DEVELOPMENT AND SYNTHESIS OF A NEW KIND OF LUMINESCENT MATERIAL FOR DOSIMETRY

Bouisri Samir

PHD thesis
(start : october 2017)

Supervisor :
Jérôme BOCH - Cathy GUASCH

IES | Institut d'Électronique et des Systèmes
UMR 5214 - CNRS - UM2
Université Montpellier 2

860, rue Saint Priest
Bâtiment 5 - CC 05001
34095 Montpellier CEDEX 5

tel +33 (0)4 67 14 37 16
fax +33 (0)4 67 54 71 34
www.ies.univ-montp2.fr

Objective

Develop luminescent materials for dosimetry in order to realize thin layer and integrate them in a microelectronic process (SoC)

Using a reproductible and reliable manufacturing proccess

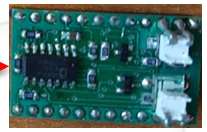
Overview of dosimetry

Passive
delayed reading

- Film
  - photographic
  - radiochromic
- TL
- OSL
- RPL

Active
direct reading

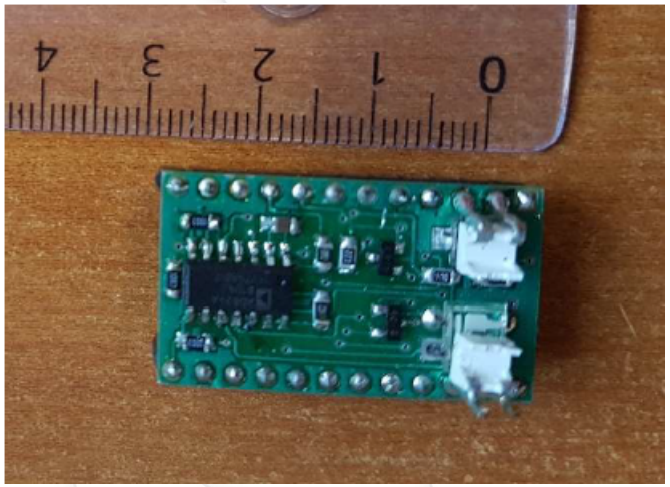
- **All integrated** or fiber dosimeter
  - OSL
  - RPL



SrS : Ce, Sm
Developed in 2004 in the team

- Scintillation counter
- Gas
  - Ionization chamber
  - Proportional counter
  - Geiger-Müller counter
- Semi-conductor detector
  - Silicon diode
  - Medipix/TIMEPIX

Historic in the laboratory
SrS : Ce, Sm



Pros

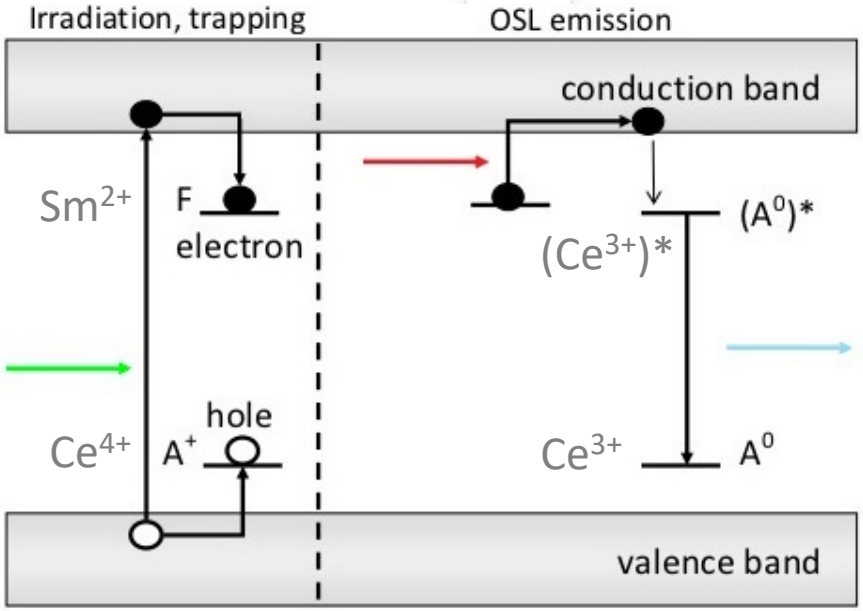
- Good Sensivity and dynamics
  - 10 µGy to 300 Gy (saturation), linear to 100 Gy
- Compact

