Chemical Engineering Journal Photon energy conversion and management in SrAl_2O_4 : Mn^{2+} , Gd^{3+} for rewritable optical information storage

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Xiaohui Lin, Kaiyuan Deng, Haoyi Wu, Bingsheng Du, Bruno Viana, et al.. Chemical Engineering Journal Photon energy conversion and management in SrAl_2O_4 : Mn^{2+} , Gd^{3+} for rewritable optical information storage. Chemical Engineering Journal, 2021, 420, Part 1, pp.129844. 10.1016/j.cej.2021.129844 . hal-03447653

HAL Id: hal-03447653

<https://hal.science/hal-03447653>

Submitted on 24 Nov 2021

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Photon energy conversion and management in SrAl₁₂O₁₉: Mn²⁺, Gd³⁺ for rewritable optical information storage

--Manuscript Draft--

Manuscript Number:	CEJ-D-21-02606
Article Type:	Research Paper
Section/Category:	Novel Materials for Energy and Advanced Applications
Keywords:	Optical information storage; SrAl ₁₂ O ₁₉ : Mn ²⁺ , Gd ³⁺ ; Optical stimulated luminescence
Abstract:	<p>In the current big data era, the state-of-the-art optical data storage has become a front-runner in the competing data storage technologies. In this work, we proposed an information storage prototype using optical stimulated luminescent phosphor of SrAl₁₂O₁₉: Mn²⁺, Gd³⁺, which converts the photon into trapped electrons and partial releases them in a form of luminescence when it is irradiated by infrared irradiation, rendering an optical information storing ability. The information storage can be realized in both graphical and digital format. In this way, graphical patterns can be stored and rejuvenated by infrared irradiation, and a set of digital data is recorded step by step by a home-make decoding system, completing an optical data reading process. This work provides a practical example for future application of writing-storing-readout-erasing-rewriting integrated optical information storage.</p>

Research highlights

- Optical stimulated luminescence is observed from $\text{SrAl}_{12}\text{O}_{19}:\text{Mn}^{2+}, \text{Gd}^{3+}$.
- The detrapping of electrons is operable by controlling the IR laser.
- An optical information storage that integrate a writing-storing-readout-erasing-rewriting is realized.

Photon energy conversion and management in $\text{SrAl}_{12}\text{O}_{19}:\text{Mn}^{2+}$, Gd^{3+} for rewritable optical information storage

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Abstract

In the current big data era, the state-of-the-art optical data storage has become a front-runner in the competing data storage technologies. In this work, we proposed an information storage prototype using optical stimulated luminescent phosphor of $\text{SrAl}_{12}\text{O}_{19}:\text{Mn}^{2+}, \text{Gd}^{3+}$, which converts the photon into trapped electrons and partial releases them in a form of luminescence when it is irradiated by infrared irradiation, rendering an optical information storing ability. The information storage can be realized in both graphical and digital format. In this way, graphical patterns can be stored and rejuvenated by infrared irradiation, and a set of digital data is recorded step by step by a home-make decoding system, completing an optical data reading process. This work provides a practical example for future application of writing-storing-readout-erasing-rewriting integrated optical information storage.

Keywords: Optical information storage; $\text{SrAl}_{12}\text{O}_{19}:\text{Mn}^{2+}, \text{Gd}^{3+}$; Optical stimulated luminescence

