a 125 micron thick sample (0.8 J/cm^3), or slightly under 1 pJ for a one square micron area of a thin-film 1 to 2 microns in thickness. Energies required for wavelengths other than 450 nm can be inferred from the inverse of Figure 9.

F. Temperature Stability

Temperature was found to have little influence on the shape of the electron trapping curve. The results for the temperature range of -10°C to +80°C were essentially identical to that shown in Figure 9.

G. Resolution

Attempts to WRITE and READ with high geometric resolution were unsuccessful in the thick film samples because of excessive scatter produced by the granularity. However, the thin evaporated films (4-8 microns) fabricated on sapphire substrates displayed electron trapping properties of similar magnitude to the thick film samples. During the Phase I contract period, the ability to write and read 0.6 micron lines was demonstrated on the thin films. A photograph of the resolution pattern employed was shown in Figure 3. The lines in the pattern are 8, 4, 2, 1 and 0.6 microns in width. Visual observation of the luminescent output was able to resolve the 0.6 micron geometry.

H. Technology Related to Device Geometry - Active islands of thin film ET materials were formed on a sapphire substrate as a first step toward a photonic integrated circuit. The small islands performed similar to large samples, which was reassuring. While the experiments employed precision shadow masks, clearly photolithography could also be used. Figure 4 shows experimental geometries generated with precision shadow masks.

I. Integration with Optical Waveguide - If ET materials are to be used on an integrated chip, one should be able to form ET spots inside of a parallel plane optical waveguide. This requires recrystallization of the thin film over a thin metal surface. These experiments were difficult, in that the interactions between metal and ET film had to be minimized.

In order to achieve optical gain and examine other optical functions in their full efficiencies, the ET islands must be confined by plane parallel optical waveguides. In this fashion, one can minimize the escape of light into space. To test the feasibility of crystallizing thin film islands on a reflecting metal surface, ET films were deposited on evaporated aluminum and silver. The films could be recrystallized in the 500-600°C temperature range. Figure 5 shows a photomicrograph of a thin film ET material transitioning between insulating and metal film substrates and the first attempt to form a three-terminal optical transistor.

It has been realized that only thin film ET materials could form active photonic devices, which are needed for certain optical logic functions. The experiments show that in granular ET materials scattering interfers with efficient operation; it is the thin film approach where scattering is minimized. In addition, for an active chip, the light should be confined in an optical waveguide and not allowed to escape into space. Much experimentation took place in forming islands of thin films on metal layers which would be one side of the parallel plane waveguide. Progress was made in the newly defined optical microcircuit area that would look similar to electronic microcircuits, but operate entirely by light on the surface plane of a substrate. The thin film breakthrough allows the formation of microphotonic circuits with ET materials through the adaptation of microelectronic technologies, such as photolithography. Of course, the Phase I funding was insufficient to develop these approaches to fruition, nevertheless, technological feasibility is apparent.

Toward the end of Phase I, it has been realized that the thin film version of ET materials offers the possibilities of constructing fast and efficient parallel optical computing devices such as Spatial Light Modulators, Optical Crossbar Switches and Optical Correlators. Current understanding of the material indicates the possibility of sub-nanosecond speeds and resolution in the sub-micron range.

V. CONCLUSIONS

From the results discussed above, it can be said that the basic feasibility of the erasable Electron Trapping Optical Memory (ETOM) has been demonstrated, an important purpose of the Phase I effort. In addition, it has been shown that the storage and readout are linear over a very broad range, which opens up the possibility for analog or multilevel digital storage. The results also project into the field of parallel optical processing — two-dimensional spatial light modulator multipliers, etc., etc.

The primary advantages of the erasable Electron Trapping Optical Memory approach are a basic mechanism that does not rely on thermal excursions, attendant aging and time constants associated with such excursions. This mechanism also reduces optical beam power requirements, and introduces linearity, which is inherent in the storage mechanism.

What needs to be done further is to concentrate efforts on thin-film technology development for control of storage volatility variance, spot resolution and quantum efficiency as compared to the relatively simple thick-film powders employed in the larger part of this Phase I effort of feasibility demonstration. The thin film approach is also the key to optical amplification and parallel processing.

