Journal of Materials and Environmental Sciences
ISSN : 2028-2508

JMES, 2017 Volume 8, Issue 7, Page 2322-2326

http://www.jmaterenvironsci.com /

ERVD4, 26-27 Oct 2016 Ifrane, Morocco

JMES

Rare earth Er^{3+}/Yb^{3+}codoped-sol gel SnO_2 For up converter solar cell

M. Y. Messous*[1], Z. El Afia[1,2], N. Haddou[3],N. Touba[2], B. Belhorma[1]
A. Moussaif[1], M. Tahri[1], A. El Yahyaoui[1], M. R. Bricha[1]

[1]*National Center for Energy, Sciences and Nuclear Techniques (CNESTEN), BP 1382, R.P 10001 Rabat, Morocco.*
[2]*Laboratory of Materials, electrochemistry and environment, university ibn Tofail, Faculty of sciences 14000 Kenitra, Morocco.*
[3]*Laboratory of Condensed Mattery, Department of Physics, 93002, Faculty of Sciences, Tetouan, Morocco.*

Received 29Aug 2016,
Revised 01Oct 2016,
Accepted 04 Oct 2016

Keywords
- ✓ Tin dioxide,
- ✓ Rare earth,
- ✓ Sol gel,
- ✓ Energy up converter,
- ✓ Solar cell

messous@cnesten.org.ma
, Phone: +212672613715

Abstract

The rare earth couple Ytterbium-Erbium doped tin dioxide (SnO_2:Yb^{3+}/Er^{3+}) were prepared by sol gel method using tin(II) chloride as source of Sn^{2+} ions, Ytterbium and Erbium chloride hydrate for doping rare earth ions source. This material is considered as a promising up-converter material for solar cell due to energy transfer (ETU) between the rare earth dopant elements. The powders of pure and doped samples were prepared and characterized by X-Ray Diffraction DRX, Infrared Spectroscopy ATR-FTIR, X-Ray Fluorescence RFX techniques. The Inductively Coupled Plasma ICP-MS were performed for elemental composition. All the results are shown and discussed. RFX and ICP-MS exhibits a ratio of 10 between the dopant's concentrations.

1. Introduction

Nowadays the largest photovoltaic solar cell problem is the limitation on the low conversion efficiency[1-5]. This is due to the discordance between the incident solar spectrum and the spectral absorption of the material of the cell [6-8].

In the last years, there has been developed various ways which consist in modifying the solar spectrum by wavelength conversion process to suit the structure of solar cell's materials. Among the emerging ideas, the conversion using rare earth elements that are good candidates for engineering photons through their wide range of energy levels structure (known as the Dieke diagram) [9-11], has an important interest in research. The Up-Conversion (UC) that is the phenomenon, by which two photons of low energy are absorbed successively by an atom to relax and emit a high-energy photon, is one of the promising approaches [12]. There are several mechanisms resulting in up-conversion within a rare earth ion subdivided into three classes [13-14]. The Energy Transfer Up-Conversion (ETU) process is obtained by incorporating a sensitizer ion with an activator ion in host material like transparent conducting oxides (TCO). The Yb^{3+} is often used as a sensitizer because it has a larger optical cross-section [15-26]. The semi-conductor SnO_2 with a band gap equal to 3.6 eV [27-28] is particularly attractive for photovoltaic application as a TCO.

In the present work the preparation of SnO_2 co-activated by Yb^{3+}/Er^{3+} ions prepared by sol gel method was studied. The structural and elemental analysis was reported. All synthesis and characterization stages were carried out at National Center for Energy, Sciences and Nuclear Techniques CNESTEN (CENM-Maamora).

2. Experimental work

2.1. Sample preparation

The pure thin oxide powder SnO_2 was prepared via simple sol gel method. Typically 22.5 mmol (5 g) $SnCl_2.2H_2O$ (Sigma-Aldrich, Purity: > 99.99%) was added into 50 mL Ethanol and the solution is stirred at room temperature for1 hour, then at reflux during 24 hours. After eliminating the solvent under reducing pressure using a rotary evaporator, 10 mL of water-Ethanol mixture is poured into the residue. It's dried at 110°c for (03) days.

