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THERMOLUMINESCENCE (TL) RESPONSE OF GAMMA-IRRADIATED RAW MATERIAL AND THE INFLUENCE OF DOPING BY DIFFERENT ACTIVATORS

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خاصية الوهج الوميضي الحراري لبعض المواد الخام المشععة بأشعة جاما وتأثير تطعيمها ببعض المحفزات

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في هذا البحث تمت دراسة خاصية الوهج الوميضي الحراري لبعض عينات من أسمنت الكلنكر ، بالإضافة إلى طور الفيريت لتلك الخامات . كما درس تأثير تطعيمها ببعض المحفزات مثل فلوريد الكالسيوم ، كلوريد الكالسيوم ، فلوريد الليثيوم ، فلوريد الماغنسيوم ، وكذلك أكسيد الزنك . ولقد كانت تلك العينات تحضر معمليا ، حيث أن أسمنت الكلنكر كان يعالج حرارياً عند درجة ١٤٥٠ْم لمدة نصف ساعة ، أما طور الفيريت فكان يعالج عند درجة ١٣٢٠ْم لمدة نصف ساعة أيضاً ، كما أمكن الحصول على منحنيات الوهج الحراري لهذه المواد ، ووجد أن لها منحنيين أساسيين عند درجة ٩٠ْم ، ٢٤٠ْم ، وعند تطعيمها ببعض الشوائب فإن حساسيتها الوميضية تزداد لكلا المنحنيين .

ولقد عينت درجة تركيز الشوائب التي تعطي أعلى كفاءة ، ووجد أن ١,٥٪ كلوريد الكالسيوم ، ١٪ فلوريد الليثيوم تعطي أعلى حساسية للوهج الوميضي الحراري . كما وجد أيضاً أن تلك الحساسية تزيد بزيادة الجرعة الإشعاعية لأشعة جاما . وقد استنتج أن أسمنت الكلنكر وطور الفيريت الخاص به والمحتوي على نسبة معينة من كلوريد الكالسيوم وفلوريد الليثيوم لها حساسية فائقة لأشعة جاما .

Keywords : Cements, Dose-response relationship, Ferrites, Gamma radiation, Glow curve radiation doses, Thermoluminescence.

ABSTRACT

Thermoluminescence of raw materials has been frequently employed to determine the exposure dose as well as effective energy of gamma radiation. In this work, thermoluminescence (TL) properties of cement clinker (C) and its ferrite phase (F) doped with different activators such as CaF_2, $CaCl_2$, LiF, MgF_2 and Zn0 were studied. The phosphors were prepared by sintering method at 1450°C for half an hour for cement clinker and at 1320°C for half an hour for its ferrite phase.

The obtained glow curves for both cement clinker and its ferrite phase have two major peaks at about 90°C and 248°C. The addition of impurities enhances the TL intensity of the two peaks. The optimum concentration of the dopant which gives maximum TL sensitivity is determined. The most effective dopants which increase the TL sensitivity of the phosphors are $CaCl_2$ and LiF at concentration 1.5% and 1% by wt respectively. It is found that the TL intensity of each peak increases with increasing radiation doses. It is found that cement clinker and its ferrite phase containing $CaCl_2$ and LiF are highly sensitive to gamma radiation.

INTRODUCTION

Thermoluminescence (TL) of naturally occuring materials is at present widely used in many fields of dosimetry due to their properties that are now known from other classical dosimetry systems [1-2]. The work of Donald *et al.* on the effect of activators on cement clinker and its ferrite phase demonstrated that the impurities can enter the structural holes of cement clinker and its ferrite phase [3].

Dixon et al. studied the TL properties of $SrSO_4$ and Ba SO_4 doped with Dy and Tm [4]. They found that $SrSO_4$: Dy and $SrSO_4$: Tm exhibit the same glow curve, both having a major glow peak at 140°C. The TL-response of concrete was examined by Franseschi *et al* [5]. They used fine powder of concrete for measuring high radiation levels. In case of radiation accident, the fine powder of concrete may help in estimating the high radiation doses. This material is called an accidental dosimetry.