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1. Introduction

The application of photon is usually focused on their conversion to photovoltage that could produce electricity. Then materials for photovoltage need not only photon absorption but also charge carrier transportation. Some materials process an insufficient carriers transporting ability because of defects in crystal may not a candidate for photovoltage conversion, but could be a photon-trapped carriers converter, such as optical stimulated luminescence (OSL) and thermoluminescence (TL).[1-5] Both are the phenomenon where excited charge carriers are trapped by lattice defect and released to luminescent centers accompanied by photon emission. Based on the photon or thermal induced emission, both OSL and TL can realize information storage after patterning by means of carriers' liberation. As listed in Table 1, depending on the amount of trapped depth that reflects the liberation energy, the thermal energy obtained from heat at a mild temperature may be insufficient to activate the trapped carriers in some phosphors [1-9]. Then the pattern can be only rejuvenated when the material is heated to a high temperature. Such prototype is suitable to disposable or confidential communication but not for set-upping the interface connecting to patterns and computers or machine. Instead of thermal energy in TL, the liberation of trapped carriers in OSL is induced by photon energy, which is normally higher than the thermal ones and sufficient to activate carrier trapped in many lattice defects.[1,4] It renders OSL more feasible to rejuvenate the information patterns. Moreover, photons used to activate trapped carriers can be confined temporally and spatially, such as laser pulse, making them feasible to manage the trapped carriers by suitable operation.[7] Therefore, the research on OSL coupled with persistent luminescent phosphors (PLPs) will open a window for information storage since the materials have been widely used as indicators, whose behavior make them as some response signal of sensing, inducing the fluorescence quenching of afterglow fluorescent marker. In particular,

carriers stored in defects PLPs releasable by near infrared (NIR) light excitation, enabling an information storing and managing capability.

In recent decades, aluminate based PSPs have been demonstrated as one of the considerable host available to transition metal ions doping for various kinds of luminescent applications. Due to available deep traps, metal cations doped $\text{SrAl}_{12}\text{O}_{19}$ appears as possible OSL phosphor. Previously, Fe^{3+} and Ce^{3+} ions in $\text{SrAl}_{12}\text{O}_{19}$ demonstrated IR and ultraviolet emission respectively, as well as TL and OSL phenomena [11,12]. However, these emissions are not suitable for lighting with naked eye and furthermore detectors for IR and ultraviolet remain costly. Thus OSL with visible light is more desirable for information storage. The Eu^{2+} ion doped SrAl_2O_4 and CaAl_2O_4 are typical TL materials with visible light emission and persistent luminescence when codoped with Dy^{3+} and Nd^{3+} ions respectively [13,14]. These phenomena are induced with traps depth about 0.5 ~ 0.7 eV, for which trapped carriers can be thermally released at room temperature [15, 16, 17]. Yet, such traps depth is not advantageous to activate OSL phenomenon because most of the trapped carriers are bleached at room temperature. Therefore, the key for searching a suitable OSL material is finding out suitable traps with proper depth that could stably store charge carriers at room temperature.

Here, we demonstrate a green OSL observed from Mn^{2+} doped $\text{SrAl}_{12}\text{O}_{19}$ phosphor, whose trap depth is estimated to be 0.7 ~ 1.1 eV, enabling a carrier storage ability. By co-doping with Gd^{3+} ions, the density of the trapped carriers can be strengthened. After an initial excitation by ultraviolet (UV), carriers are excited to traps and then OSL is induced by IR laser excitation, which provide sufficient photon energy to release carriers from traps. As expected, the number of trapped carriers decreased with

the increase of either time or excitation power, giving raise to the photon energy management. Thus it demonstrates the feasible to a writing-storing-readout-erasing-rewriting process in one set, which is advantageous towards optical data storage. The system with such strategy provides a new prototype for future optical information storage.

2. Experimental Section

2.1 Materials and Preparation of $\text{SrAl}_{12}\text{O}_{19}$: A% Mn^{2+} B% Gd^{3+} phosphors

SrCO_3 (99.95%), Al_2O_3 (99.99%), MnO_2 (99.99%), Gd_2O_3 (99.99%), and H_3BO_3 (99.99%) and methyl methacrylate were purchased from Macklin. $\text{SrAl}_{12}\text{O}_{19}$: A% Mn^{2+} B% Gd^{3+} phosphors were produced through solid state reactions. The initial calcination was performed at 800° C for 12 h. The mixtures were then grounded in an agate mortar for 15 min and finally sintered at 1500 °C for 4 h. Then, $\text{SrAl}_{12}\text{O}_{19}$:A% Mn^{2+} B% Gd^{3+} phosphor were sintered under a reductive atmosphere (20% H_2 +80% N_2). Fig. S1 shows SEM and EDS mapping of $\text{SrAl}_{12}\text{O}_{19}$: 0.5% Mn^{2+} , 5% Gd^{3+} .