Cons

- Reproductiblity of the process and integrabillity
  - Powder (deposited by screen painting)
  - Sulfur (oxidation -> not inert)

OSL vs RPL

Optically Stimulated Luminescence



OSL (visible)

Stimulation (IR)

Ionizing radiation

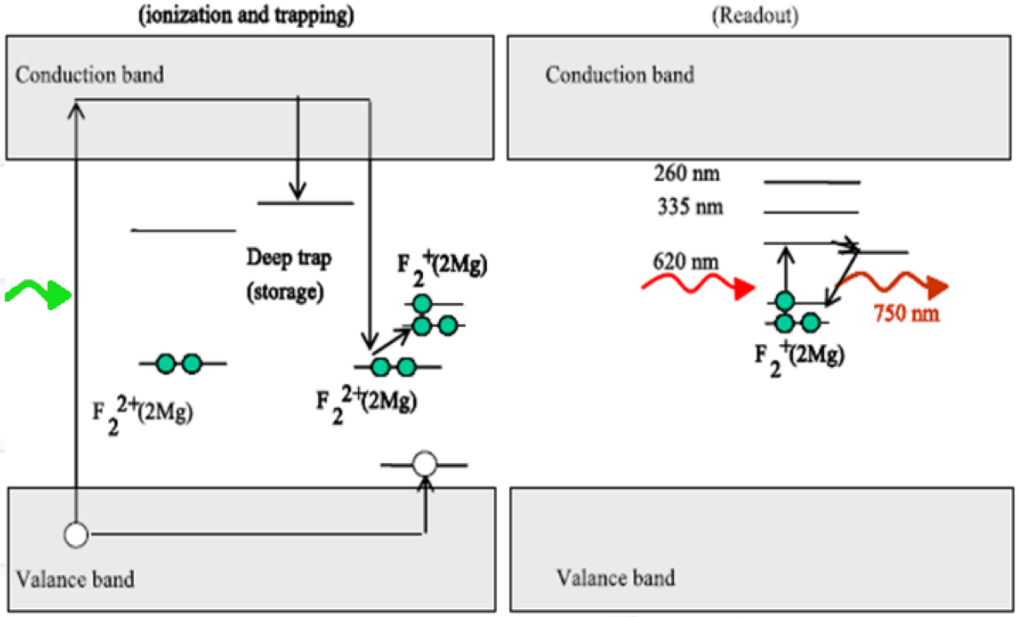
F Electron trap center

A^+ Hole trap center

A^0 Luminescent center

SrS : Ce,Sm

Radio-PhotoLuminescence



RPL (visible)

Stimulation (UV)

Ionizing radiation

Al_2O_3:C,Mg

OSL vs RPL

OSL

Pros

- Can be reset by light beam
- Multiple readings…

Cons

- Fading (loss of information due to ambient temperature)
- …but with loss of information

RPL

Pros

- No fading (deep trap)
- Multiple readings without loss of information

Cons

- Need to be annealed at high temperature to be reset

Specifications

in order to make an all integrated dosimeter

- Easy to integrate
- Can be reset without damaging the system
- Good sensitivity and dynamics
  - Depend on the aimed application
  - It will be easier to adjust this parameters, mastering the fabrication process
- Low fading

