Sustainability and eco design of nanomaterials

Wednesday March 19th

10:30 A.M. - 12:30 A.M.

ROOM CD

Program of the session :

Chair: Emmanuel FLAHAUT

HOUR	NAME	TITLE
10:30	**Simon CLAVAGUERA** **LITEN - CEA**	**-**
11:00	Jamie SILK LMGP - Grenoble INP	Life Cycle Assessment of Metal Oxide Nanowires for Applications in Passive Atmospheric Water Collection
11:15	Gustavo Vinicios MUNHOZ GARCIA GET - CNRS	Glyphosate-based nanosystems: from design using natural polymers to toxicity in target and nontarget organisms
11:30	Chiddharth MUTHURAJ LCMCP - Soronne Univ.	Solvent free sol-gel strategy: The road to sustainability for the synthesis of oxides and mixed oxides based heterogeneous catalysts
11:45	Lucas NOLANN LERMaB - Univ. Lorrainne	Nanolignins for innovative materials
12:00	Gaëlle CHARRON MSC - Univ. Paris Cité	Surface enhanced Raman Scattering: the winding road from a fundamental phenomenon to action research
12:15	-	-

Abstract

Thematic Session: Sustainability and Eco-design of Nanomaterials
Disciplinary fields involved: Chemistry, Materials Science, Eco-design
Keywords (max. 4-5)**:** life cycle assessment, atmospheric water harvesting, nanowires, biphilic surfaces

Life Cycle Assessment of Metal Oxide Nanowires for Applications in Passive Atmospheric Water Collection

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Water is essential for human life, yet roughly two billion people worldwide still lack access to safely managed drinking water, with this number expected to increase through 2050 as a result of the climate crisis affecting global water supply [1]. Passive atmospheric water collection is a novel approach that aims to collect the large quantity of clean water stored in the Earth's atmosphere without ongoing electricity input, addressing climate change-induced water scarcity without further contributing to the climate crisis [2]. The goal of this study is to develop a device inspired by nature that combines a biphilic metal oxide nanowire film with a radiative cooling coating to passively harvest atmospheric water. To develop the biphilic nanowire film, both zinc oxide and cuprous oxide nanowires are considered due to their low cost, ease of fabrication, and safety for the human body. With the goal to develop the most environmentally sustainable device possible, a life cycle assessment (LCA) methodology is employed to quantitatively compare the environmental impacts of each of these nanomaterials and their synthesis methods in a variety of impact categories including global warming, water consumption, and ozone depletion. Further, LCA methodology is used to understand the largest contributing factors to these impact categories, which encourages further innovation in the design process to reduce negative impacts. The results of this LCA will be used to guide decision-making to design the most efficient passive atmospheric water harvester with the fewest negative impacts on the environment.

References:
[1] "The Sustainable Development Goals Report 2022," United Nations, New York, USA, Jul. 2022. Accessed: Apr. 17, 2024. [Online]. Available: https://unstats.un.org/sdgs/report/2022/
[2] H. Jarimi, R. Powell, and S. Riffat, "Review of sustainable methods for atmospheric water harvesting," International Journal of Low-Carbon Technologies, vol. 15, no. 2, pp. 253–276, May 2020, doi: 10.1093/ijlct/ctz072.

Thematic Session: Sustainability and eco design of nanomaterials.
Disciplinary fields involved: Chemistry, Agriculture, Biology.
Keywords: nanoparticle, sustainability, weed control, green chemistry.

Glyphosate-based nanosystems: from design using natural polymers to toxicity in target and nontarget organisms

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Abstract

Natural polymers have become a viable tool for smart-delivery of drugs and pesticides using nanotechnology. Glyphosate is the most used herbicide worldwide for weed control (0.7 Mt per year), being necessary in several crop systems. It is also a contaminant in the environment, due this high use, being necessary to optimize and reduce the amount used in agriculture. This work aimed to elaborated strategies to enhance glyphosate efficacy using polymeric nanosystems (zein, chitosan and lignin) to reduce the amount applied to the environment, as well as to control the toxicity to non-target organisms. System responses were assessed through toxicity to weed species, soil respiration (^{14}C-glucose mineralization), and soil enzyme activity (β-glucosidase and arylsulfatase). Zein + pluronic (ZN-PL) nanosystems in *A. hybridus* showed higher weed control efficacy (90-96%) at half the recommended dose, compared to the commercial glyphosate showing a moderate efficacy (40%) at full dose. A reduced control was proportioned by ZN-PL to *E. indica* (51%) and *I. grandifolia* (18%). No toxicity of glyphosate (both formulation) was observed in glyphosate-resistant crops, soil respiration, or soil enzymes. This work suggests that the ZN-PL system could be an alternative for glyphosate delivery with improved efficiency to *A. hybridus*, but the environmental impact is similar to the commercial glyphosate. It could yet be an interesting approach to reduce the doses applied on fields, while managing *A. hybridus* in agriculture using glyphosate, highlighting the potential of nanotechnology in contributing to a more efficient and rational agriculture.

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Thematic Session: Sustainability and eco design of nanomaterials
Disciplinary fields involved: Chemistry
Keywords: Sol-gel, sustainability, solvent-free, zirconia

"Solvent free sol-gel strategy" – The road to sustainability for the synthesis of oxides and mixed oxides based heterogeneous catalysts

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Catalysts play an essential role, significantly affecting processes across various industries and aspects of daily life. Though catalysts pave the way to provide sustainable chemical processes, the environmental burden caused in preparing a catalyst must also be taken into account. There are several strategies for synthesizing heterogeneous catalysts. All of them are environmentally detrimental.