2.3 Characterization

The phase identification of as-synthesized phosphors were characterized via X-ray diffractometer (Beijing, Puxi XD-2) using $\text{Cu K}\alpha$ irradiation ($\lambda = 1.5405 \text{ \AA}$) at 36 kV and 20 mA to confirm the presence of $\text{SrAl}_{12}\text{O}_{19}$ as the sole crystalline phase. Room-temperature photoluminescence (PL), PL excitation (PLE) spectra, afterglow spectra and decay curves were measured with a high-resolution spectrofluorometer (UK, Edinburgh Instruments, FLS980) equipped with a 500 W Xenon lamp as an excitation source, with a Hamamatsu R928P visible (VIS) photomultiplier (250–850 nm) as the

detectors. Thermo-luminescence glow curves were measured with a SL08-L meter(Guangzhou-radiation science and technology) by heating the irradiated phosphors from room temperature up to 350 °C.

2.4 Disc-like digital data storage prototype:

The disc-like digital data storage prototype is fabricated with a rotating disc holder, a fixing IR laser and liner array CCD camera. The disc were covered by a photomask of specific information and irradiated for 10 min by UV light (254 nm) and aging for 24 hours. After the removal of UV light and photomask, the desired information was recorded. In this process, 254 nm laser was used as the write-in light source, while 980 laser was used as readout light source to access the information stored in trap in a rotation mode.

3. Results and Discussion

The data storage of OSL is illustrated in 3 basic steps, including writing, reading and erasing. As shown in Fig. 1, traps are created during a high temperature synthesizing process. A small number of charge carriers may exist in traps when the crystal is formed. After excited by ultra- violet light, electrons are excited from the ground state to the excited state of Mn^{2+} , and most of them return to ground state accompanied by photon emission (PL). Some of the excited carriers are transferred to traps through the conduction bands -because of the small gap between the bottom of conduction band and the d levels of Mn^{2+} ions- or by tunneling. After this first filling process, the so-call “writing process” for data storage is completed. When traps are sufficiently deep stored carriers stand stability in such deep traps. In OSL phenomenon, NIR laser excitation could release the carriers from these traps leading to

a readable pattern and generate green emission in $\text{SrAl}_{12}\text{O}_{19}: 0.5\%\text{Mn}^{2+}, 5\%\text{Gd}^{3+}$ phosphor. After switching-off the NIR laser, persistent luminescence occurs for long time [10, 18]. During this procedure, the recorded photons also serve as OSL response for data reading. The traps could be bleached by returning all electrons to luminescence in the case of sufficient excitation power or excitation time, showing a data erasing ability. Then the phosphor could be rewritten, going to another storage cycle.

Fig. 1 Diagrammatic rewritable information storage based on OSL.

Fig. 2 (a) Schematic diagram of SrAl₁₂O₁₉ structure and coordination environments of the Al³⁺ cations. (b) XRD patterns for SrAl₁₂O₁₉: 0.5% Mn²⁺, 5% Gd³⁺ and SrAl₁₂O₁₉: 0.5% Mn²⁺ phosphors. (c) Photoluminescence spectrum and photoluminescence excitation spectrum of SrAl₁₂O₁₉: 0.5% Mn²⁺, 5% Gd³⁺ and SrAl₁₂O₁₉: 0.5% Mn²⁺ phosphors; (d) Variable temperature PL emission spectra of SrAl₁₂O₁₉: 0.5% Mn²⁺, 5% Gd³⁺ phosphor under 424 nm excitation wavelength. (e) Afterglow intensity monitored at 520 nm of Mn²⁺ in SrAl₁₂O₁₉: 0.5% Mn²⁺, 5% Gd³⁺ phosphor after being pre-irradiated by 30 W UV lamp for 10 min.