For doped SnO_2 with Erbium (2%), 0.17 g of $ErCl_3.6H_2O$ (Sigma-Aldrich, 99.9%) was added to $SnCl_2.2H_2O$ in the first step. For preparation of SnO_2 doped with Ytterbium (20%) as sensitizer and Erbium (2%) as activator, $YbCl_3.6H_2O$ (Sigma-Aldrich, 99.9%) was also used.

2.2. *Characterization*

Fourier Transformed Infrared by Attenuated Total Reflection (ATR-FTIR) spectrum of the synthesized powder was recorded in the range 400-4000 cm^{-1} on a Perkin-Elmet spectrometer UATR two. Powder Diffraction (XRD) data were carried out with a D2-Phaser Bruker-diffractometer in the range diffraction angle $2\theta = 0\text{-}120°$. The chemical composition of the obtained powders was determined using Inductively Coupled Plasma Emission Spectroscopy (ICP-MS). A S2 Picofox –Bruker based on total reflexion X-Ray Fluorescence (TXRF) is used to provide a semi-quantitative analysis.

3. **Results and discussion**

3.1. *Fourier Transform Infrared Spectroscopy (FT-IR)*

Fourier transform infrared spectroscopy was usually employed as analytical technique to identify organic (in same cases inorganic) material. The FT-IR spectra of the synthesized SnO_2 are shown in Figure 1.The intense band (at 1599 cm^{-1}, 1610 cm^{-1} and 1608 cm^{-1}) and the broad band (at 3351cm^{-1}, 3395 cm^{-1} and 3427cm^{-1}) can be attributed to the O-H vibration from hydroxyl groups presents on surface of the material. The broad bands between 400 and 800 cm^{-1} are attributed to the O-Sn-O bridge functional groups, the terminal oxygen vibration of Sn-OH and the framework vibrations of the Sn-O bond in SnO_2[29].

3.2. *X-Ray Fluorescence spectroscopy (XRF)*

The compositional analysis of the samples was observed by RFX, as shown in Figure 2. Apparently visible peaks due to presence of Sn, Er and Yb elements were detected. This spectrum shows the existence of traces of some metals and chloride for undoped (N0) and doped (N1,N2) samples. The peaks at 6,94keV, 7.78 keV, 8.18 keV, 9.06 keV and 9. 44 keV in Fig.2 (b) reveals the presence of Er^{3+} in sample N1. In addition to those peaks, the appearance of others at 6.53 keV, 7.41 keV, 8.38 keV, 8.72 keV, 9.75 keV and 10.06 keV in Fig. 3(c) indicated the presence of Yb^{3+} with Er^{3+} in sample N2.

3.3. *Inductively Coupled Plasma Mass spectroscopy ICP-MS*

The results of elemental concentrations obtained for samples N0 (SnO_2), N1 (SnO_2: Er) and N2 (SnO_2: Er,Yb) are presented in Table 1. These data show a ratio equal to 10 between the concentrations of Er and Yb and coincide with the quantity from precursors.

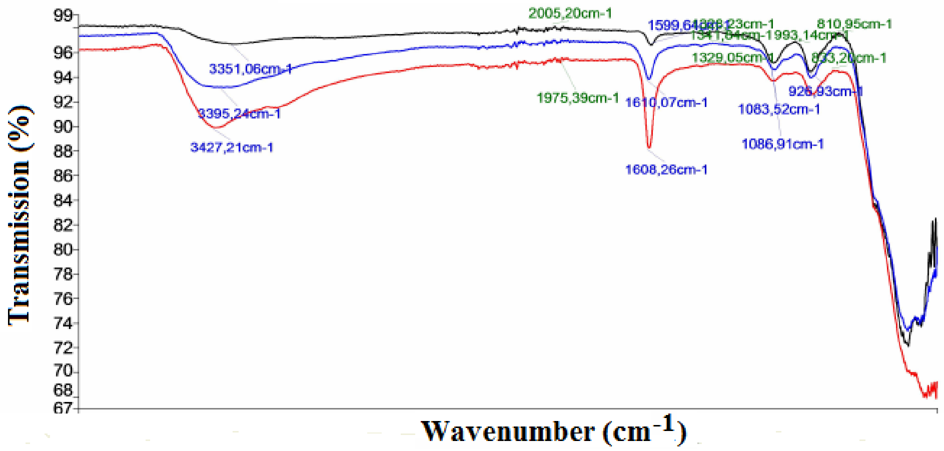

Figure 1:ATR-FTIR spectra of:

