16 April 2024

PhD contract offer

Optimisation of the structural and liquid water diffusion properties of carbons architected by 3D printing of biosourced resins for the development of solar evaporators

General information

Workplace: Epinal, France
Type of contract: PhD contract funded by the National Research Agency with PRIMA Med program
Contract period: 36 months
Compensation : 2100€ growth salary/month
Expected date of employment: October 1st 2024
Proportion of work: Full time
Desired level of education: Master's degree in materials science or chemistry
Experience required: -

Subject description

The countries of the Mediterranean basin produce around 97% of the world's olives, representing up to 3 million tons of olive oil per year. The various olive oil extraction processes generate huge quantities of solid and liquid waste. It is estimated that processing one ton of olives generates an average of 1 m^3 of oil mill wastewater (OMWW). This project aims to treat and recover toxic OMWW in line with the principles of green and sustainable chemistry for a circular economy. Current regulations allow only a small proportion of these materials to be applied directly to land, and manufacturers are looking for other ways of managing this toxic liquid waste.

The proposed solution is to use solar distillation, a process that has the advantage of having a low environmental impact, to treat the effluents from olive oil production in order to accelerate their evaporation/drying so that they can be better processed and recovered. The solar distiller developed for this project will consist of an evaporation cell and a condensation cell (Figure 1a and b). The thesis proposal will be to develop the evaporation cell. The special feature of this evaporation cell is that it uses a porous 3D carbon matrix produced by 3D printing (stereolithography), after pyrolysis of biosourced resins (Figure 1d). The role of this 3D matrix is to intensify evaporation performance by (i) increasing the exchange surface between the water to be purified and the surrounding air and (ii) capturing solar flux thanks to the carbon's high solar radiation absorption capacity (Figure 1d).

Promising initial evaporation trials have been carried out with these 3D evaporative matrices, but limitations in terms of the diffusion of liquid water within the porous structure have been identified. The main obstacle to the diffusion of liquid water is the small size of the pores on the surface of the porous structure (0.7 nm, whereas the core is of the order of 10 µm).

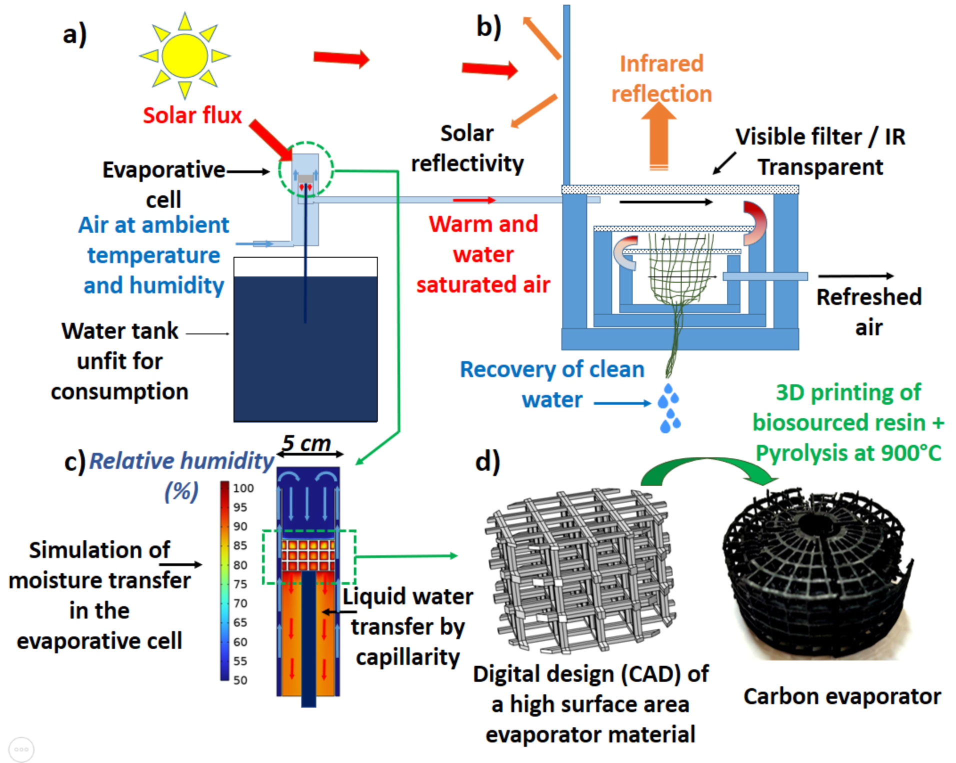

Figure 1: Scheme of the evaporation (a) and condensation (b) system; (c) Zoom on the evaporative cell coupled with a simulation of moisture transfers in the case where a water-saturated evaporator material is positioned in the center of the cell;(d) Example of a carbon structure with high exchange area printed in 3D by UL - IJL.

The aim of the thesis will be to optimize the structural and liquid water diffusion properties of 3D carbon matrices for the development of solar evaporators. The work will involve developing solutions at several scales:

(i) On a microscopic scale, the aim will be to develop biosourced resins that can control the structural properties (porosity, pore size, etc.) of the porous matrix. As these properties are directly correlated with liquid water diffusion performance, the pore size needs to be increased at the surface and reduced at the core. To achieve this objective, innovative resin formulations could be proposed, in particular with the addition of porogens. Another possibility is to improve the hydrophilic nature of the structures by post-treatment with CO2 or steam, or by chemical treatment (oxidation by acid-base treatment).

