CHARACTERIZATION OF AL_2O_3 AND SIO_2 ULTRA-THIN FILMS DEPOSITED BY ALD FOR MICROFABRICATED RUBIDIUM VAPOR CELLS

F. M. Cunha*, M. F. Silva, J. H. Correia

CMEMS – UMinho, University of Minho, 4800-058, Guimarães, Portugal
LABBELS – Associate Laboratory, Braga/Guimarães, Portugal
* pg47183@uminho.pt

Introduction

- The **Atomic Layer Deposition (ALD)** technique can be used to **increase the lifetime** of **microfabricated rubidium vapor cells** (magnetic sensors for magnetoencephalography) by an ultra-thin coating layer deposited on the internal cell walls (Figure 1). The ALD presents excellent control over the ultra thin films thickness (< 20 nm) and allows complex 3D structures to be covered with a high-aspect-ratio coating.
- This work shows the characterization of **alumina (Al_2O_3)** and **silicon dioxide (SiO_2)** ultra-thin films deposited by **Thermal ALD (ThALD)** and **Plasma-Enhanced ALD (PEALD)**.

Methods

- The SENTECH ALD system has an **excellent thickness precision control** by using an *in-situ* ellipsometer **in real-time** during the deposition.
- A 10 nm ultra-thin film of Al_2O_3 was deposited by ThALD and 10 nm ultra-thin films of Al_2O_3, and SiO_2 were deposited by PEALD technique at **200 W** of electrical power in a silicon (Si) n-type (100) substrate with the substrate temperature fixed at **250 ºC**. A warmed-up reactor at 100 ºC was controlled and the precursors' lines were heated to 125 ºC.
- The ALD **precursors pulverization time** varies between 60 - 180 ms with a **co-reactant pulverization time** between 60 ms for ThALD and 5 s for PEALD. The ALD **purge time** varies between 1 s and 5 s.

