Thermoluminescent properties of undoped and Ce-doped LSO and YSO single crystals and single crystalline films scintillators

A.Twardak[a*], P..Bilski[a], Y. Zorenko[b,c], T. Zorenko[b], V. Gorbenko[c], E. Mandowska[d], A. Mandowski[d], O. Sidletskiy[e]

[a]*Institute of Nuclear Physics, Polish Academy of Science, Radzikowskiego 152, Krakow,31-342, Poland*
[b]*Institute of Physics, Kazimierz Wielki University in Bydgoszcz, Chodkiewicza 30, Bydgoszcz, 85-064, Poland*
[c]*Electronics Department, Ivan Franko National University of Lviv, Universytetska 1, Lviv,79-000, Ukraine*
[d]*Institute of Physics, Jan Dlugosz University, Waszyngtona 4/8, Czestochowa,42-200, Poland*
[e]*Institute for Scintillation Materials, National AS of Ukraine, Lenina 60, Kharkiv, 61-001, Ukraine*

INTRODUCTION

Thermoluminescence (TL) is a phenomenon of light emission by an insulator or semiconductor, which can be observed when previously irradiated material is thermally stimulated. This effect is competitive to scintillation. The study of TL properties of materials is therefore complementary for scintillation research and can provide additional information on luminescent centers.

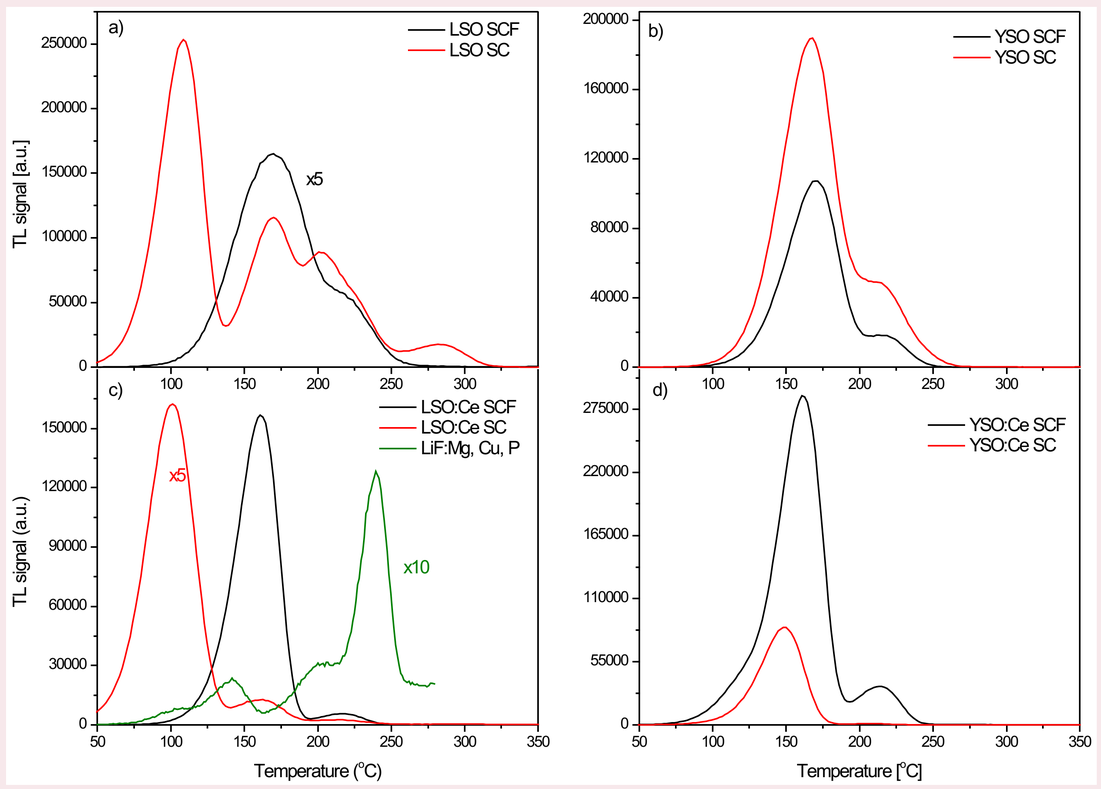
In this work the comparative analysis of thermoluminescent properties of undoped and Ce-doped LSO (Lu_2SiO_5) and YSO (Y_2SiO_5) single crystals (SC) and single crystalline films (SCF) were performed. The samples were prepared with the Czochralski method (SC) and with the liquid phase epitaxy (SCF) technique. Such different methods of material preparation resulted in the presence or absence of main host defects (first of all, antisite defects and oxygen vacancies) as emission and trapping centers.