As far as optical memories are concerned, there is presently a great deal of effort being expended by numerous entities in several countries on technology development[1,2]. The commercial implications of these memories are enormous and the impetus for such development activities has largely been for commercial products. At present, however, *erasable* optical storage media pose the limiting factor in the full realization of fast, high-density, reliable optical memories. Having all three characteristics in one of the media (speed, density and cycle life) has been elusive for erasable media. In addition, most approaches store only one binary bit at each storage location, which limits the ultimate storage bit density to an optically resolvable spot. There is one approach, the IBM "multispectral hole burning" technique[3], which stores more than one bit in a physical location, but it requires operation at very low temperatures. Quantex has demonstrated the basic feasibility of a new approach to erasable optical memory media in Phase I which now appears to indeed have the potential to satisfy all of the desirable criteria. (The prospects are so exciting that Quantex recently started a new company, Optex Corporation, to prepare for developing the commercial aspects, and Optex is already exploring arrangements for direct financing, joint ventures, and second-source licensing for volume manufacture.)

The ET materials being developed by Quantex were being investigated in Phase I for binary digital memory application, but have shown *both* an extremely linear relationship between the intensity of WRITE input light and the light output from the storage location produced by a fixed-intensity READ command *and* the output for a given WRITE level produced by varying the READ intensity. So far, this linear relationship has been found to exist for some *three orders* of magnitude (equipment limitations). Obviously, this capability has also shown the possibility of tremendous information storage density when employed as an *analog or multilevel digital memory medium*. Information storage on a multilevel scale, at each microscopic location in the ET storage media, offers the opportunity to provide the very high density erasable memory capabilities needed for advancing computing systems.

Also, it is obviously feasible to have outputs which are the *product* of WRITE and READ inputs, or to form a two-dimensional parallel multiplier.

The Phase I effort has not only demonstrated the feasibility of ET erasable optical memory, the opportunity identified in the Phase I proposal as an alternative to the thermal-excursion requirements of magneto-optic, phase-change and dye-polymer approaches, but has also shown the capability for superior speed and multilevel storage at each location, at room temperature.

The expanded opportunity now presented as a result of the Phase I effort is to develop extremely high density erasable optical storage media and the associated hardware for a new generation of optical computer systems. This approach is no longer seen as mainly a means to resolve the WRITE-ERASE cycle longevity difficulties of previous approaches to erasable optical memory media, but rather as a true analog or multilevel digital storage media which offers an order of magnitude or more storage density as well.

In addition, it is apparent that these materials can also offer significant capabilities in parallel optical processors as well. The fast response and resolution of these materials can offer 10^8 operations per square centimeter in sub-nanosecond timeframes, or greater than 10^{17} operations/cm^2/second, with memory, if desired.

VI. RECOMMENDATIONS FOR PHASE II

What is required in Phase II is to perform specific research and development work on optimizing thin film ET material properties. The fact is that the introduction of a new material technology always requires an extensive effort. While the erasable memory system received much attention by potential investors, the field of optical processing and computations is more abstract to such entities. At any rate, the success in these fields is still determined by the easy manufacturability of thin film ET materials.

As to erasable optical memories, the issues concerning the performance of the ET media have been significantly reduced. Now that the speed, storage time and density issues have been resolved, the remaining main issue is the concern over dual colors; for writing and rewriting in the digital mode, a visible solid state laser is required. There are some frequency-doubled lasers showing up in the market, which will do well since a modest power is required to write. Interestingly, for analog recording, it is possible to use only an IR laser, since one can write "down" from the filled traps state (a simple fluorescent light will charge the traps fully). If the information is not to be modified, but only erased and replaced by new information, a simple IR solid state laser will do the job. (The modulated IR beam writes "down" and the information is read by a low-level steady beam.)

In the memory issue, much discussions took place with experts in the field. For a while, much concern was expressed over the issue of how many times can one read the information before the traps are depleted. It appears that there are about 10^8 electrons trapped in a cubic micron of ET material - the depletion of these depends on the sensitivity of the detector. If a photomultiplier is used (detecting 100 photons per bit), the site could be read a million times. If a simple photodiode is used, the number of reads (before refreshing) may be ten thousand. After these arguments matured, most experts agreed that, in the ET system, it is perfectly possible to rewrite directly behind the read beam - in this fashion, the issue of refresh became mute.

The major issue in the optical memory system is related to the thin film crystallization of the ET material on a disk substrate. At the present time, films could be crystallized on sapphire and glass in the temperature range of 500-600°C. The reduction of these temperatures offers a wider range of possible substrate materials - there is good indication that the temperature could be lowered and flash-heat approaches have not yet been tried at all. At this point, even this issue is unclear; very highly flat blank glass disks were obtained from Japan, indicating that someone believes that glass may be desirous as a disk substrate. (In certain time-compressed, high speed analog applications, a highly balanced glass disk would be the ideal fixed memory disk.)

Much of the physics that has been learned in conjunction with memory applications has a direct bearing on optical processing as well.

The Phase II research and development effort for the erasable ETOM media and processor devices should pursue the following:

A. The primary technical effort should be to complete the thin-film materials and coating technology research and development. Such work will impact both the memory and optical processing fields.