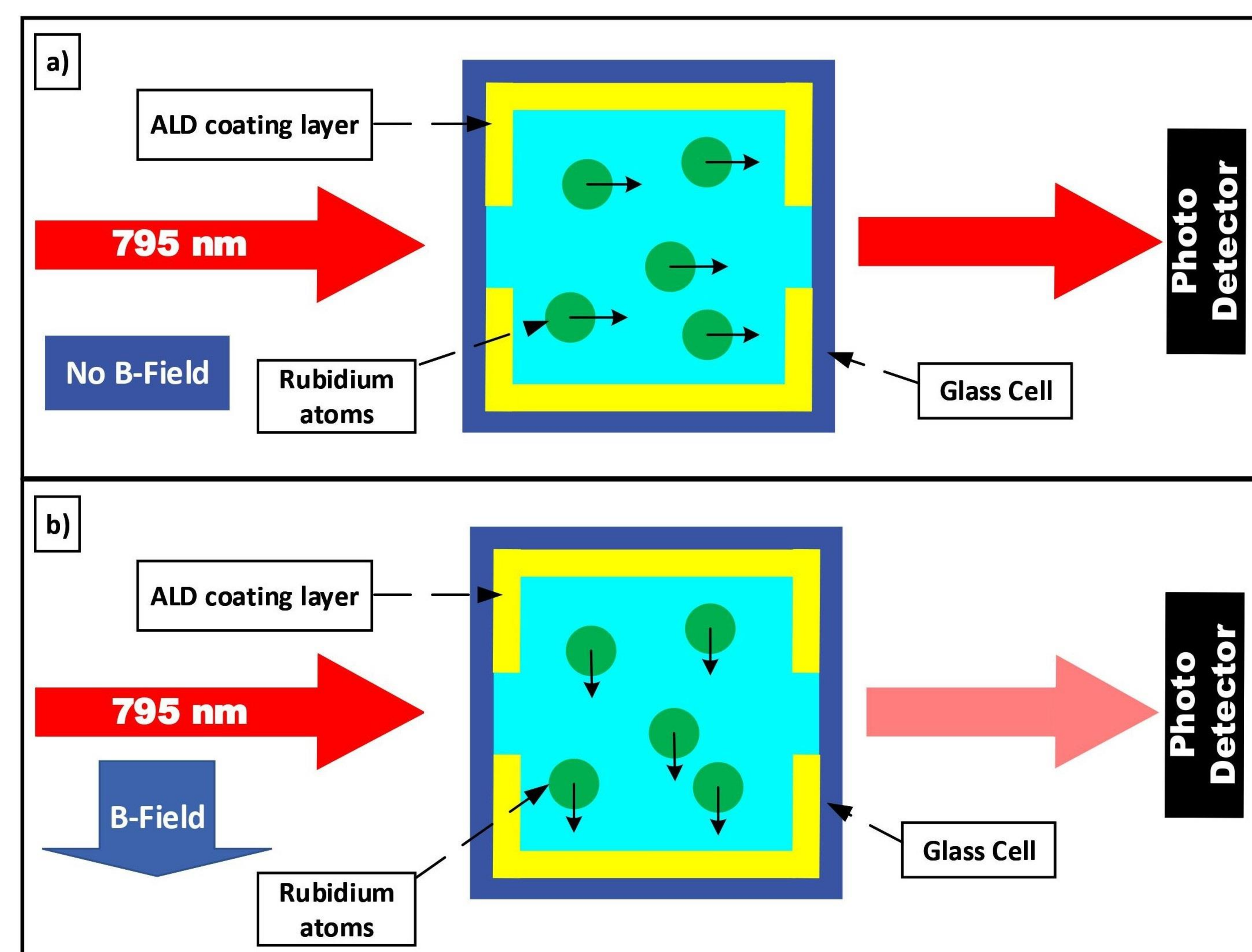

Figure 1 – Microfabricated rubidium vapor cell; (a) Without magnetic field; (b) With a magnetic field

Results

- Figure 2 shows the **refractive index results** in comparison to literature obtained by a **spectroscopic ellipsometer.**
- The **Energy Dispersive Spectroscopy (EDS)** chemical characterization shows a main peak that represents the Si n-type substrate (represented in Figure 3). However, the PEALD Al_2O_3 shows an **atomic percentage** of 58.65% for Oxygen (O) and 41.35% for Aluminum (Al) with a **mass percentage** of 45.69% for O and 54.31% for Al. The **atomic percentage** for ThALD Al_2O_3 shows 59.37% for O and 40.63% for Al with a **mass percentage** of 46.42% for O and 53.57% for Al.

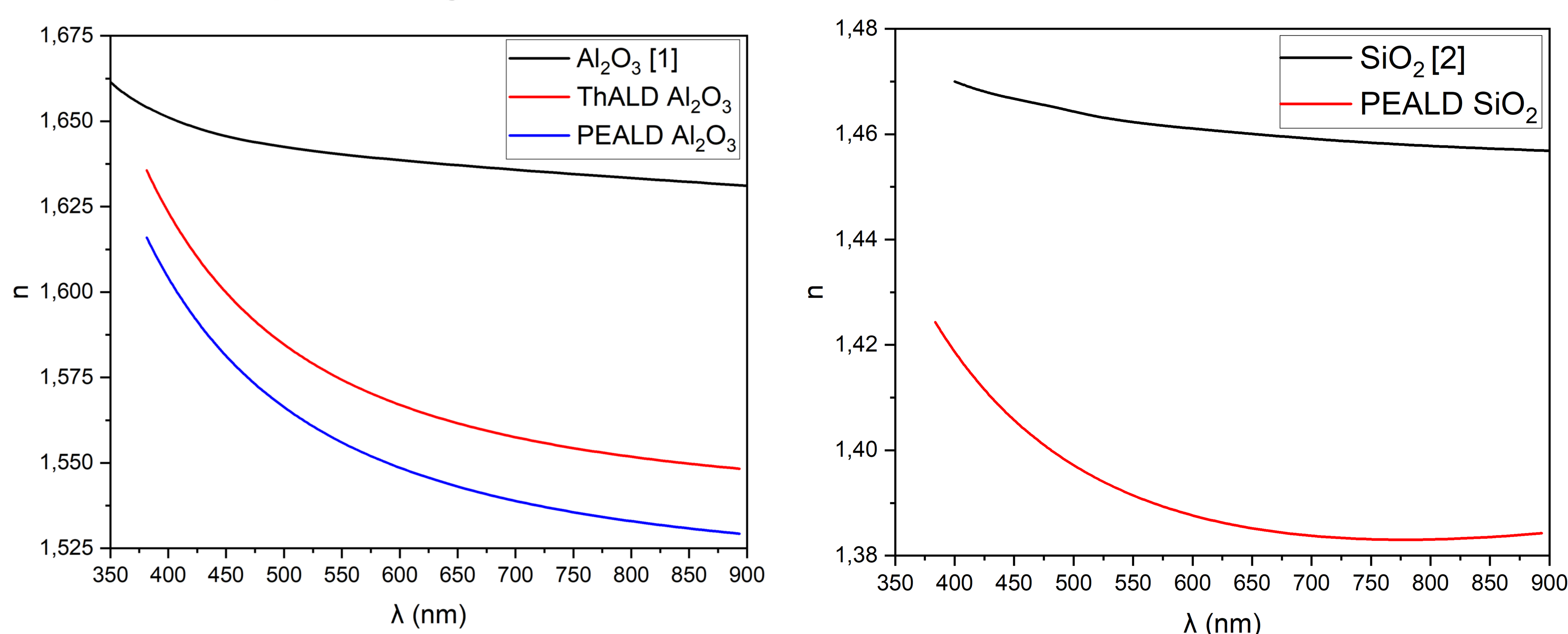

Figure 2 – Comparison between the refractive index values measured and the literature.