This paper deals with the TL properties of cement clinker and its ferrite phase doped with certain activators such as ($CaCl_2$, CaF_2, MgF_2, LiF and ZnO). These activators were added to the investigated samples due to the presence of metal halides and some oxides in limestone and clay which are the starting raw material in preparing cement clinker in industry.

The thermoluminescence of metal halides and ZnO activated cement clinker or its ferrite phase has not been studied. The present work is conducted to study the influence of some activators and their concentrations on the TL properties of cement clinker and its ferrite phase. Finally, if these phosphors exhibited a high sensitivity they might prove useful for TL dosimetry in application.

EXPERIMENTAL

The cement clinker was prepared from pure oxides mixture of CaO (79.7%), SiO_2 (14.5%), Al_2O_3 (3.3%) and Fe_2O_3 (2.5%). The raw mixture was heated up to 1450°C for half an hour and then cooled rapidly to room temperature. The ferrite phase was prepared from pure oxides mixture of CaO (66%), Al_2O_3 (17%) and Fe_2O_3 (17%).

Different TL activators such as CaF_2, $CaCl_2$, MgF_2 and ZnO have been added individually to another raw mixtures of cement clinker and its ferrite phase. The concentration of these activators in the host materials are ranging between 0.5 wt % and 3 wt %. The samples were then fired at 1450 °C or 1320 °C for half an hour and then rapidly cooled to room temperature.

The samples were irradiated by Co-60 gamma ray cell with dose rate 4.83 R/sec. After irradiation to different doses, the samples were kept in refrigerator to prevent thermal decay. For TL measurement, the TL reader used is the pico processor Harshaw model 2080 (installed from Harshaw Chem. Co.). It is connected with pen chart recorder for plotting the glow curves. The measurements were carried out at maximum tray temperature 400 °C with a heating rate of 6.5 °C/s. The mass of each sample is 5 mg and in general 5 samples were counted per exposure. The TL signals were normalized and the experimental error does not exceed ± 8 %.

RESULTS AND DISCUSSION

Typical examples of glow curves of both cement clinker (A, B) and its ferrite phase (C, D) after doping with $CaCl_2$ of concentration 1 wt% and 3wt% are shown in figure 1A, B, C and D. The TL materials have been measured after giving 1.3, 158, 535.5, 7352 Gy doses.