B. The second effort area should be demonstration of operating ET memory disks with storage/processing location resolution at one micron spot size. The aim here should be to achieve specific optical power levels, response times and duration of the WRITE, READ, ERASE and PROCESS inputs to and outputs from the devices in testbeds compatible with expected available external components. This will lead to the stage of prototype process readiness, for transition to Phase III private-sector engineering development of the product, along with estimates of probable manufacturing cost ranges.

C. Based on thin-film availability on substrates, the third effort area should be related to optical processing. The breakthrough development of ET materials offers the possibilities of constructing fast and efficient parallel optical computing devices such as Spatial Light Modulators, Optical Crossbar Switches and Optical Correlators. It has already been established that the material is capable of sub-nanosecond speeds and has resolution in the sub-micron range.

D. The fourth effort area should be taking steps towards a planar microphotonic circuit. The Phase I work has shown that the key to this work is the availability of thin films and their potential integration with deposited-metal parallel waveguides. At this point, the techniques available to modern VLSI microelectronic fabrication could adapted.

Thin film ET materials should be tested as the base for potential active photonic devices, which are required for optical logic functions. Since planar optical waveguides can be formed readily on a substrate, the technical difficulty was the integration of ET thin films. Experimentation that took place in forming ET islands on thin films of metal layers could only be accomplished recently. The Phase I funding and time were insufficient to develop these approaches to a higher level, nevertheless, technological feasibility is apparent. The search for active logic functions should be continued in Phase II.

Successful efforts in these areas would generate the requisite confidence for Phase III success in private-sector development and manufacturing.

VII. REFERENCES

1. R. Rosenberg, et al., "Special Report: The Options Multiply in Mass Storage", Electronics; May 19, 1986.

2. SPIE Conference No. 695, "Optical Mass Data Storage II", San Diego, California, August 18-22, 1986.

3. F. M. Schellenberg, W. Lenth and G. Bjorklund, "Technological Aspects of a Practical Frequency-Domain Optical Storage System", Conference on Lasers and Electro-optics, Paper No. FD4, San Francisco, California, June 13, 1986.

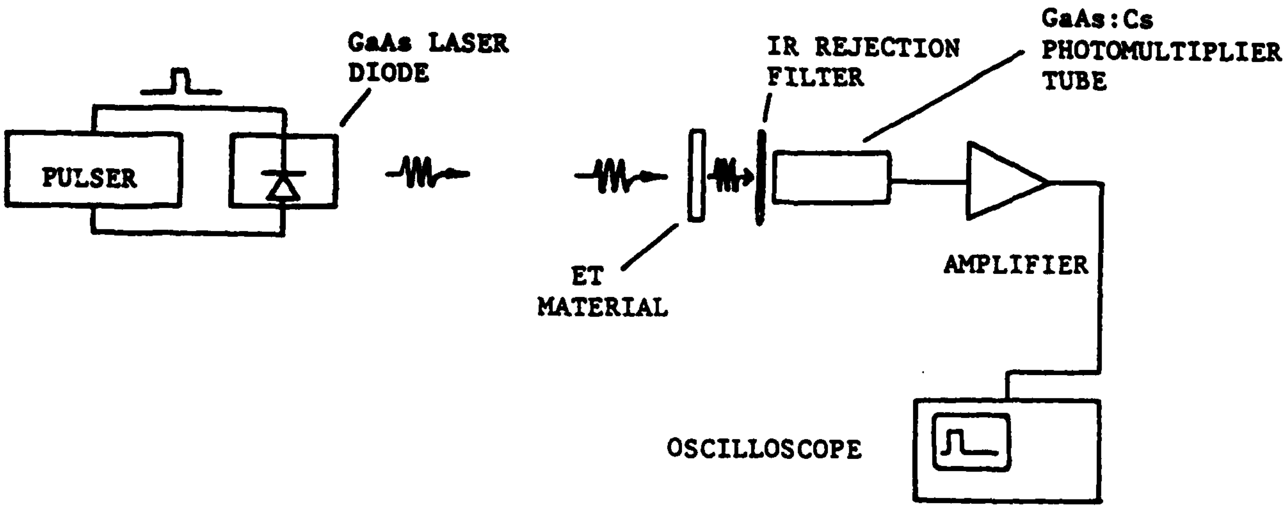


Figure 1. Experimental set-up for measurement of the rise and fall times of the ET materials.