We developed a new strategy called "solvent free sol-gel" which allows the synthesis of catalysts in a single step, without using any solvents, producing no waste, in a continuous process. Haddad et al., for the first time, used this approach to synthesize Ru doped γ-Al_2O_3 materials and used them for the CO_2 methanation reaction. They were able to synthesize high surface area materials ($700 m^2/g$) with good dispersion of Ru over the alumina support[1]. An assessment was carried out to demonstrate the energy efficiency of the process compared with the conventional industrial process, and a huge atom economy was achieved.

By taking this as a proof of concept, we wanted to extend this approach to other metal oxides in order to demonstrate its versatility and potential for rethinking an industry that is more respectful of the environment and in tune with energy issues. To do that, we work on zirconium oxides and doped zirconium oxide catalysts. It is a more challenging system than the former because the alkoxides of zirconium are highly reactive. We try to decrease the reactivity of the precursors using a chelating ligand. This approach has also been used to synthesize doped or mixed oxides which includes Ni/γ-Al_2O_3 and CeO_2 doped ZrO_2. The challenge in using multi-metallic system lies in choosing the right precursors. Yet the approach of solvent free sol-gel strategy can be applied to many chemical systems that can be used for a plethora of applications.

<u>Reference</u>

[1] Haddad R, Zhao Y, et al., Chemistry of Materials (2023) 8248-8260, 35(19).

Abstract

Thematic Session: Sustainability and eco design of nanomaterials
Disciplinary fields involved: Chemistry
Keywords): Nano-lignin, nanoparticles, Organosolv, Pickering emulsion, Biomass

Nanolignins for innovative materials

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Abstract :
In light of fossil resource depletion and the need for sustainable solutions, the interest for lignocellulosic biomass-derived products is always bigger. Among them, lignin, the most abundant renewable aromatic biopolymer, remains underutilized, often limited to energetic valorization[1], despite its antioxidant, UV protection, and antimicrobial properties, which could address various technical and industrial needs[2]. Waste produced by the wood industry or agriculture offers significant potential for extraction of macro-lignin.
In this work macro-lignin are firstly extracted using the eco-friendly organosolv process[3]. Then the nano-lignins are produced through an anti-solvent process[3-4]. Nano-lignins, with their small size (100-150 nm)[4], has a larger specific surface area, and a better homogeneity making their incorporation promising in various applications. One example of this valorization is the stabilization of Pickering emulsions. Pickering emulsions are widely used in the cosmetic[5] and pharmaceutical industries, particularly for encapsulating active ingredients. The majority of nanoparticles currently used are manufactured using environmentally detrimental processes, and thus, the study of the stability of Pickering emulsions stabilized with nano-lignins addresses this issue. To optimize this process, a parametric study is conducted, optimizing key factors such as the concentration of nano-lignins in suspension, the energy supplied for agitation, the oil/water ratio, and the lignin sources (Beech, Spruce, Wheat Straw). This study highlights the strong ability of nano-lignin to stabilize emulsions, notably through the achievement of emulsions stable for 60 days with a suspension concentration of only 5 mg/g.

References :
[1]Bajwa, D., et al. (2019). Industrial Crops And Products, 139, 111526. [2]Zhang, Z., et al. (2021). Nanomaterials, 11(5), 1336. [3]Girard, V., et al. (2024). ACS Sustainable Chemistry & Engineering, 12(18), 7055-7068. [4]Girard, V., et al. (2024). Nanomaterials, 14(22), 1786. https://doi.org/10.3390/nano14221786[5]Espinoza-Acosta, J. L., et al. (2021). (2016). BioResources, 11(2), 5452-5481.

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Abstract

Thematic Session: Sustainability
Disciplinary fields involved: physical chemistry, chemical analysis, scientific integrity
Keywords (max. 4-5)**: SERS, sensors, environmental analysis**

Surface enhanced Raman Scattering: the winding road from a fundamental phenomenon to action research

Gaëlle Charron[1]

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Abstract (**no longer than 250 words** or 18 lines max. incl. figure), Calibri 11, single line spacing, black)

Surface Enhanced Raman Scattering – SERS -, is a spectroscopic phenomenon that has been deemed groundbreaking for quantitative analysis of environmental contaminants since its first discovery 50 years ago.

Yet, about 1,500 research papers related to environmental applications of SERS later, only about 60 actually deal with the practical use of SERS as an analytical tool for monitoring contaminants. And only a handful claim quantitative measurements by non-expert users.

There is patent disconnection between the meaning of “applications” in the scientific community and the actual, routine use and impact of SERS outside of research labs. I experienced this disconnection through ten years of working on the development of frugal SERS-based sensors of aquatic contaminants that would be practical to use by non-expert communities. The considerations of cost, robustness and practicality were largely neglected in favour of the pursuit of exceptional sensitivity, more often than not without relevance to actual pollution issues.

Based on an original scientometric analysis, I will discuss were the research efforts of SERS for environmental monitoring have gone so far, and were they should go from now on in the context of increasing ethic pressure on conducting research with a positive impact on sustainability.