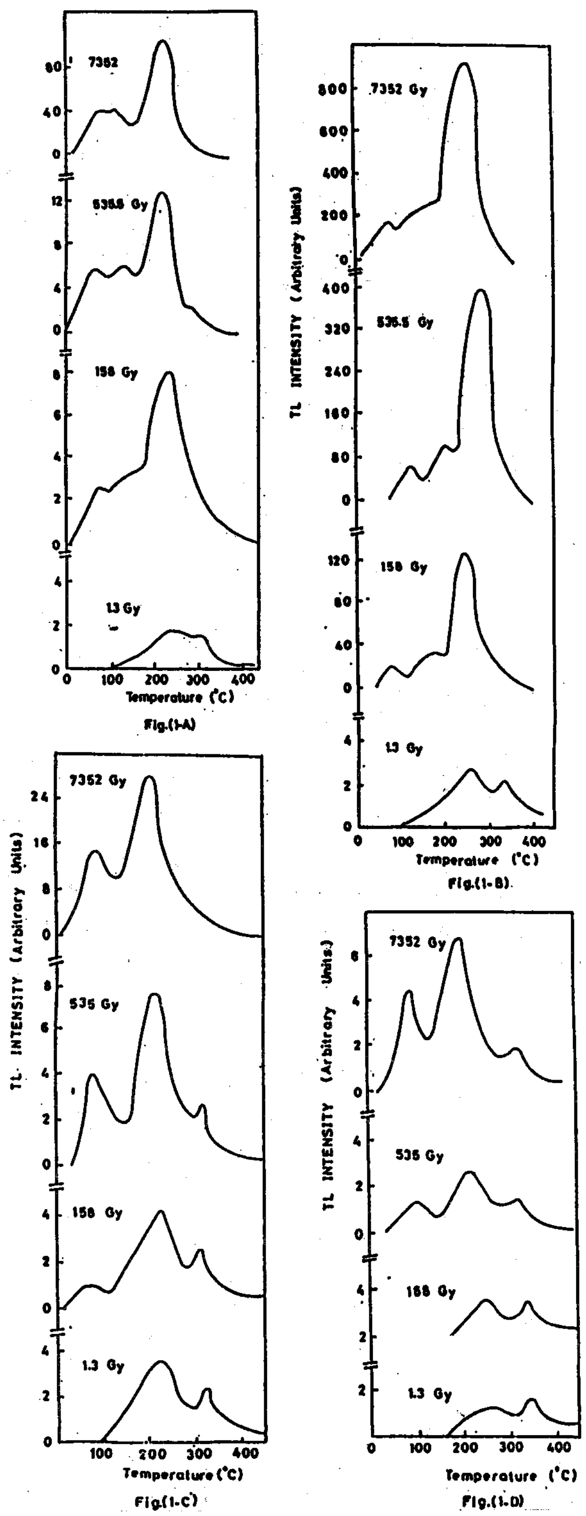

Fig. 1: Glow curves of cement clinker and its ferrite phase after doping with $CaCl_2$ irradiated with various dose levels (A) C: $CaCl_2$(1wt%), (B) C: $CaCl_2$ (3 wt%), (C) F: $CaCl_2$ (1 wt%), and (D) F: $CaCl_2$ (3 wt%).

Two main glow peaks are around 90 °C and 248 °C. There are two other faint glow peaks, one at about 150 °C in case of cement clinker and the other at about 350 °C in ferrite phase. In some cases the glow peaks around 90 °C may not appear especially at low doses. This may be attributed to quick thermal decay (fading). From Fig. 1 it is clear that the dopant $CaCl_2$ in the two phosphors gives three glow peaks. Some other activators for the two phosphors have also been tested, among them, ZnO, LiF, MgF_2 and CaF_2. These activators give only two peaks.

Table 1 indicates the TL response (area under the curve) obtained for the two phosphors when doped with different activators of concentration 1 wt% and exposed to 1000 Gy of Co-60, gamma rays. On the basis of relative TL response, the sensitivity varies from one dopant to another. The most sensitive dopants are $CaCl_2$ and LiF. TL response of cement clinker (doped with 1 wt% $CaCl_2$) as an example for the 90 °C (PKI), 150°C (PKII) and 248 °C (PKIII) peaks is shown in Fig. 2. The 248 °C peak appears at lower doses (~ 1 - 3 Gy). It is considered as the dosimetry peak because it is the most intense and sensitive one. The other two peaks appear at relatively higher doses (~ 100 - 200 Gy). The gamma radiation induces gradual build up in the TL intensity up to a certain dose of 100 Gy, after which the three peaks are more or less parallel to each other.

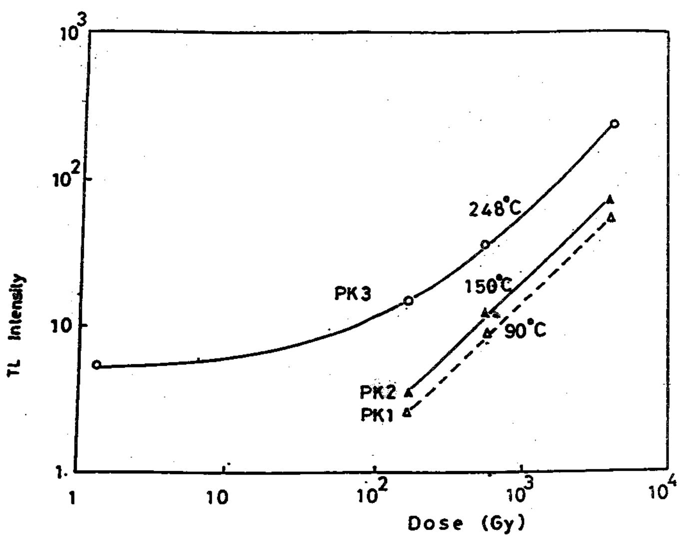

Fig. 2: Variation of TL intensity with radiation dose TL 248°C peak.
TL 150°C peak TL 90 °C peak