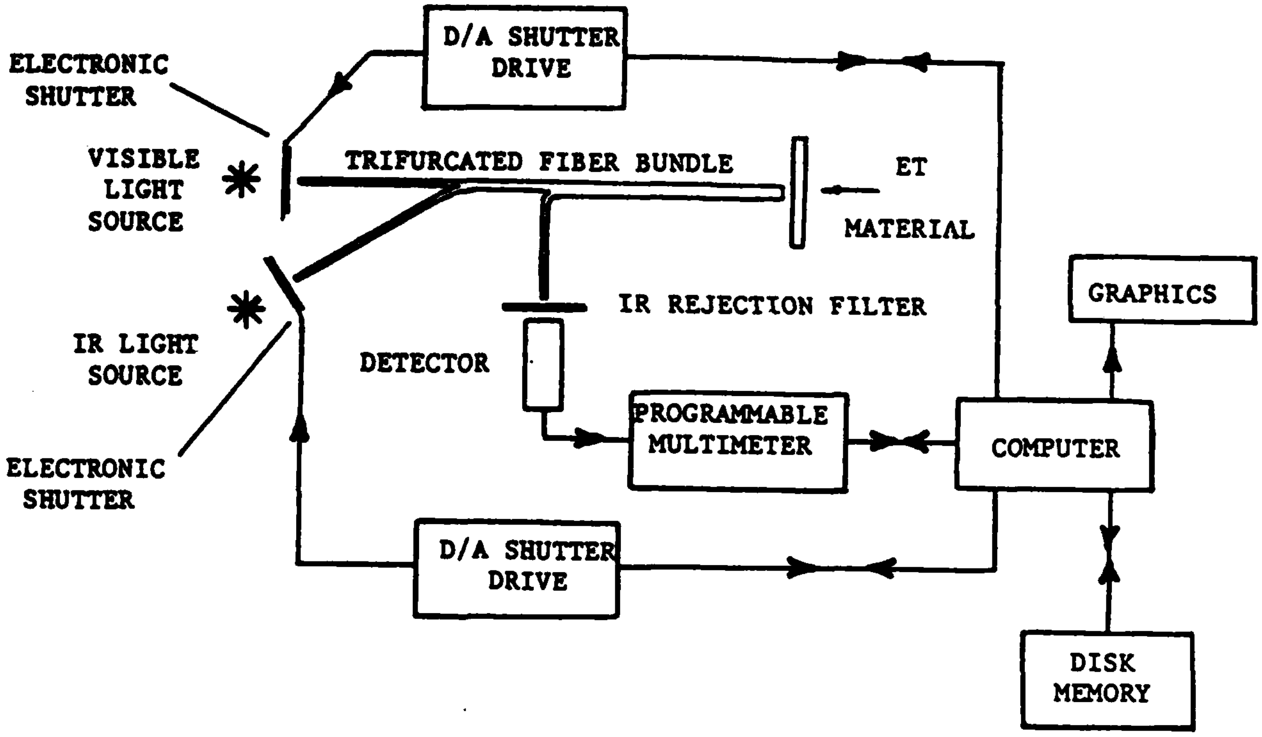


Figure 2. Experimental set-up for the measurement of media erasure.

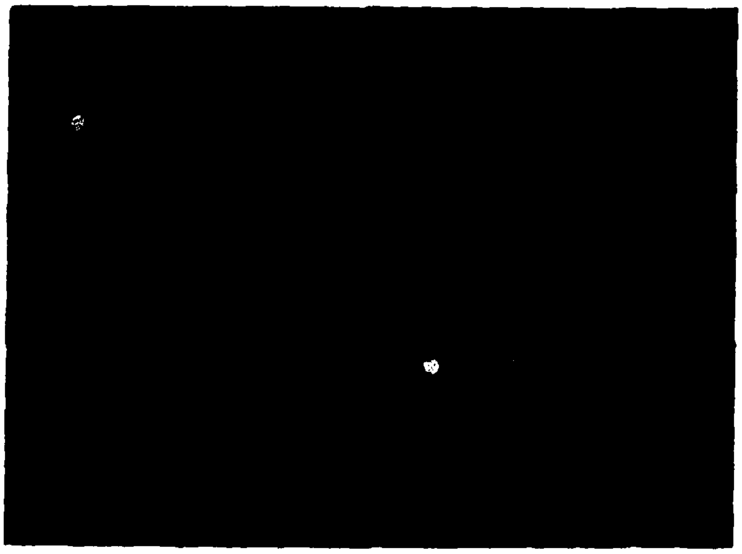


Figure 3. Resolution pattern employed to determine minimum WRITE dimension obtainable. Line widths are 8, 4, 2, 1 and 0.6 microns.

