

MASTER DE CHIMIE DE PARIS CENTRE - M2S2

Proposition de stage 2025-2026

Internship Proposal 2025-2026

Parcours type(s) / Specialty(ies) :

- ☐ Chimie Analytique, Physique et Théorique / *Analytical, Physical and Theoretical Chemistry* :
☐ Chimie Moléculaire / *Molecular Chemistry* :
☐ Chimie et Sciences Du Vivant / *Chemistry and Life Sciences* :
☒ Chimie des Matériaux / *Materials Chemistry* :
☒ Ingénierie Chimique / *Chemical Engineering* :

Laboratoire d'accueil / Host Institution

Intitulés / *Name* : Laboratoire de Réactivité de Surface (LRS) – UMR 7197

Adresse / *Address* : Campus Pierre et Marie Curie, Tours 43-33, 43-44 et 43-53, 3^{ème} étage

Directeur / *Director (legal representative)* : Vincent Vivier

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Equipe d'accueil / Hosting Team : -

Adresse / *Address* : Campus Pierre et Marie Curie, Tours 43-33, 43-44 et 43-53, 3^{ème} étage

Responsable équipe / *Team leader* : -

Site Web / *Web site* : <http://www.lrs.sorbonne-universite.fr>

Responsable du stage (encadrant) / *Direct Supervisor* : Josefine Schnee & Alberto Mezzetti

Fonction / *Position* : Chargée de recherche CNRS

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Période de stage / *Internship period* * : February - July 2026

Titre / Title

Metal exsolution from nanozymes for improving catalytic reactions involved in cancer treatments

Projet scientifique (1 page maximum) / Scientific Project (maximum 1 page) :

1. Contexte de l'étude / Background

Cancer is one of the leading causes of human mortality. Although treatment strategies such as radiotherapy, chemotherapy and immunotherapy have been developed and validated for various types of cancers, the clinical efficiency of these therapies is still restricted. Radiation resistance, drug insensitivity, toxic side effects and immunodeficiency remain important hurdles. To relieve or counterbalance the latter, and ultimately win the fight against cancer, scientists are constantly seeking novel increasingly efficient therapeutic routes/agents to be combined with the traditional therapies. The currently rising star in that context is called “nanozymes”.^{1,2} Nanozymes are nanomaterials (typically materials with a size of 1-100 nm) with enzyme-mimicking properties. One of the first examples of nanozymes, discovered by Yan and coworkers in 2007, were Fe₃O₄ nanoparticles showing intrinsic peroxidase (POD)-mimicking catalytic activity, by converting H₂O₂ into hydroxyl radicals (•OH). Since then, thousands of nanozymes have been

* min. 5 mois maximum 6 mois à partir du 26 janv 2026 / *min. 5 months and max. 6 months not earlier than January, 26th 2026.*

Fin des conventions de stage au plus tard le 15/07/2026 ou le 15/09/2026 et le 15 novembre 2026.

End of internship at the latest July 15th, 2026 or September 15th, 2026 and November 15th, 2026.

found, with applications in various fields such as environmental protection, biosensing, catalysis and nanomedicine.^{1,3,4,5} Compared with natural enzymes, nanozymes are less expensive, easier to produce, to modify and to store, more stable, more tolerant to surrounding environments. Moreover, the unique physico-chemical properties of nanomaterials often endow nanozymes with the ability to mimic several enzymes at a time, and provide far more opportunities for rational design than natural enzymes.^{4,6,7,8} In particular, nanozymes showing POD-like, catalase (CAT)-like, oxidase (OXD)-like, superoxide dismutase (SOD)-like, glutathione peroxidase (GPx)-like and/or glucose oxidase (GOD)-like catalytic activities stand at the heart of cutting-edge multi-mode strategies for synergistic treatment of solid tumors.¹ Under pathological conditions in which natural enzymes are quickly inactivated, the above-mentioned nanozymes are able to efficiently catalyze a series of key chemical reactions leading to the death of tumor cells.