The SrAl₁₂O₁₉: 0.5% Mn²⁺ and SrAl₁₂O₁₉: 0.5% Mn²⁺, 5% Gd³⁺ phosphors were employed to realize the re-writable OSL prototype. As confirmed by XRD shown in Fig. 2b, pure SrAl₁₂O₁₉ phase is observed according to the JCPDS standard card (No. 26-0976) [19]. The structure of the phosphor has a hexagonal magnetoplumbite structure with P63/mmc space group (with lattice parameters a=0.5585nm, b=0.5585nm, and c=2.207nm) (Fig. 2a) [20, 21]. The potential lattice site for Mn²⁺ substitution is the Al³⁺ ions which occupy five different lattice sites, in which four sites have O²⁻ ligands, constituting [AlO₄] tetrahedral structure. As expected with such low content, the structure change induced by the doping of Mn²⁺ and Gd³⁺ is not detectable [22]. The PL spectra of SrAl₁₂O₁₉:

0.5% Mn²⁺ and SrAl₁₂O₁₉: 0.5% Mn²⁺, 5%Gd³⁺ excited at 424nm irradiation are shown in Fig. 2c. In the SrAl₁₂O₁₉, Mn²⁺ coordinated with the tetrahedron produces a single band green emission centered at 520 nm which is attributed to d-d transition (⁴T₁ → ⁶A₁) of Mn²⁺. A codoping strategy of Gd³⁺ is proposed to enhance the afterglow intensity, since Gd³⁺ has been proven its ability to control the trap distribution and to improve the persistent duration. The codoping of Gd³⁺ ion does not affect the other spectroscopic configuration of Mn²⁺ [23]. The PLE spectra showed five distinct peaks centered at 358, 382, 424 and 450 (Fig. 2c) which are assigned to the transitions of Mn²⁺ from ground levels ⁶A₁ (⁶S) to ⁴E (⁴D), ⁴T₂ (⁴D), [⁴A₁ (⁴G), ⁴E (⁴G)] and ⁴T₂ (⁴G), excited levels [24, 25]. Fig. 2d shows the PL spectra of the SrAl₁₂O₁₉: 0.5%Mn²⁺, 5%Gd³⁺ phosphor under the excitation of 424 nm in the temperature range of 50-300°C with a step of 50°C. It is observed from the spectra that the luminescence intensity decreases with the increment of temperature due to the thermal quenching of the excitation state of Mn²⁺. The decrease of the intensity may be due to the existence of traps that could store the charge carriers during excitation and thermally release them to compensate the loss of excited carriers after excitation, thus maintaining the good performance of the high temperature spectrum. As a small decrease of about 16.6% is obtained for the PL intensity when the temperature rises to 300°C (Fig. S2), this confirms favorable thermal stability behavior favourable for data storage to prevent undesirable loss. Among the phosphors prepared within this work with different Gd³⁺ contents (Fig. S3a, S3b), the SrAl₁₂O₁₉: 0.5%Mn²⁺, 5% Gd³⁺ sample features the higher intensity and longer afterglow. After ceasing the irradiation of 254 nm UV light and by monitoring the 520 nm emission, SrAl₁₂O₁₉: 0.5%Mn²⁺, 5%Gd³⁺ exhibits a persistent luminescence longer than 10 h) (Fig. 2e). Such afterglow is also detectable after NIR laser post-irradiation, showing typical OSL [26-28].

Fig. 3 (a) The phosphor $\text{SrAl}_{12}\text{O}_{19}: 0.5\%\text{Mn}^{2+}, 5\%\text{Gd}^{3+}$ of TL curve measured at 10 s after the stoppage of irradiation. The phosphor was pre-irradiated by a 30 W 254 nm UV lamp for 1, 2, 5 and 10 min, respectively. (b) TL curves over 50–350 $^{\circ}\text{C}$ acquired at 10 s, 3 min, 60 min, 8 h and 24 h after the stoppage of irradiation. The phosphor $\text{SrAl}_{12}\text{O}_{19}: 0.5\%\text{Mn}^{2+}, 5\%\text{Gd}^{3+}$ were pre-irradiated by a 30 W 254 nm UV lamp for 10 min; $\text{SrAl}_{12}\text{O}_{19}: 0.5\%\text{Mn}^{2+}, 5\%\text{Gd}^{3+}$ sample by monitoring 520 nm emission upon periodic excitation with (c) 980 nm, (d) 1064nm and (e) 1550nm lasers. Before the measurements, the phosphor was pre-irradiated using a UV light for 10 min, and then the measures were taken at 24 h after the stoppage of irradiation.