— SnO_2 pure — SnO_2 : 2% Er^{3+} — SnO_2 : 2% Er^{3+}, 20% Yb^3

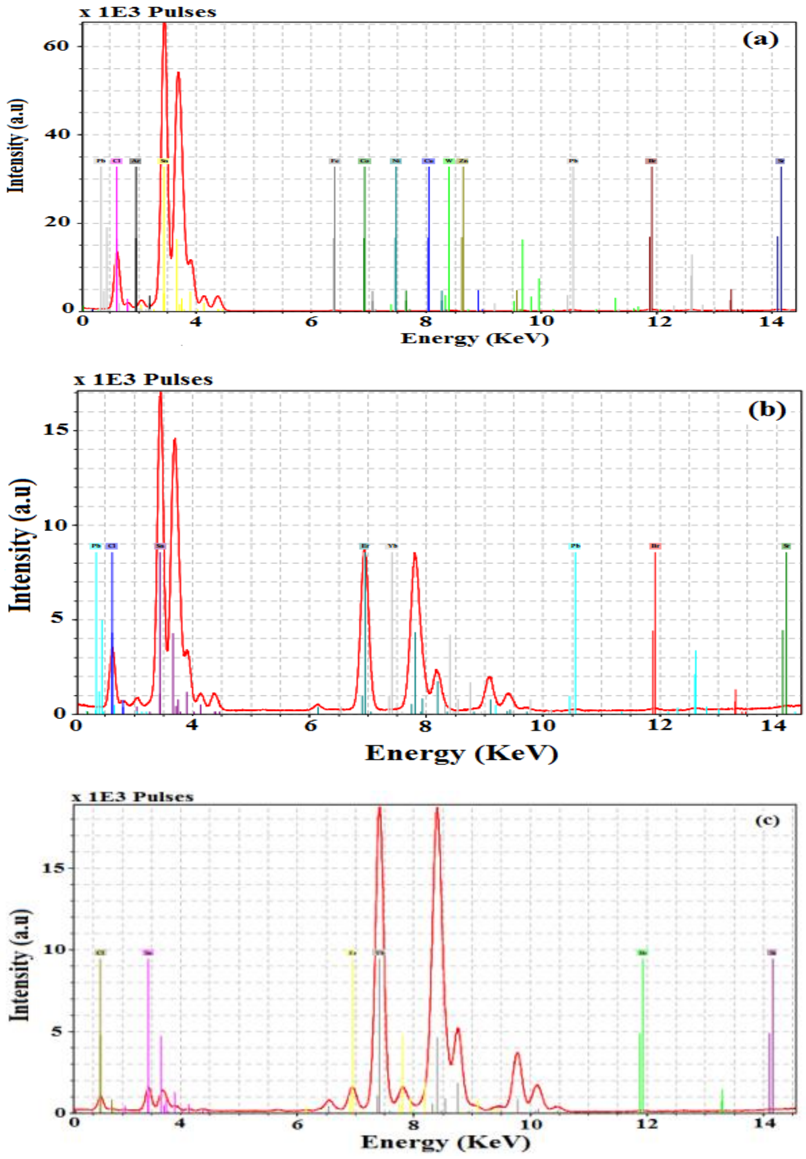

Figure 2: The Fluorescence X-Ray of(a)SnO_2,(b)SnO_2: Erand(c)SnO_2:Er,Yb

Table 1: The concentrations of Er and Yb in SnO_2 samplesdetermined by ICP-MC analysis

Sample	^{118}Sn (mg/g)	^{166}Er (mg/g)	^{172}Yb (mg/g)
N0	1.67625	0	3.5032E-05
N1	1.61524	0.00314	<LD
N2	1.07473	0.00081	0.00824

3.4. X-Ray Diffraction Analysis (XRD)

The results of the XRD pattern of undoped and doped SnO_2 are shown in Figure 3. The analysis in the range 20°-65° is sufficient to identify the major peaks. The mean diffraction peaks corresponding to tetragonal SnO_2 are observed. The peaks at $2\theta = 26.13°$, 33.14°, 36.55°, 50.84° and 51.38° can be attributed to SnO_2 (110), (101), (200), (211) and (220)and are similar to those observed by Z. L. He and al. [30]. The doping with 2% of Er^{3+} ion seems to have a little influence on the particle size as shown on the diffractogram in figure 3(b) where the width of the peaks are constant after doping to 2% Erbium. While the addition of 20% Ytterbium shown the appearance of a new peak at 2θ =14.13° and the width are changed.