Silica materials

- Compatible with microelectronic process

2 ways

Amorphous

- Aerogels
- Xerogels
- Thin layers

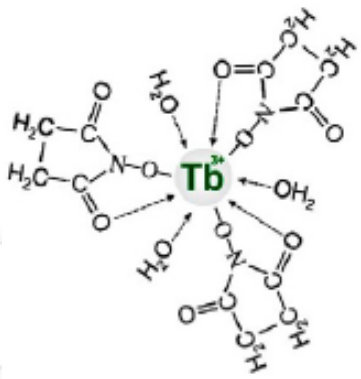
Crystalline

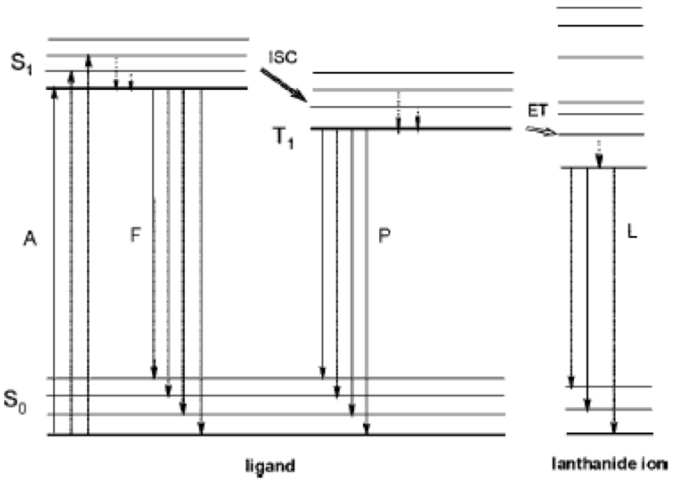
- Thin layers of quartz

Amorphous silica

SiO_2 : [Tb(NHSI)]

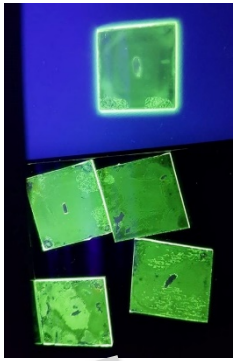
- Terbium
  - $\lambda_{emission}$ does not depend on the crystalline environment
  - But a low molar absorptivity
    →Antenna effect : ligand (NHSI)





- Aerogel and Xerogel
  - Sol-gel process + supercritical drying (aerogel) or air drying (xerogel)
  - Large emission area due to his high porosity
  - Easily shapable