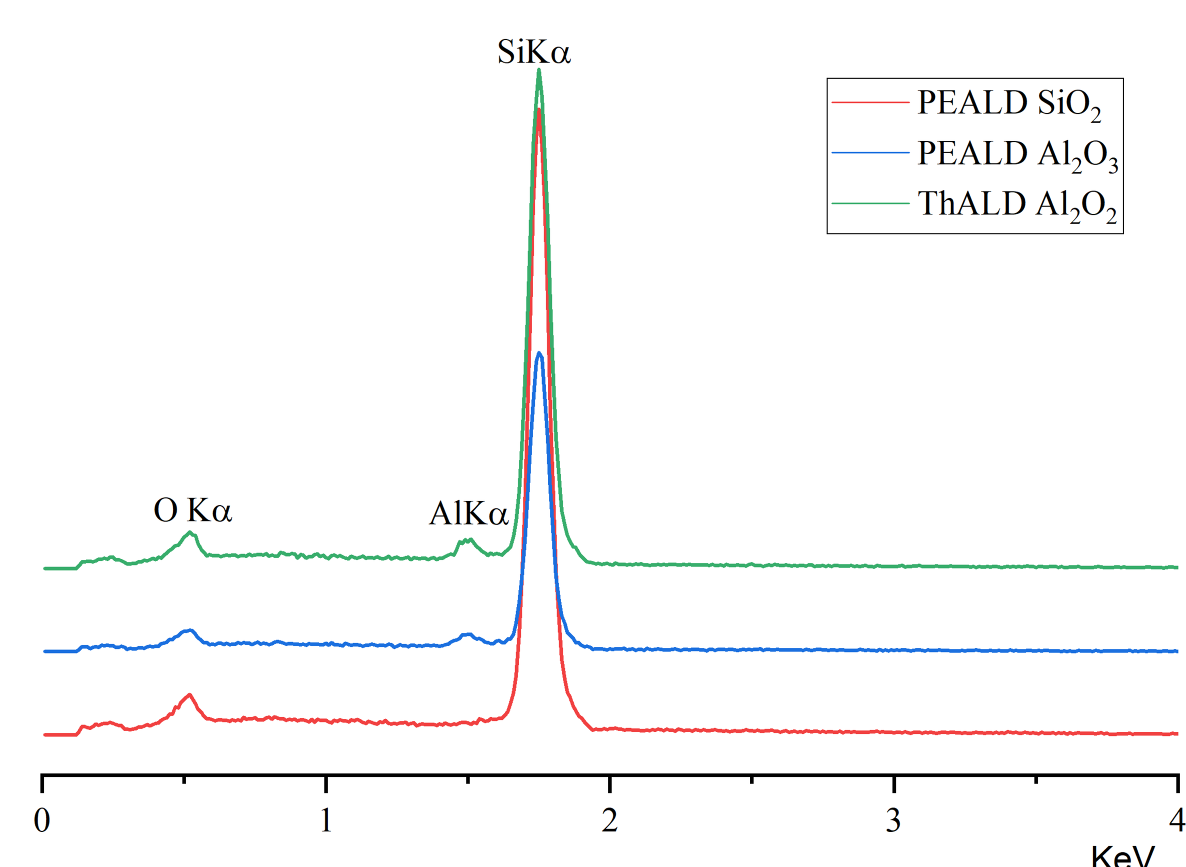

Figure 3 – Elementary analysis with EDS of PEALD Al_2O_3, ThALD Al_2O_3, and PEALD SiO_2.

Conclusions

- The ThALD Al_2O_3 show optical and chemical characterization closer to the reference. However, the results are very close to literature.
- This work presents the characterization of the Al_2O_3 and SiO_2 ultra-thin films to increase the lifetime of microfabricated rubidium vapor cells (in glass or silicon) for application in magnetoencephalography.

Universidade do Minho
UMINHO CMEMS CENTER FOR MICROELECTROMECHANICAL SYSTEMS
LABBELS ASSOCIATE LAB
FCT Fundação para a Ciência e a Tecnologia
REPÚBLICA PORTUGUESA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR
NORTE 2020 PROGRAMA OPERACIONAL REGIONAL DO NORTE
UNIÃO EUROPEIA Fundo Social Europeu

Acknowledgements

This work was supported by Project MME reference 105399 and FCT with the project MPhotonBiopsy, PTDC/FIS-OTI/1259/2020, Infrastructures Micro&NanoFabs@PT, reference NORTE-01-0145-FEDER-022090, POR Norte, Portugal 2020.

References

[1] - Castillo-Saenz, Jhonathan, et al. "Properties of Al_2O_3 Thin Films Grown by PE-Ald at Low Temperature Using H_2O and O_2 Plasma Oxidants." Coatings, vol. 11, no. 10, 2021, p. 1266., doi:10.3390/coatings11101266.

[2] - Pfeiffer, Kristin, et al. "Comparative Study of ALD SIO_2 Thin Films for Optical Applications." Optical Materials Express, vol. 6, no. 2, 2016, p. 660., https://doi.org/10.1364/ome.6.000660.