2. Description du projet / *Description of the project*

The present project aims at improving the above-mentioned key chemical reactions by tuning the properties of nanozymes through a concept that is up to now restricted to the field of heterogeneous catalysis out of the medical context, namely metal exsolution. The latter phenomenon is reported mainly in the literature on perovskite materials. It consists in the migration of metals incorporated on bulk sites of the material towards the surface under a reducing thermal treatment. It leads to metal nanoparticles having a controlled size and distribution (depending on the temperature, the composition of the reducing atmosphere, etc.), and being socketed at the surface, thus unable to leach under liquid-phase catalytic reaction conditions.⁹ In the internship, nanozymes will be prepared, characterized by various physico-chemical approaches before and after exsolution treatments, and investigated as catalysts for chosen liquid-phase chemical reactions involved in cancer treatments. These catalytic investigations will be conducted with *in situ/operando* monitoring the nanozymes through time-resolved attenuated total reflectance (ATR) - infrared (IR) spectroscopy, in order to get mechanistic insight to be able to improve the properties of the nanozymes in a controlled way.

3. Techniques ou méthodes utilisées / *Specific techniques or methods*

Materials will be prepared by various approaches, and their physicochemical properties will be characterized by multiple techniques such as inductively coupled plasma atomic emission spectroscopy (ICP-AES), infrared, UV-Visible and Raman spectroscopies, nuclear magnetic resonance (NMR) spectroscopy, X-ray (thermo-)diffraction ((thermo-)XRD), X-ray photoelectron spectroscopy (XPS), transmission and scanning electron microscopies, N₂ physisorption, H₂-temperature programmed reduction, etc. Catalytic evaluations will be conducted in liquid phase with *in situ/operando* ATR-IR.

4. Références / *References*

1. Wang, Q.; Liu, J.; He, L.; Liu, S.; Yang, P., Nanozyme: a rising star for cancer therapy. *Nanoscale* **2023**, *15* (30), 12455-12463.
2. P. N, N.; Mehla, S.; Begum, A.; Chaturvedi, H. K.; Ojha, R.; Hartinger, C.; Plebanski, M.; Bhargava, S. K., Smart Nanozymes for Cancer Therapy: The Next Frontier in Oncology. *Advanced Healthcare Materials* **2023**, *n/a* (n/a), 2300768.
3. Cao, C.; Yang, N.; Wang, X.; Shao, J.; Song, X.; Liang, C.; Wang, W.; Dong, X., Biomedicine meets nanozyme catalytic chemistry. *Coordination Chemistry Reviews* **2023**, *491*, 215245.
4. Wu, J.; Wang, X.; Wang, Q.; Lou, Z.; Li, S.; Zhu, Y.; Qin, L.; Wei, H., Nanomaterials with enzyme-like characteristics (nanozymes): next-generation artificial enzymes (II). *Chemical Society Reviews* **2019**, *48* (4), 1004-1076.
5. Wei, H.; Wang, E., Nanomaterials with enzyme-like characteristics (nanozymes): next-generation artificial enzymes. *Chemical Society Reviews* **2013**, *42* (14), 6060-6093.
6. Yang, W.; Yang, X.; Zhu, L.; Chu, H.; Li, X.; Xu, W., Nanozymes: Activity origin, catalytic mechanism, and biological application. *Coordination Chemistry Reviews* **2021**, *448*, 214170.
7. Zhang, Q.; Song, L.; Zhang, K., Breakthroughs in nanozyme-inspired application diversity. *Materials Chemistry Frontiers* **2023**, *7* (1), 44-64.
8. Tang, G.; He, J.; Liu, J.; Yan, X.; Fan, K., Nanozyme for tumor therapy: Surface modification matters. *Exploration (Beijing)* **2021**, *1* (1), 75-89.
9. Kwon, O.; Sengodan, S.; Kim, K.; Kim, G.; Jeong, H. Y.; Shin, J.; Ju, Y.-W.; Han, J. W.; Kim, G., Exsolution trends and co-segregation aspects of self-grown catalyst nanoparticles in perovskites. *Nature Communications* **2017**, *8* (1), 15967.