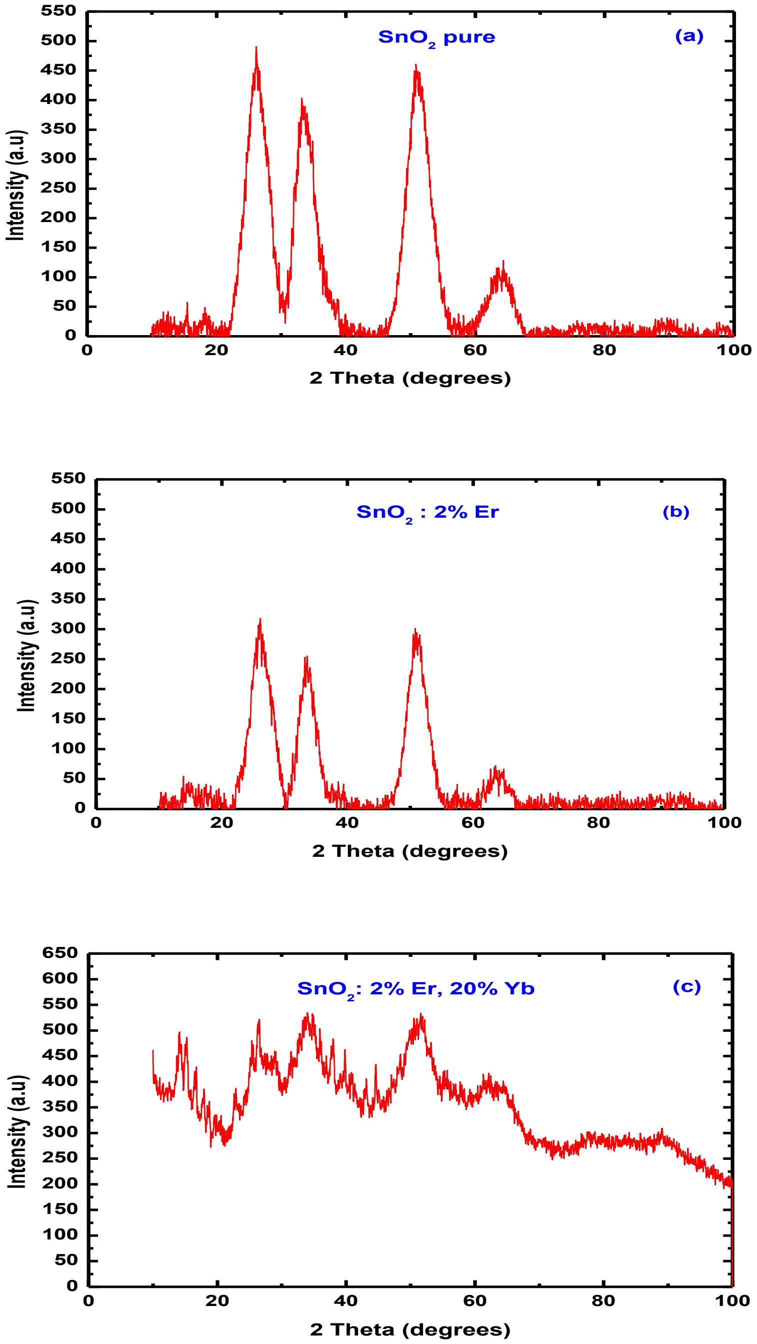

Figure 3: XRD of synthetized of(a)SnO$_2$,(b)SnO$_2$:Er and (c) SnO$_2$:Er/Yb

Conclusions

The tin oxide SnO$_2$: Er,Yb powder was successfully prepared by sol-gel technique. The samples were characterized by ATR-FTIR, XRF, XRD and ICP-MS. All data showed the incorporation of Er and Yb in the doped SnO$_2$. There was no influence in the rutile structure of pure SnO$_2$. The compositional analysis showed a ratio [Yb]/[Er] equal to 10.

Acknowledgments: The authors are grateful to K. Laraki Doctor-Engineer and head of the Laboratory Holding Division at CNESTEN for his help in having at our disposal the materials and instruments for the preparation and characterization of samples.

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(2017) ; http://www.jmaterenvironsci.com