MATERIALS AND METHODS

The Ce-doped and undoped LSO and YSO SCF samples were grown at the Laboratory of Optoelectronics Materials (LOM) of Lviv University using the liquid phase epitaxy method (LPE) from super-cooled melt solution based on $PbO\text{-}B_2O_3$ flux. The LSO and YSO-based single crystals were grown from melt by the Czochralski method in Ar atmosphere at the Institute of Scintillation Materials (ISMA) in Kharkiv. For Ce-doped samples the concentration of CeO_2 activator oxide ions in melt solution was equal to 5.0 mol%, 10.0 mol% and 20.0 mol%.

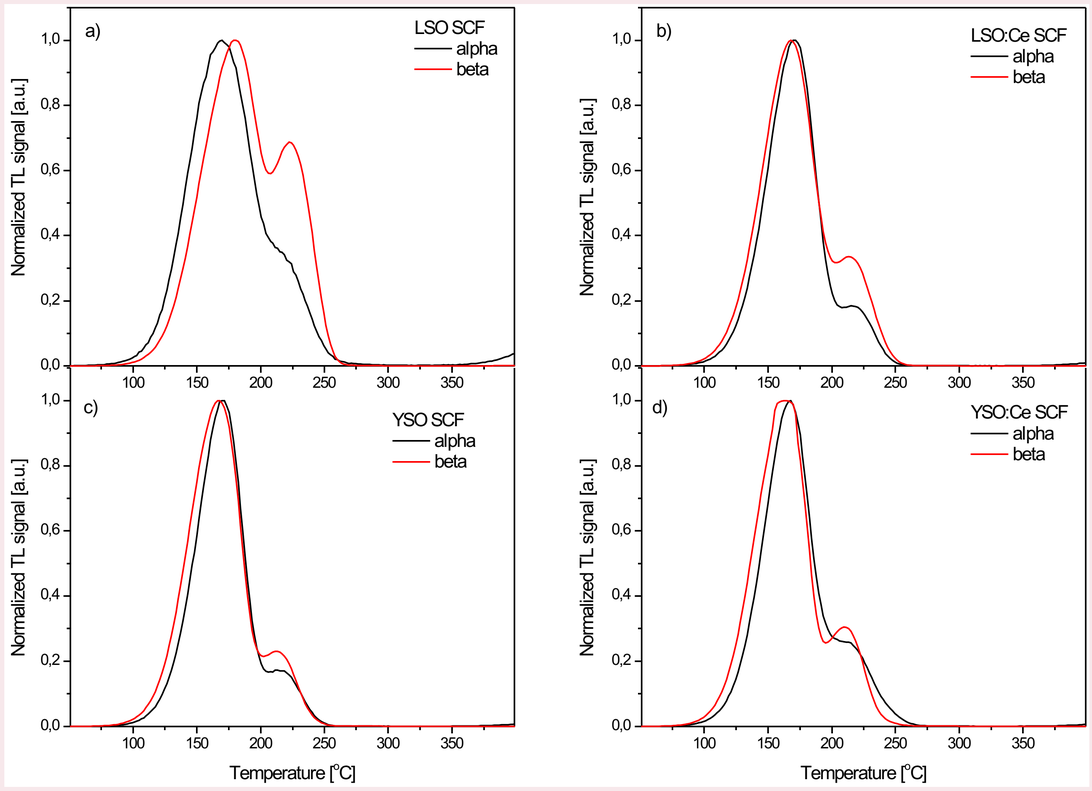
The samples under study were irradiated with various doses of alpha (Am-241, energy at sample surface 4.5 MeV, fluence $1.7 \cdot 10^5$ $cm^{-2}s^{-1}$) and beta particles (Sr-90/Y-90, 2.3 MeV). The range of alpha particles in LSO and YSO is comparable with the thickness of single crystalline films (about 10-15 μm). Beta particles used in measurements penetrated uniformly the whole volume of the samples. The TL glow curves were registered using a commercial reader Risoe TL/OSL - DA-20 (Risoe DTU, Denmark) equipped with Schott BG39 filter (350-650 nm transmission). All irradiations and TL measurements were conducted in darkness.