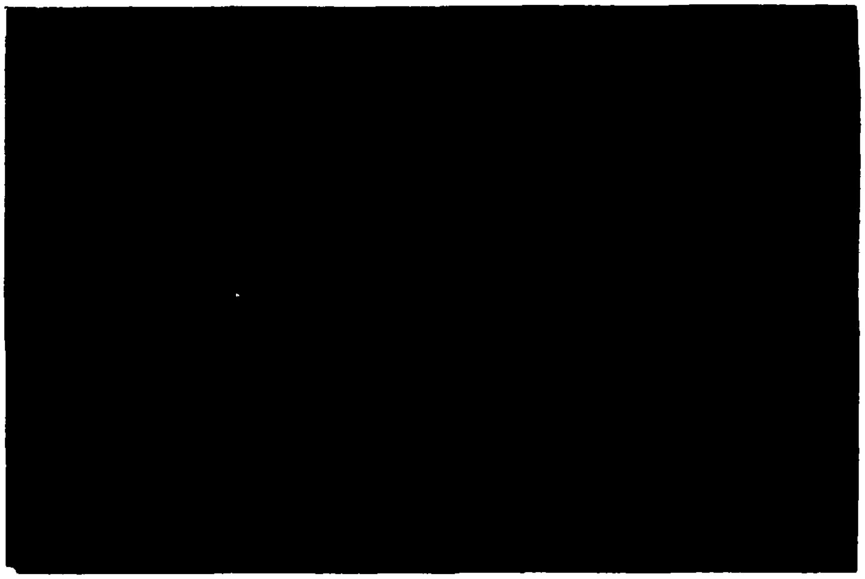


Figure 4. Pattern of islands of ET materials produced on a sapphire substrate. Diameter of islands is approximately 500 microns.

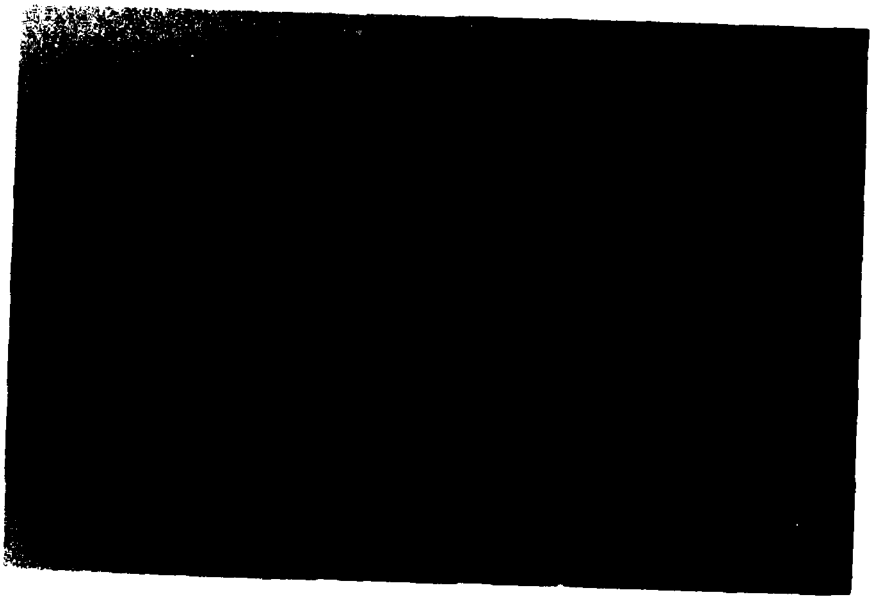


Figure 5. Photomicrograph of thin film ET material deposited on a thin film metal substrate.