Fig. 3a-b show the irradiation-time-dependent and interval-time-dependent TL curves of $\text{SrAl}_{12}\text{O}_{19}: 0.5\%\text{Mn}^{2+}$ and $\text{SrAl}_{12}\text{O}_{19}: 0.5\%\text{Mn}^{2+}, 5\%\text{Gd}^{3+}$ phosphors. Co-doping with Gd^{3+} modulates the trap status and intensity in deep (Fig. S4). With the increment of pre-irradiation time and interval time, no any TL peak-shift is observed but the intensity change in all of the TL spectra is obvious for both phosphors. The phosphor of $\text{SrAl}_{12}\text{O}_{19}: 0.5\%\text{Mn}^{2+}, 5\%\text{Gd}^{3+}$ exhibited a wide band from room temperature to 350 $^{\circ}\text{C}$, including three strong peaks at 75 $^{\circ}\text{C}$, 141 $^{\circ}\text{C}$, 172 $^{\circ}\text{C}$ and 281 $^{\circ}\text{C}$ (Fig. S5),

corresponding to three kinds of traps that possibly contributing their trapped carriers to the afterglow. The depth of traps E was roughly estimated by using the empirical Urbach formula [29, 30]

$$E = \frac{T_m}{500}$$

where E is trap depth, T_m is the temperature (K) of each TL curves peak. Then, estimated trap depths of $\text{SrAl}_{12}\text{O}_{19}: 0.5\%\text{Mn}^{2+}, 5\% \text{Gd}^{3+}$ are 0.696 eV, 0.828 eV, 0.89 eV and 1.108 eV respectively. This indicates that $\text{SrAl}_{12}\text{O}_{19}: 0.5\%\text{Mn}^{2+}, 5\% \text{Gd}^{3+}$ phosphor provide not only a trap at ~0.7 eV depth to generate afterglow at room temperature, but also the relatively deep ones (at about 1eV) to store the carriers for OSL applications [31-33].

As shown in Fig. 3c-e, the OSL is observed and it could be repeatedly rejuvenated by the excitation of near IR light. After switching-off the light, the intensity of OSL rapidly falls to a certain value and then becomes stable. Fig. 3c shows the OSL decay curve of the $\text{SrAl}_{12}\text{O}_{19}: 0.5\%\text{Mn}^{2+}, 5\% \text{Gd}^{3+}$ sample by monitoring the 520 nm emission when an 980 nm laser with periodic on/off was applied as the stimulation source. Obviously, OSL can be repeatedly recovered upon excitation with a 980 nm laser. After turning off the laser, the OSL rapidly falls down to a certain value and then decays slowly. Notably, the corresponding emission intensity in the OSL decay curve after switching-off the laser is always higher than that in the normal decay one. All these results indicate that deep traps can be release through the conduction band by 980 nm photons and there is a trap redistribution as part of these traps are recaptured by the shallow traps while others recombine at Mn^{2+} emitting centers [34,35]. As revealed in Fig. 3d and 3e, similar OSL is observed when the 1064 nm and 1550 nm NIR lasers excitation is applied as excitation source. Indeed optical and thermal detrapping could require different energy values, but according to the excitation energy, electrons in the shallow traps present different

kinetics according to the laser wavelength. This could be potentially used in information storage because of highly sensitive OSL to NIR light. For example, optical patterns can be rejuvenated.

