LMGP Laboratoire des matériaux et du génie physique — une vision des matériaux

GRENOBLE INP UGA — CNRS — UGA Université Grenoble Alpes

2022-2023 Internship proposal at LMGP Lab.

Life cycle assessment of Spatial Atomic Layer Deposition Processes

Abstract

Spatial ALD (SALD) is a versatile technology that enables the fast manufacturing of material layers at the nanoscale. The assessment of the environmental impacts associated to SALD technology is important as it can help detecting its main sources of pollution while also finding a path towards their reduction. However, there is no report of studies yet focusing on the environmental aspects of SALD. Life cycle assessments (LCA) enable to unravel the environmental aspects and potential impacts throughout a product or process life cycle (i.e. cradle-to-grave) from raw materials acquisition through production, use and disposal. In this project, we aim to perform thorough life cycle assessments (LCA) of several SALD processes, in order to assess their environmental impact and detect the key parameters to modify in order to reduce their carbon footprint and overall impact. The project will address the research gap in quantifying and understanding the environmental impacts of SALD technology, and the LCA studies will provide a comprehensive data support for understanding the environmental impacts of SALD.

Project description

According to recent global assessments, our planet is experiencing a huge and fast decline of biodiversity and nature is declining globally at rates unprecedented in human history, with grave impacts on people around the world.[1,2] Thus, as a species, we are currently facing massive environmental challenges. In parallel to policy makers, academic and industrial researchers should focus on the development of innovative routes enabling to reduce pollution and to produce energy and goods using more environmentally friendly technologies. In a quest for consistency and role models, researchers should analyze and quantify the environmental impact of their activities and debate on reduction options.[3,4] The assessment of the environmental impact of a given technology, along with the design of a plan to reduce the generation and emissions of pollutants, will directly contribute to the required global effort.
Atomic layer deposition (ALD) and its variant Spatial ALD (SALD) are an important and versatile technology that enables the fast manufacturing of material layers at the nanoscale.[5–7] The assessment of the environmental impacts associated to SALD technology is important as it can help detecting its main sources of pollution while also finding a path towards their reduction. However, there is no report of studies yet focusing on the environmental aspects of SALD.
Life cycle assessments (LCA) enable to unravel the environmental aspects and potential impacts throughout a product or process life cycle (i.e. cradle-to-grave) from raw materials acquisition through production, use and disposal.[8,9] The general categories of environmental impacts needing consideration include resource use, human health, and ecological consequences.
In this project, we aim to perform thorough life cycle assessments (LCA) of several SALD processes, in order to assess their environmental impact and detect the key parameters to modify in order to reduce their carbon footprint and overall impact. For this purpose, the trainee will have the opportunity to perform SALD of ZnO as well as more complex processes such as SALD of palladium or copper oxides. Dedicated LCA softwares such as OpenLCA or Simapro will be used to carry the LCA. The key parameters will be modified to decrease the amount of energy and materials required for the given depositions. The project will address the research gap in quantifying and understanding the environmental impacts of SALD technology, and the LCA studies will provide a comprehensive data support for understanding the environmental impacts of SALD. Finally, the project also aims to use the results to create a database that will hopefully be extrapolated to other SALD but also ALD and CVD (chemical vapor deposition) processes, opening prospects for a sustainable scale-up of these technologies.

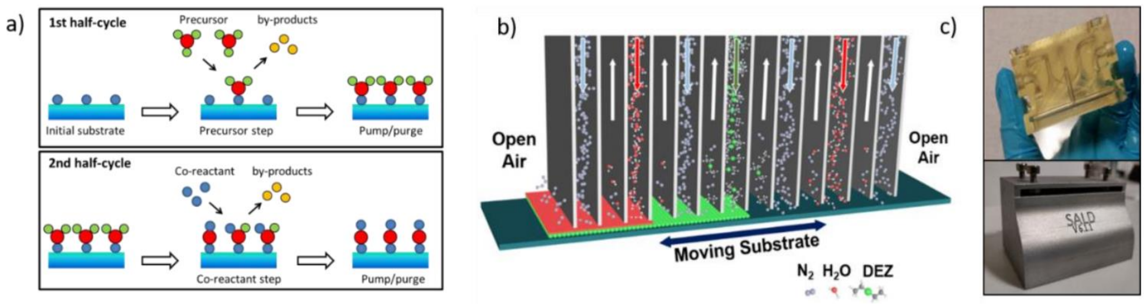

Figure 1. Scheme of a) ALD and b) SALD close–proximity approach showing the deposition of ZnO from diethyl zinc (DEZ) and water. c) Two diffusion heads used by LMGP, printed with either resin or metal, respectively.

References:

1. Ceballos, G., Ehrlich, P. R. & Dirzo, R. Biological annihilation via the ongoing sixth mass extinction signaled by vertebrate population losses and declines. *Proc. Natl. Acad. Sci.* **114**, E6089–E6096 (2017).
2. UN Report: Nature's Dangerous Decline 'Unprecedented'; Species Extinction Rates 'Accelerating'. https://www.un.org/sustainabledevelopment/blog/2019/05/nature-decline-unprecedented-report/ (2020).
3. Aujoux, C., Blanchard, O. & Kotera, K. How to assess the carbon footprint of a large-scale physics project. *Nat. Rev. Phys.* **3**, 386–387 (2021).
4. Mariette, J. *et al.* Product Carbon Footprint – A study on methodologies and initiatives. *bioRxiv* **1**–**5**, 457–466 (2010).
5. George, S. M. Atomic layer deposition: An overview. *Chem. Rev.* **110**, 111–131 (2010).
6. Munoz-Rojas, D. & MacManus-Driscoll, J. Spatial atmospheric atomic layer deposition: a new laboratory and industrial tool for low-cost photovoltaics. *Mater. Horizons* **1**, 314–320 (2014).
7. Weber, M. J., MacKus, A. J. M., Verheijen, M. A., Van Der Marel, C. & Kessels, W. M. M. Supported core/shell bimetallic nanoparticles synthesis by atomic layer deposition. *Chem. Mater.* **24**, (2012).
8. Westkämper, E., Alting, L. & Arndt, G. Life cycle management and assessment: approaches and visions towards sustainable manufacturing. *Proc. Inst. Mech. Eng. Part B J. Eng. Manuf.* **215**, 599–626 (2001).
9. Balgobin, T. & Evrard, D. A framework for modelling emerging processes' upscaling from an environmental perspective. *Procedia CIRP* **90**, 154–158 (2020).

Scientific environment:

The candidate will work within 2 laboratories, namely the LMGP, Materials and Physical Engineering Laboratory, in the SALD group and in the GSCOP laboratory, focused on the Conception, optimization and production of industrial processes. Located in the heart of an exceptional scientific environment, the LMGP and GSCOP laboratories offer the applicant a rewarding place to work.
LMGP Web Site: http://www.lmgp.grenoble-inp.fr/
LMGP Web site: https://g-scop.grenoble-inp.fr/

Profile & requested skills:

The trainee will work in 2 different laboratories in Grenoble (LMGP and GSCOP). The candidate should have a background in chemistry, physics or material science, and any experience with LCA would be highly appreciated. The trainee should be motivated, autonomous and comfortable in an international environment.

Subject could be continued with a PhD thesis: YES

Allowance: Internship allowance will be provided

CONTACTS

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