(ii) On a macroscopic scale, the design of the 3D matrix will be studied. A methodological approach of the experimental design type is envisaged to quantify the impact of certain parameters on performance, such as the height of the cell, the thickness of the strands allowing water to be transferred and the space between the strands.

Once the properties have been optimized, the 3D matrices will be integrated into a prototype in order to study the performance of the evaporation cell in the laboratory. The system will be studied using our experimental test bench. Initially, evaporation performance will be studied with pure water, then with nutrient- and salt-laden water to get closer to the OMWW context.

In previous work, a numerical model was developed to simulate mass and heat transfer within the evaporation cell. It will be necessary to learn how to use and develop this model as a tool for optimizing evaporation performance. By going back and forth between the model and the experimental prototype, it will be possible to optimize the design and maximize performance

Keywords: Bio-based resins; Additive manufacturing; Stereolithography; Porous carbons; 3D architectures, Liquid water diffusion, Solar evaporation

References:

[1]P. Blyweert, V. Nicolas, V. Fierro, A. Celzard, 3D-Printed Carbons with Improved Properties and Oxidation Resistance, ACS Sustainable Chem. Eng. (2023). https://doi.org/10.1021/acssuschemeng.3c00152.
[2]P. Blyweert, V. Nicolas, J. Macutkevic, V. Fierro, A. Celzard, Tannin-Based Resins for 3D printing of Porous Carbon Architectures, ACS Sustainable Chem. Eng. 10 (2022) 7702–7711. https://doi.org/10.1021/acssuschemeng.2c01686.
[3]P. Blyweert, V. Nicolas, V. Fierro, A. Celzard, Experimental Design Optimization of Acrylate—Tannin Photocurable Resins for 3D Printing of Bio-Based Porous Carbon Architectures, Molecules 27 (2022) 2091. https://doi.org/10.3390/molecules27072091.
[4]R. Fillet, V. Nicolas, V. Fierro, A. Celzard, Modelling heat and mass transfer in solar evaporation systems, International Journal of Heat and Mass Transfer 181 (2021) 121852. https://doi.org/10.1016/j.ijheatmasstransfer.2021.121852.
[5]R. Fillet, V. Nicolas, A. Celzard, V. Fierro, Solar evaporation performance of 3D-printed concave structures filled with activated carbon under low convective flow, Chemical Engineering Journal 457 (2023) 141168. https://doi.org/10.1016/j.cej.2022.141168.

Work context

This thesis is part of an overall project called 3D-STELLAR (PRIMA SECTION 2 2023 - MULTI-TOPIC call for projects), which aims to treat and recover toxic wastewater from oil mills (OMWW). Olive oil is obtained by pressing, which generates lipid residues made up of pulp, stones and water, which are sent to decantation tanks. Current regulations allow only a small proportion of this material to be spread directly on land, so the industry and public authorities are looking for alternative solutions to manage this toxic liquid waste. 3D-STELLAR will treat these effluents and transform them into irrigation water and high added-value carbon products. This will be done by producing clean water for irrigation and biochars of different compositions for several applications.
This thesis will form part of this project and will follow on from two previous theses: one developing carbon architectures using 3D printing of biosourced resins, and the other starting to use these matrices for evaporation as part of the development of a solar distiller.

Skills

The candidate will join a research team specialised in materials science, the "Biosourced Materials" team from the Jean Lamour Institute (IJL, UMR CNRS 7198), housed at the ENSTIB premises in Epinal. He/she must have followed training in solid-state chemistry or materials science as a priority, but knowledge of additive manufacturing will be particularly appreciated. The candidate must demonstrate great ease with the materials processing and characterization tools (3D printer, UV-visible spectrometer, UV source, cone-plate viscometer and TGA / DSC) on which he/she will be trained to become quickly autonomous. Knowledge in computer-aided design (CAD), in numerical simulation, on natural substances, polymers and polymerisation processes will be a plus. He/she must be dynamic, curious and persevering to carry out the multiple syntheses, characterisations, tests and interpretations of the results, and demonstrate the ability to work in a team.

Constraints and risks

The position you are applying for is located in a sector relating to the protection of scientific and technical potential. It therefore requires, in accordance with the regulations, that your arrival be authorized by the competent authority of the Ministry of Higher Education, Research and Innovation.

About Institut Jean Lamour

The Institute Jean Lamour (IJL) is a joint research unit of CNRS and Université de Lorraine.
Focused on materials and processes science and engineering, it covers: materials, metallurgy, plasmas, surfaces, nanomaterials and electronics.
The IJL has 263 permanent staff (30 researchers, 134 teacher-researchers, 99 IT-BIATSS) and 394 non-permanent staff (182 doctoral students, 62 post-doctoral students / contractual researchers and more than 150 trainees), of 45 different nationalities.
Partnerships exist with 150 companies and our research groups collaborate with more than 30 countries throughout the world.

Its exceptional instrumental platforms are spread over 4 sites ; the main one is located on Artem campus in Nancy.

Application

Only high quality applications will be considered: Master 2 average ≥ 14/20, 1st quartile, international experience required. Applicants who do not meet these requirements are asked not to submit an application.
Highly qualified applicants are invited to send a CV and a motivation letter, together with diploma copies and/or marks obtained during the Master degree on the C2MP doctoral school's online recruitment application for 1st May 2024:
http://doctorat.univ-lorraine.fr/fr/les-ecoles-doctorales/c2mp/offres-de-these/optimisation-des-proprietes-structurales-et-de-diffusion

Then, interviews will be organised and visits of the labs will be possible on request.

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