SINGLE CRYSTALS VS SINGLE CRYSTALLINE FILMS



Comparison of thermoluminescent glow curves of single crystals and single crystalline films irradiated with alpha particles (21.6 Gy). Results were normalized to 1 mg of surface mass. TL signal of LSO SCF and LSO:Ce SC were multiplied by factor 5. LSO:Ce samples are compared with standard TL material LiF:Mg, Cu, P (MCP).
a - LSO SCF and LSO SC c - LSO:Ce SCF (5 mol%) and LSO:Ce SC (10 mol%)
b - YSO SCF and YSO SC d - YSO:Ce SCF and YSO:Ce SC

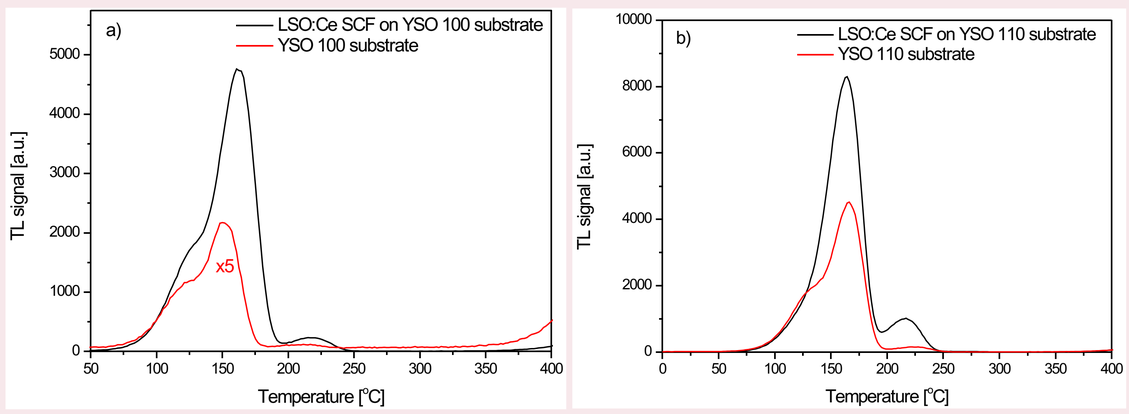
ALPHA VS BETA IRRADIATION



Comparison of thermoluminescent glow curves single crystalline films irradiated with alpha (21.6 Gy) and beta (70 mGy) particles. Results were normalized to range [0;1].

a - undoped LSO SCF and LSO SC c - Ce doped LSO SCF and LSO SC
b - undoped YSO SCF and YSO SC d - Ce doped YSO SCF and YSO SC

SINGLE CRYSTALLINE FILM VS SUBSTRATE



TL glow curves of single crystalline films and YSO substrates after irradiation with alpha particles (21.6 Gy). Results were normalized to surface area of the samples.

a - LSO:Ce SCF based on YSO 100 substrate compared with YSO 100 substrate
b - LSO:Ce SCF based on YSO 110 substrate compared with YSO 110 substrate

CONCLUSIONS

Thermoluminescent behaviours of undoped and Ce-doped LSO explicitly depend on crystalline form of the samples and method of their preparation.

Undoped LSO and YSO SC and SCF samples shown very different TS properties. The intensity of TL signal is significantly higher for LSO SC (five times) and YSO SC (two times). These results indicate the substantially different concentration of host defects as trapping centres in LSO and YSO SC and SCF due to different conditions of their preparation.

Ce-doped LSO SCFs possess very high TL signal which is ten times larger then their SC counterpart. In comparison with known dosimetric materials LiF:Mg, Cu, P (MCP) the TSL intensity of LSO:Ce SCF is 5 times higher (peak height). Therefore, the LSO:Ce SCF can be considered as promising materials for dosimetry of the alpha particles.

In Ce^{3+} doped YSO:Ce SC and SCF the intensity of TSL signals is comparable.

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