Fig. 4 Images were taken after the first, second, third, and 10th irradiation 5 s to the samples with 980 nm (a-b) and 1064nm (e-h) lasers, respectively, the interval time of each laser irradiation is 1h. The phosphor was pre-irradiated for 10 min under a 25 W 254 nm UV lamp, and photographed 24 h after the irradiation stopped.

As shown in Fig. 4, S6 for the schematic of the composite, the composite flat prepared by co-mixing $\text{SrAl}_{12}\text{O}_{19}: 0.5\%\text{Mn}^{2+}, 5\%\text{Gd}^{3+}$ and PMMA in a weight ratio of 1:2 is excited by patterning a mask on it. The pattern exposure under UV light undergo an information writing process. After aging and fading for 24 hours, there is no more emission. Due the deep traps storage, the patterning area re-appears after scanning by NIR laser at 980 or 1064 nm. The photon emission in the patterns could last for several seconds and vanishes again after switching-off the laser. This process is repeatable for more than 10

times, until all traps are emptied. Notice that the standard sample without UV pre-excitation does not emit any detectable photon under NIR light [36]. To go further towards information storage, the following set-up was used.

Fig. 5 (a) Schematic illustration of optical disc; (b) The result of decoding the optical information; (c) The disc of optical storage; (d-k) Dynamic optical information reading process.

The information storage can be also realized in digital format, in which data is represented by 0 and 1.

As exhibited in Fig. 5a, a disc-like digital data storage prototype is fabricated with a rotating disc holder, a fixing IR laser and liner array CCD camera. The matrix is made by coating $\text{SrAl}_{12}\text{O}_{19}$:

0.5% Mn^{2+} , 5% Gd^{3+} with PMMA on a disc. The unit of the information bit is defined by a certain area depending on the rotation speed. Then units emitting photons are employed to indicate 1 while those without photon emission indicate 0. As illustrated in Fig. 5 b-k, the data can be written by patterning the disc using 254 nm UV excitation. After switching-off the excitation, the sequence of the data units can be read by using CCD camera in a rotating process. Prior to the reading process, the data units is irradiated by an IR laser, those pre-excited by UV are read as 1, otherwise are read as 0. Then a set of digital data is recorded step by step by a home-make decoding system. For example in Fig. 5 b~k, an 8-bit data 10010101 was read and shown in the system correctly, completing an optical data reading process. Such reading process was realized by recording both OSL and its persistent luminescence. In addition, the data capacity is determined by the spatial size of the units. Fig. S7 shows the minimum possible size of the patterns that could be implemented by 6mm. Normally the smaller of the size renders the higher pattern density and thus a higher data capacity.

Fig. 6 a) Laser power (980 nm, 2.4W), TL curves are obtained by irradiating samples at 0s, 7s, 30s, 60s, 300s, 600s and 900s respectively. The $\text{SrAl}_{12}\text{O}_{19}: 0.5\%\text{Mn}^{2+}, 5\% \text{Gd}^{3+}$ phosphor is pre-irradiated by a 30 W 254 nm UV lamp for 10 min; b) TL intensity of fig. 6a and its fitting curve when the temperature is 163°C; c) $\text{SrAl}_{12}\text{O}_{19}: 0.5\%\text{Mn}^{2+}, 5\% \text{Gd}^{3+}$ sample by monitoring 520 nm emission upon periodic excitation with 980 nm lasers (5s and 10min). Before measurements, the phosphor was pre-irradiated using a UV light for 10 min, and then the measures were taken at 24 h after the stoppage of irradiation. d) TL curves of samples irradiated by different laser powers (0.5w, 1w, 1.5w 2w and 2.4w) for 10min. The phosphor $\text{SrAl}_{12}\text{O}_{19}: 0.5\%\text{Mn}^{2+}, 5\% \text{Gd}^{3+}$ were pre-irradiated by a 30 W 254 nm UV lamp for 10 min; e) TL intensity of fig. 6d when the temperature is 163°C; f) Dynamic optical information erasing process.