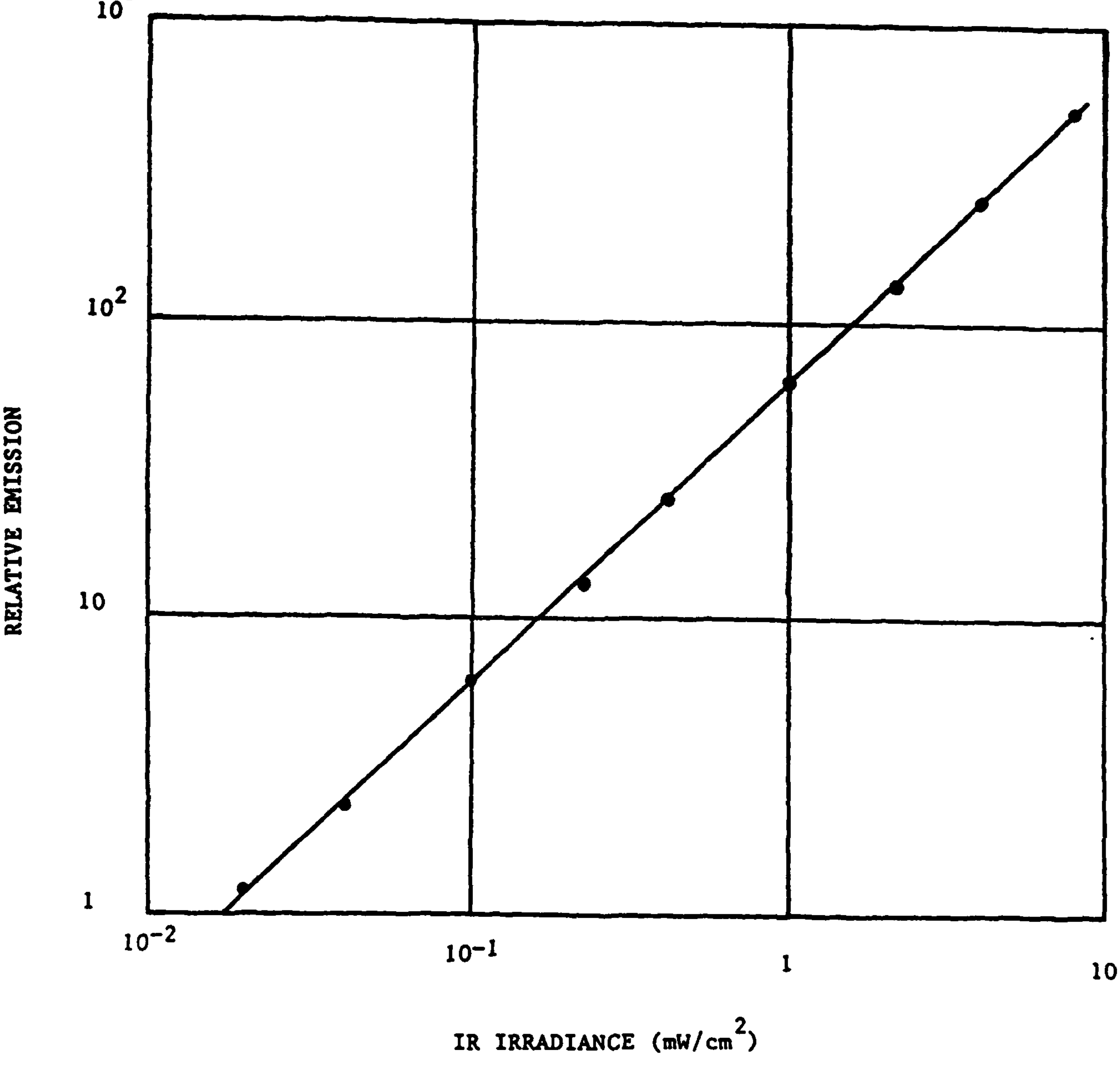


Figure 6. Relative visible emission (READ output) as a function of infrared irradiance (READ input) for sample Q-42.

