

MASTER DE CHIMIE DE SORBONNE UNIVERSITE

Proposition de stage 2026-2027

Internship Proposal 2026-2027

Parcours type(s) / Specialty(ies) :

- ☐ Chimie Analytique, Théorique, Spectroscopies et Electrochimie/ *Analytical, Theoretical Chemistry, Spectroscopies, Electrochemistry*
- ☒ Chimie Moléculaire / *Molecular Chemistry*
- ☒ Chimie des Matériaux / *Materials Chemistry*
- ☒ Ingénierie Chimique / *Chemical Engineering*

Laboratoire d'accueil / Host Institution

Intitulés / *Name* : Laboratoire de Réactivité de Surface

Adresse / *Address* : Tours 43-53 étage 3 - Campus Pierre et Marie Curie

Directeur / *Director (legal representative)* : Dr Vincent VIVIER

Tél / *Tel* : 01 44 27 55 21

E-mail : vincent.vivier@sorbonne-universite.fr

Equipe d'accueil / Hosting Team :

Adresse / *Address* : Tours 43-53 étage 3 - Campus Pierre et Marie Curie

Responsable équipe / *Team leader*: Dr G. COSTENTIN

Site Web / *Web site*: <https://lrs.sorbonne-universite.fr/la-recherche-au-lrs/theme-3-catalyse-du-nanomateriau-la-reactivite-du-site-actif>

Responsable du stage (encadrant) / *Direct Supervisor* : Franck LAUNAY

<https://lrs.sorbonne-universite.fr/personnes-lrs/franck-launay>

Fonction / *Position* : Professor

Tél / *Tel* : 01 44 27 58 75

E-mail : franck.launay@sorbonne-universite.fr

Période de stage / *Internship period* * : 25 janvier au 23 juillet 2027

Preparation and characterization of heterogeneous photocatalysts based on micro-sized SiO₂ platforms bearing sulfonic groups for polystyrene upcycling

Projet scientifique du stage (1 à 2 pages) / Internship scientific Project (1 to 2 pages) :

1. Contexte de l'étude / Background

Polystyrene (PS) accounts for *c.a.* 5% of the worldwide plastic production (20 Mt/y) [1] but used PS is often incinerated due to the high stability of its backbone. Recently, there has been a growing interest for the chemical recycling of PS, for example, through its high temperature depolymerization into styrene, as patented by Ineos Styrosolution [2]. A complementary and attractive strategy is **chemical upcycling**, which aims at converting PS selectively into value-added chemicals. Several photocatalysts (PC) have been investigated to induce the aerobic oxidative cleavage of PS into benzoic acid [3]. Such reaction is initiated by a Hydrogen Atom Transfer (HAT) step (Fig. 1), then PS benzylic radicals are trapped by molecular O₂ to produce tertiary hydroperoxides, then tertiary alkoxy radicals undergo an homolytic β-C-C cleavage. Under irradiation, the interaction of strong acids with the aromatic rings of PS can be at the origin of the production of ¹O₂ which is known to be a HAT promoter. Recently,

* min. 5 mois, maximum 6 mois à partir du 25 janvier 2027 / *min. 5 months and max. 6 months not earlier than January, 25th 2027.*

Fin des conventions de stage au plus tard le 15/07/2027 ou le 15/09/2027 et le 15 novembre 2027. *End of internship at the latest July 15th, 2027 or September. 15th, 2027 and November 15th, 2027.*

the LRS team has developed a PC-free and recyclable catalytic system based on solids bearing sulfonic groups such as Nafion™ affording benzoic acid from PS with relatively high yields (70%) and running under visible light [4]. However, such system has limited quantum efficiency.