The data on disc can be erased by increasing the irradiation time of IR laser. In this process, the number of the trapped carriers is kept decreasing until the OSL or TL is not readable. Fig. 6a shows TL curves of the sample which is sufficiently excited by UV and erased by IR laser irradiation for 0s, 7s, 30s, 60s, 300s, 600s and 900s respectively. With the increment of irradiation time, the intensity of TL progressively decreases. The TL intensity can be fitted by the double-exponential formula (Fig. 6b and Eq S2 in supporting information), by monitoring 520 nm emission upon periodic excitation with 980 nm lasers (5s and 10min). When the phosphor is irradiated with a 980nm laser for 10 min, no optical signal of afterglow delay is detected and used as a reference line (Fig. 6c). Moreover, the data can be also erased by increasing the power of laser. Fig. 6d shows TL curves of samples irradiated by different laser power (0.5w, 1w, 1.5w 2w and 2.4w) for 10 min. With the increase of laser power, TL intensity decreases gradually. TL intensity is proportional to the strength (fig. 6e), indicating a fast data erasable process during the optical information storage. For example, as shown in Fig. 6f, the optical data in the highest bit units of 10010101 is erased. Then data become 00010101. Using a moderate power laser, the digital data is erasable in high-speed disc rotation, getting ready for another writing process. This was an example of the possible use of the system for memory applications.

4. Conclusions

In summary, we proposed an novel information storage prototype using OSL phosphor which was realized by $\text{SrAl}_{12}\text{O}_{19}:\text{Mn}^{2+}, \text{Gd}^{3+}$. By rational testing of the PL, OSL, and TL, the scientific mechanism of information storage prototype has been expounded and exhibited entirely. PL with afterglow and OSL at 520 nm emission wavelength were observed. Due to the deep traps in the materials, the OSL was induced by NIR light excitation (980nm, 1064nm, 1550nm) by taking out parts of the trapped carriers, rendering a readable and rewritable data storage ability by photon energy conversion and management. For the first time, a proof-of-concept study to develop an OSL material with a disc-like digital data storage prototype is fabricated with a rotating disc holder and completing an optical data reading process. In addition, the data on disc can be erased by increasing the irradiation time of IR laser. Such reading process was realized by recording both OSL and its persistent luminescence. It provides a feasible example for future writing-storing-readout-erasing-rewriting integration optical information storage application.

Acknowledgments

This work was financially supported by the National Natural Science Foundation of China (Grant No. 51972065).

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Table

Table 1. Potential phosphors for optical information storage

Materials	Erasable	Trap depths (eV)	Luminous band (nm)
CaS: Eu ²⁺ , Sm[1]	---	0.76	500-800
LiTaO ₃ : Bi[2]	---	0.64-0.76	300-600
NaCa ₂ GeO ₄ F: Mn, Yb[3]	---	0.52-1.15	500-800
(Sr _{1-x} Ba _x)Si ₂ O ₂ N ₂ : Eu/Yb, Dy[4]	thermal	1.12-1.31	450-750
LiGa ₅ O ₈ : Cr[5]	---	0.8-0.95	700-800
Zn ₃ Ga ₂ SnO ₈ : Cr[6]	---	1.25	650-800
Y ₃ Al _{5-x} Ga _x O ₁₂ : Ce, V[7]	thermal	1.2-1.6	450-750
YAGG: Er, Cr[8]	---	0.6-0.82	600-1700
Sr ₃ SiO ₅ : Eu, Dy[9]	thermal	0.6-1.09	450-700
ZnGa ₂ O ₄ :Cr [10]	Thermal/Photon	0.6-1	650-750

Figure captions

Fig. 1 Diagrammatic rewritable information storage based on OSL.