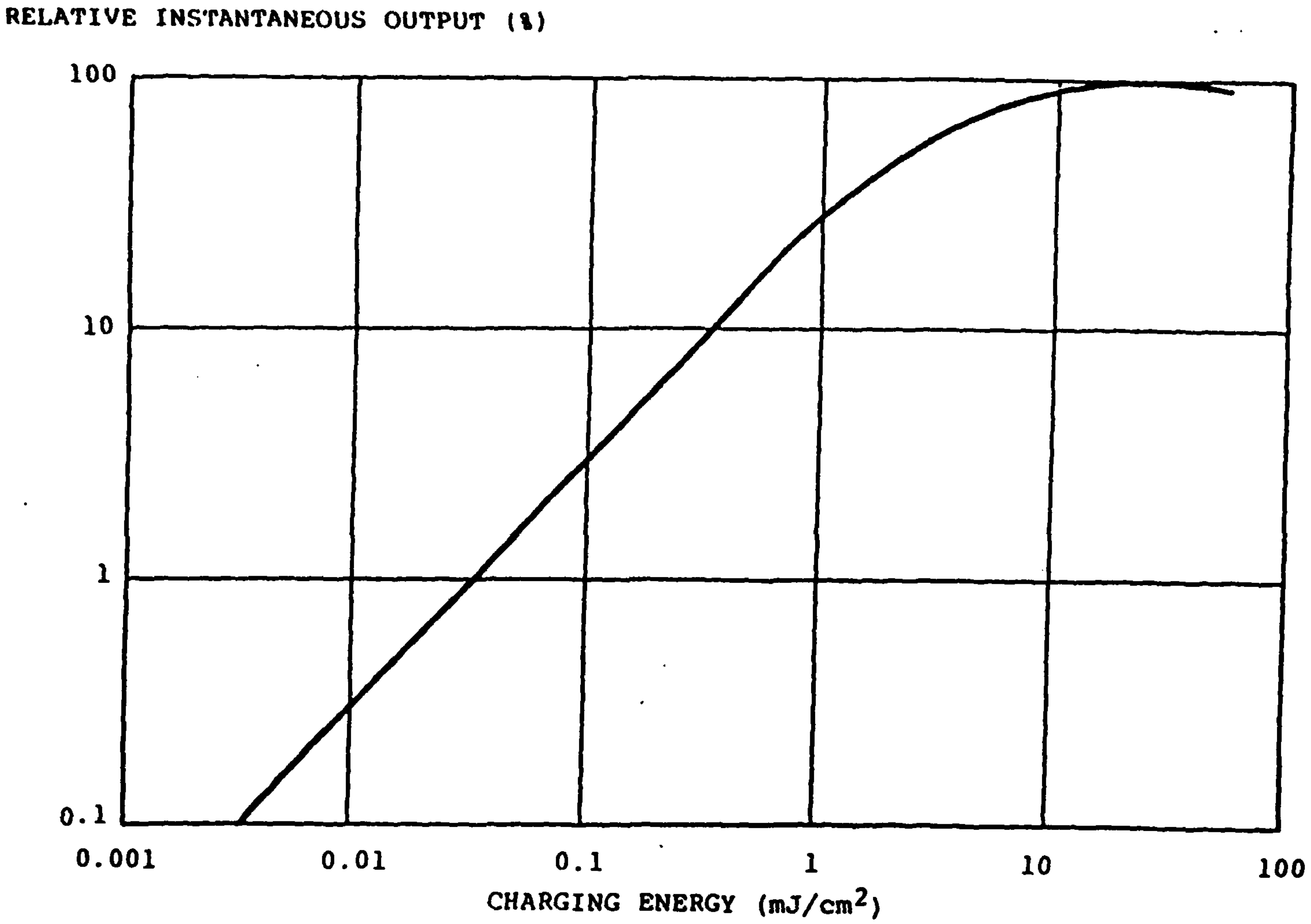


Figure 7. Relative luminescence (READ) output as a function of WRITE energy in sample Q-42 at 22°C.