Table 1

TL response for different dopants of concentration 1 wt% (test dose = 1000 Gy)

	Cement Clinker			Ferrite Phase		
Dopant	PKI	PKII	PKIII	PKI	PKII	PKIII
Ca F_2	13	35		1.05	4.5	
ZnO	5.8	11.7		2.65	18	
$CaCl_2$	16	20	86	10.4	25	3.6
LiF_2	14.8	19		11.5	18	
MgF_2	6.6	14.5		3.75	13.5	

To find the connection between percentage and measured TL intensity, a series of samples was prepared. The percentage concentration range of the dopants was from 0.5 wt % to 3 wt%. The TL intensity measurements were done after giving the samples 1000 Gy Co-60 gamma rays.

The results are shown graphically in Fig. 3. This figure represents the relation between percentage concentration of different dopants ($CaCl_2$, CaF_2 and ZnO). It can be observed that the TL intensity increases with increasing percentage concentration of the different dopants up to a particular concentration depending on the dopant, beyond which the TL intensity decreases due to activator quenching [6].

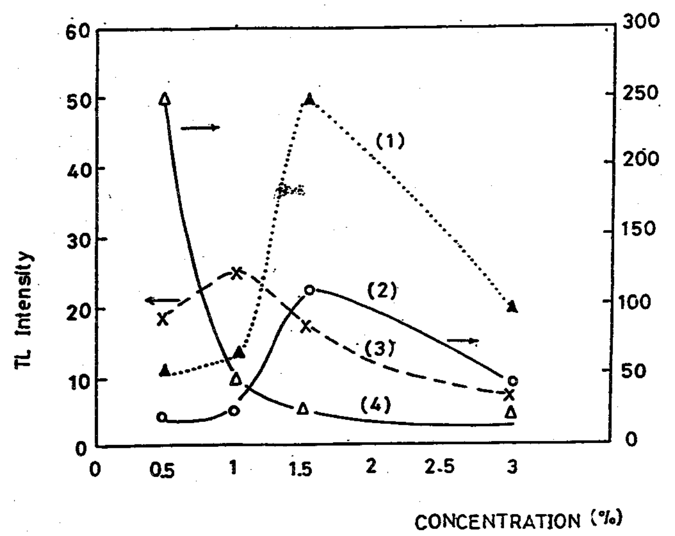

Fig. 3: Variation of TL intensity with percentage concentration of different activators
(1) C: $CaCl_2$ (2) C: CaF_2 (3) F: $CaCl_2$
(4) C: ZnO_2 Test dose = 1000 Gy.

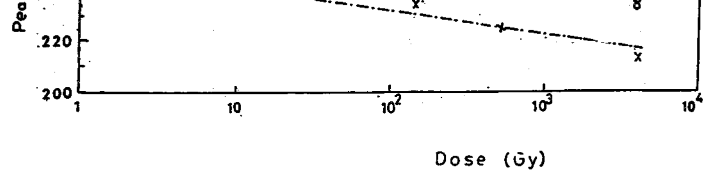

Fig. 4: Variation of maximum temperature (Tm) with radiation dose
(1) C: MgF_2 (2) C: $CaCl_2$ (3) C: ZnO
(4) C: CaF_2 (5) F: $CaCl_2$

Fig. 4 shows that on increasing radiation dose, the TL dosimetric peaks shift towards lower temperatures for the different studied samples. This may be due to mutual charge transition from deep to adjacent shallow traps.

CONCLUSIONS

On the light of the experimental results presented in this paper, it can be concluded that:

(1) The obtained glow curves characterize cement clinker and its ferrite phase, while the activitors enhance their TL intensities.

(2) The maximum of the TL intensity depends on the type of the dopants and their concentrations.

(3) The shallow traps (low temperature peaks) appear at relatively higher radiation doses.

(4) The position of the TL peaks shifts to lower temperatures by partial filling with increasing radiation doses.

(5) The TL peak at 248°C can be considered as the dosimetric peak. Since this peak is far from room temperature, it does not suffer from thermal decay and in this case it gives a real reading.

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