- Thin layers
  - deposited by spin coating
  - 1500 - 2200 nm thick

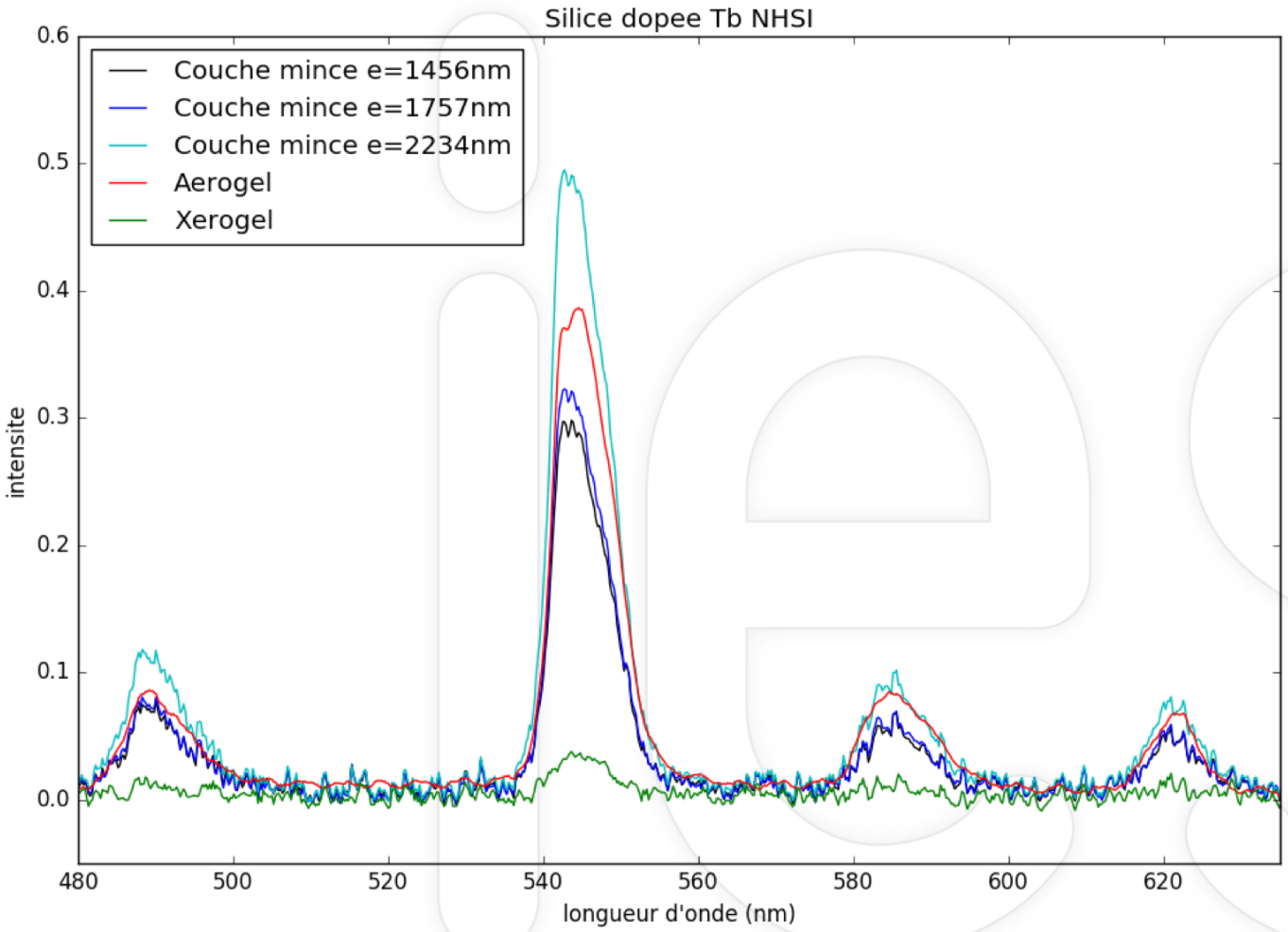


Under UV (254 nm)

C.S.Stan and al, *Journal of Sol-Gel Science and Technology* **69** (2014) 207–213

Amorphous silica

First results



PL spectra under UV (254 nm)

- No RL observed under Xrays
  - Sensivity of the detection system ?
  - Other mechanism ?
    - Fluorescence X
    - Quenching

$^5D_4 \rightarrow {}^7F_6$ 488 nm

$^5D_4 \rightarrow {}^7F_5$ 543 nm

$^5D_4 \rightarrow {}^7F_4$ 584 nm

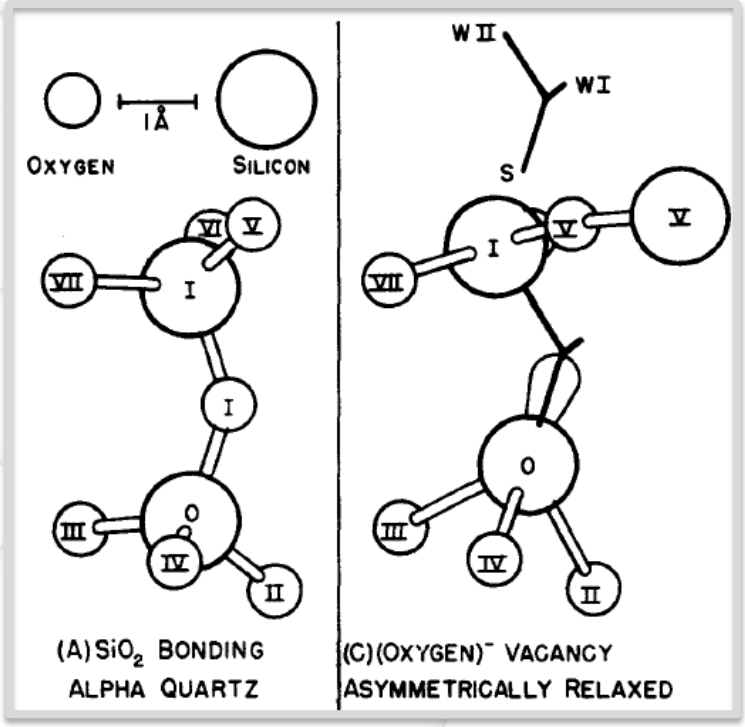
$^5D_4 \rightarrow {}^7F_2$ 618 nm

Tb^{3+} radiative emissions

Crystalline silica
Quartz α

- SiO_2 + traces of H, Li, Na, K, Al, Ga, Ti, Fe, Ge, P growing on a Si substrate with sol-gel process

- Radiation-induced defects in quartz
  - E_1' center : O^- vacancy (electron trap)
  - Al center : Al^{3+} in substitution of Si^{4+} (hole trap)
  - …



F. Preusser and al, *Earth-Science Reviews* **97** (2009) 184-214

Conclusion

- We want to develop luminescent materials for dosimetry
- 2 types of materials are studied (amorphous silica and quartz)
- First results on amorphous silica didn’t show any luminescence under Xrays
  - A more sensitive detection system based on a PM and an experiment to see if Xray fluorescence occurs in the material are in development
- Quartz samples are in development, first samples will be recieved in may