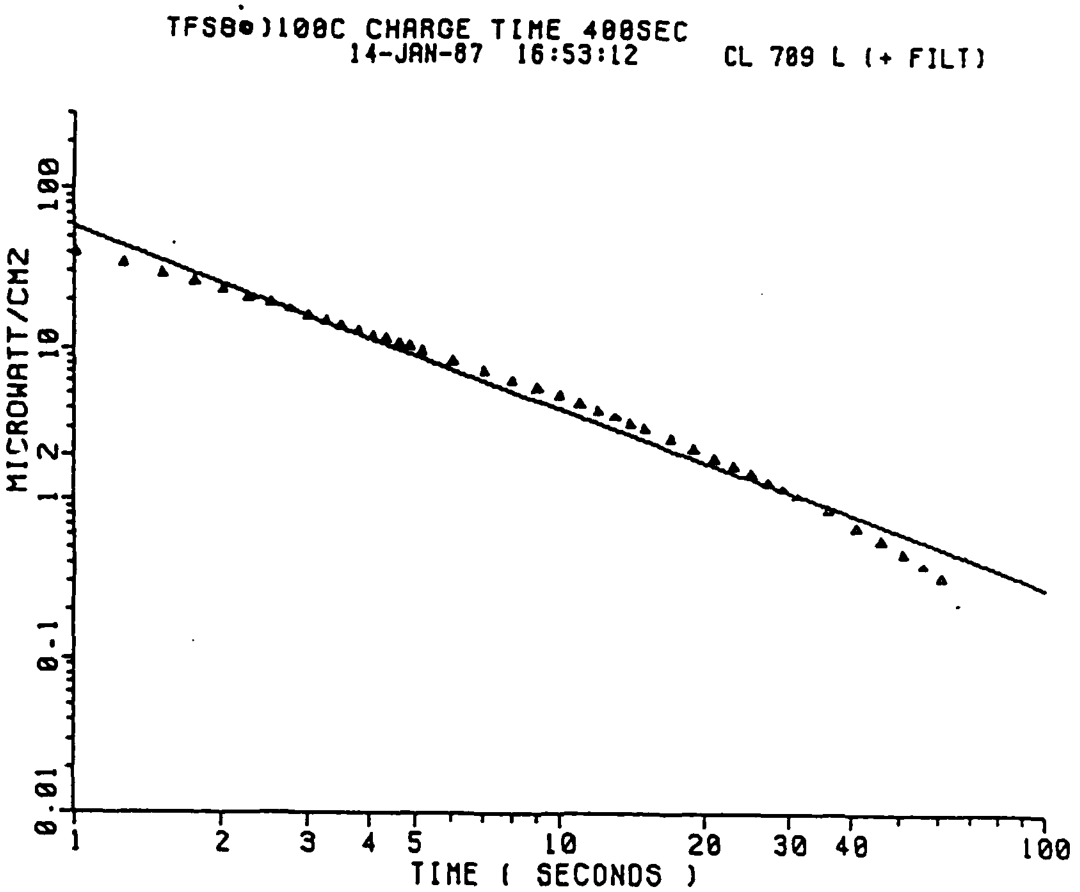


Figure 8. Infrared stimulated discharge (Erasure) of sample Q-42 at 22°C as a function of time.

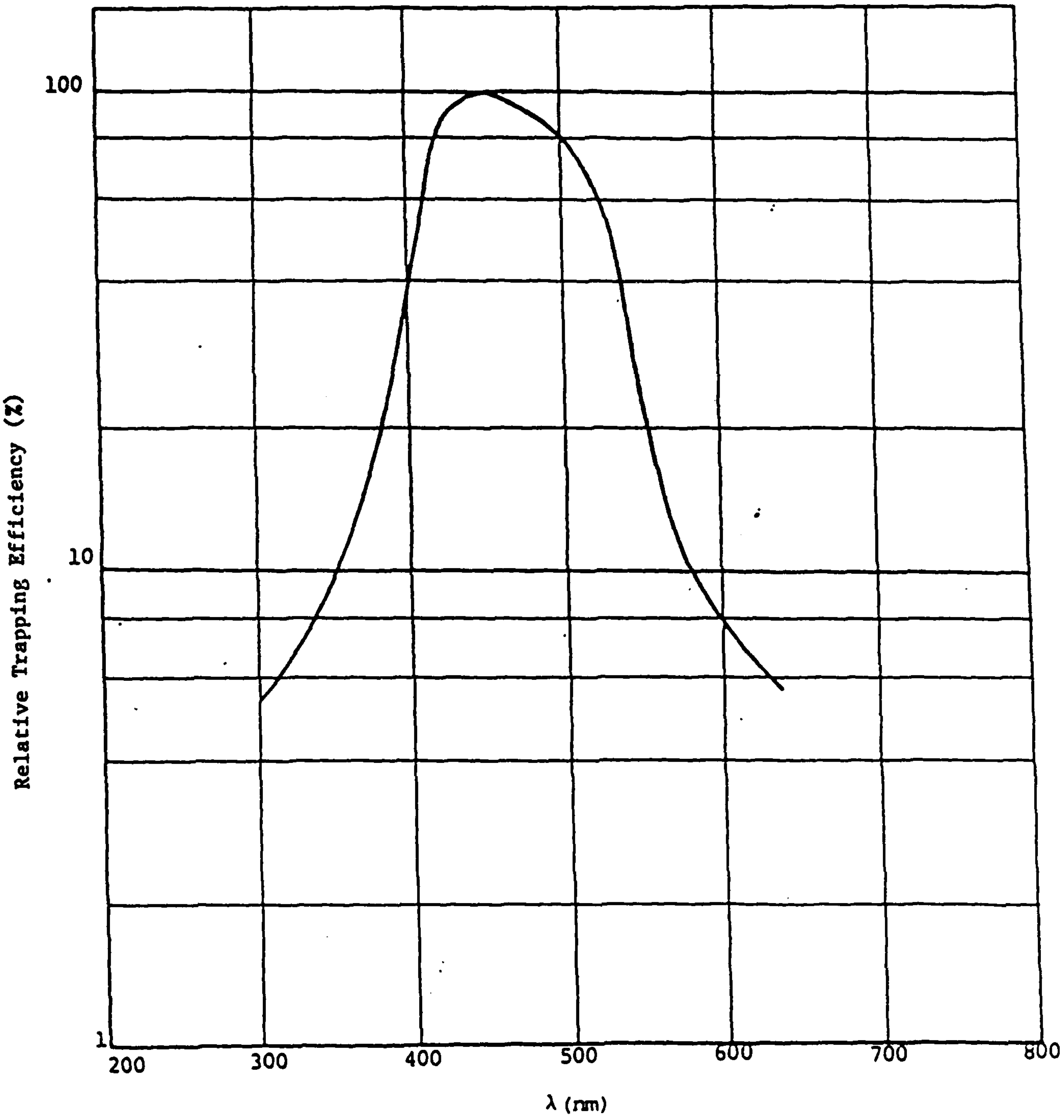


Figure 9. Spectral dependence of the electron trapping (WRITE) efficiency for sample Ω-12.

END

7-87

DTIC