Fig. 2 (a) Schematic diagram of $\text{SrAl}_{12}\text{O}_{19}$ structure and coordination environments of the Al^{3+} cations. (b) XRD patterns for $\text{SrAl}_{12}\text{O}_{19}: 0.5\%\text{Mn}^{2+}, 5\% \text{Gd}^{3+}$ and $\text{SrAl}_{12}\text{O}_{19}: 0.5\%\text{Mn}^{2+}$ phosphors. (c) Photoluminescence spectrum and photoluminescence excitation spectrum of $\text{SrAl}_{12}\text{O}_{19}: 0.5\%\text{Mn}^{2+}, 5\% \text{Gd}^{3+}$ and $\text{SrAl}_{12}\text{O}_{19}: 0.5\%\text{Mn}^{2+}$ phosphors; (d) Variable temperature PL emission spectra of $\text{SrAl}_{12}\text{O}_{19}: 0.5\%\text{Mn}^{2+}, 5\% \text{Gd}^{3+}$ phosphor under 424 nm excitation wavelength. (e) Afterglow intensity monitored at 520 nm of Mn^{2+} in $\text{SrAl}_{12}\text{O}_{19}: 0.5\%\text{Mn}^{2+}, 5\% \text{Gd}^{3+}$ phosphor after being pre-irradiated by 30 W UV lamp for 10 min.

Fig. 3 (a) The phosphor $\text{SrAl}_{12}\text{O}_{19}: 0.5\%\text{Mn}^{2+}, 5\% \text{Gd}^{3+}$ of TL curve measured at 10 s after the stoppage of irradiation. The phosphor was pre-irradiated by a 30 W 254 nm UV lamp for 1, 2, 5 and 10 min, respectively. (b) TL curves over 50–350 °C acquired at 10 s, 3 min, 60 min, 8 h and 24 h after the stoppage of irradiation. The phosphor $\text{SrAl}_{12}\text{O}_{19}: 0.5\%\text{Mn}^{2+}, 5\% \text{Gd}^{3+}$ were pre-irradiated by a 30 W 254 nm UV lamp for 10 min; $\text{SrAl}_{12}\text{O}_{19}: 0.5\%\text{Mn}^{2+}, 5\% \text{Gd}^{3+}$ sample by monitoring 520 nm emission upon periodic excitation with (c) 980 nm, (d) 1064nm and (e) 1550nm lasers. Before the measurements, the phosphor was pre-irradiated using a UV light for 10 min, and then the measures were taken at 24 h after the stoppage of irradiation.

Fig. 4 Images were taken after the first, second, third, and 10th irradiation 5 s to the samples with 980 nm (a-b) and 1064nm (e-h) lasers, respectively, the interval time of each laser irradiation is 1h. The phosphor was pre-irradiated for 10 min under a 25 W 254 nm UV lamp, and photographed 24 h after the irradiation stopped.

Fig. 5 (a) Schematic illustration of optical disc; (b) The result of decoding the optical information; (c) The disc of optical storage; (d-k) Dynamic optical information reading process.

Fig. 6 a) Laser power (980 nm, 2.4W), TL curves are obtained by irradiating samples at 0s, 7s, 30s, 60s, 300s, 600s and 900s respectively. The $\text{SrAl}_{12}\text{O}_{19}: 0.5\%\text{Mn}^{2+}, 5\%\text{Gd}^{3+}$ phosphor is pre-irradiated by a 30 W 254 nm UV lamp for 10 min; b) TL intensity of fig. 6a and its fitting curve when the temperature is 163°C; c) $\text{SrAl}_{12}\text{O}_{19}: 0.5\%\text{Mn}^{2+}, 5\%\text{Gd}^{3+}$ sample by monitoring 520 nm emission upon periodic excitation with 980 nm lasers (5s and 10min). Before measurements, the phosphor was pre-irradiated using a UV light for 10 min, and then the measures were taken at 24 h after the stoppage of irradiation. d) TL curves of samples irradiated by different laser powers (0.5w, 1w, 1.5w 2w and 2.4w) for 10min. The phosphor $\text{SrAl}_{12}\text{O}_{19}: 0.5\%\text{Mn}^{2+}, 5\%\text{Gd}^{3+}$ were pre-irradiated by a 30 W 254 nm UV lamp for 10 min; e) TL intensity of fig. 6d when the temperature is 163°C; f) Dynamic optical information erasing process.