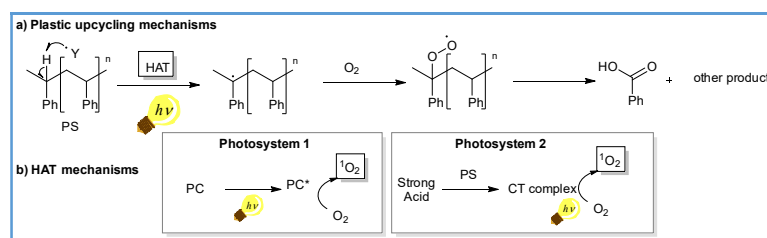


Fig. 1. Mechanisms for the photooxidative upcycling of PS

2. Description du projet / Description of the project

While most of the reported works dealing with PS upcycling were carried out at small scales in batch reactors requiring very long irradiation times, the **UpPhotoFlow** consortium[†] proposes the implementation of innovative heterogeneous organic (photo)catalysts with continuous-flow LED-driven processing strategies. It is hypothesized that grafting soluble PCs and/or strong acids onto silica-based supports could offer a recyclable and scalable solution with enhanced photostability and promote an alternative C-C cleavage affording phenol. Based on **LRS** and its partner **CNAM** backgrounds, three families of supported catalysts will be prepared by immobilizing (i) sulfonic acids (enabling ¹O₂ generation in the presence of PS under visible light), (ii) Near-infrared responsive PCs [5] and ultimately (iii) both PCs and acid functions. *This Master's (M2) internship which may be extended into a PhD project funded by the ANR will be dedicated to the immobilization of the sulfonic acids (Fig. 2).*



Fig. 2. Targeted materials

Silica samples with high specific surface area are expected to display a greater density of acid sites than commercially available resins while being resistant to shrinking or swelling induced by the organic solvents used. Well-defined micro-sized SiO₂ with tunable size and surface reactivity will be prepared using the Stöber method (seeded growth) [6]. These should measure tens of microns which is suitable for the catalyst dispersion and the use of centrifugation for recycling purposes (after flow experiments). To introduce acid functionalities (SiO₂@SO₃H), **LRS** will employ post-synthetic sulfonation using chlorosulfonyl reagents [7] or thiols.

3. Techniques ou méthodes utilisées / Specific techniques or methods

All synthesized materials will undergo comprehensive characterization particle size distribution (DLS, TEM, SEM) and surface chemistry evaluation (N₂ physisorption, TGA, FTIR, XPS, MAS NMR). Particular attention will be given to particle size effects, as micrometric materials are better suited for continuous-flow processes using slurry Taylor flows configurations. The (photo)catalytic activity of these solids will be compared to that of Nafion™ and Amberlyst™ under visible-light irradiation [4]. The reaction will be monitored by size-exclusion chromatography and ¹H NMR.

We are seeking a Master's or engineer student with experience and/or knowledge in materials chemistry and heterogeneous (photo)catalysis.

4. Références / References

- [1] Plastics Europe Plastics Europe (2022), <https://plasticseurope.org/knowledge-hub/plastics-the-facts-2022/>.
- [2] Niessner et al. (2024), Patent US11999686 (B2), Ineos Styrolution Group GmbH.
- [3] Wang, Wen, Huang & Hu *ChemSusChem* (2021), 14, 5049-5056, DOI: 10.1002/cssc.202101762; Oh & Stache *J Am Chem Soc* (2022), 144, 5745-5749, DOI: 10.1021/jacs.2c01411; Li et al. *ACS Catal* (2022), 12, 8155-8163, DOI: 10.1021/acscatal.2c02292; Nikitas, Skolia, Gkizis, Triandafillidi & Kokotos *Green Chem* (2023), 25, 4750-4759, DOI: 10.1039/D3GC00986F; De Abreu, Taton & Bassani *Angew Chem Int Ed* (2025), 64, e202418680, DOI: 10.1002/anie.202418680.
- [4] Chen & Launay *Chem. Eur. J.* (2026) 32, e71025.
- [5] Fortier, Lefebvre & Hoffmann *Beilstein J Org Chem* (2025), 21, 296-326, DOI: 10.3762/bjoc.21.22; Lancel et al. *ACS Sus Chem. Eng* (2023), 11, 15674-15684, DOI: 10.1021/acssuschemeng.3c04688.
- [6] Han et al. *Langmuir* (2017), 33, 5879-5890, DOI: 10.1021/acs.langmuir.7b01140.
- [7] Habib et al. *J Mol Cat A: Chem* (2007), 271, 117-125, DOI: 10.1016/j.molcata.2007.02.022.

[†] **UpPhotoFlow ANR project** – Plastic upcycling using continuous-flow photooxidation processes with recyclable photocatalysts.
Partners N°1 : LRS – CNRS / Sorbonne Université • N°2 GBSM – CNAM • N°3 IPREM – CNRS / Université de Pau et des Pays de l'Adour • N°4 LGC – CNRS / INP–Université Paul Sabatier.