MASTER DE CHIMIE DE SORBONNE UNIVERSITE
Proposition de stage 2025-26
Internship Proposal 2025-26

Parcours type(s) / *Specialty(ies) :*

☐ Chimie Analytique, Théorique, Spectroscopies et Electrochimie/ *Analytical, Theoretical Chemistry, Spectroscopies, Electrochemistry*

☐ Chimie Moléculaire / *Molecular Chemistry*

X Chimie des Matériaux / *Materials Chemistry*

☐ Ingénierie Chimique / *Chemical Engineering*

Laboratoire d'accueil / *Host Institution*

Intitulés / *Name* : Chimie du Solide et Energie (CSE)
Adresse / *Address* : Collège de France, 11 place Marcelin-Berthelot, 75005, Paris
Directeur / *Director (legal representative) : Jean-Marie Tarascon*
Tél / *Tel* : 06 23 02 39 36
E-mail : jean-marie.tarascon@college-de-france.fr

Equipe d'accueil / *Hosting Team : Synthesis team*

Adresse / *Address :* 11 place Marcelin-Berthelot, 75005, Paris
Responsable équipe / *Team leader* : Jean-Marie Tarascon
Site Web / *Web site :* Solid-State Chemistry and Energy Lab – Research towards better energy storage and conversion systems
Responsable du stage (encadrant) / *Direct Supervisor : Clément Morel*
Fonction / *Position : 2nd year PhD student*
Tél / *Tel* : 06 37 73 01 25
E-mail : clement.morel@college-de-france.fr

Période de stage / *Internship period* * : 6 mois (février – juillet 2026)

* **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.

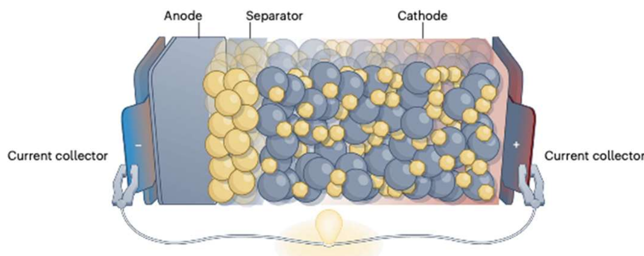
Titre

Towards new high entropy solid electrolytes for all solid-state batteries

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

One of the major society challenges is the development of new energy storage technologies. Great hopes lie in lithium ion batteries for which numerous innovation led this technology to reach a level of performance beyond our expectations. However, the need for batteries having higher energy density, power and safety while enhancing environmental concerns is pushing the interest for all-solid-state batteries in which the liquid electrolyte is replaced by a non-flammable solid electrolyte capable of pairing with lithium metal. Present research is mainly parted in mastering the solid-solid interfaces and identifying new and better solid electrolytes.

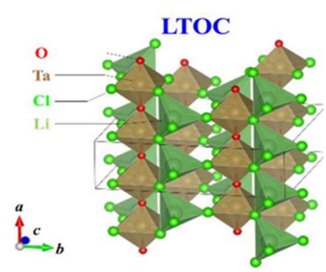
The aim of this internship will be to discover and synthesize new solid electrolytes and characterize their main features that are their structure, their ionic conductivity and their electrochemical stability. The best identified material will lately be tested in a real all-solid-state battery.



Scheme of an all-solid-state battery[1]

Currently, there are many different families of solid electrolytes such as the oxides, the sulfides, the argyrodites, or the halides and each one of them displays its own advantages and drawbacks in terms of ionic conductivity, electrochemical stability or toxicity.

Recently, a new class of solid electrolytes referred as oxyhalides just emerged displaying a high ionic conductivity of around 10 mS.cm^{-1} along with a high potential stability (stable up to 4.5 V vs Li^+/Li) enabling them to be used with high voltage cathodes. Tanaka et al.[2] discovered a new material of formula $LiTaOCl_4$ reaching a conductivity of 12 mS.cm^{-1} at room temperature and crystallizing in the $Cmc2_1$ space group.



Crystal structure of orthorhombic $LiTaOCl_4$[2]

Moreover, a new concept of high entropy materials just emerged in the past few years. It consists of mixing multiple elements in near-equal proportions. This allow us to tune the conductivity or the reactivity of the basis material by modifying its composition[3]. In our case, it would consist of synthesizing materials having the formula $LiTaOCl_{4-x-y-z}Br_yF_z$. The intern will have the freedom to synthesize all the compositions he wants in order to find the best one.

The experimental methods will include materials synthesis relying either on ceramic or mechano-chemical synthesis. The obtained phases will be structurally characterized by XRD and complementary techniques such as PDF will be performed at large instrument. Other techniques such as NMR or SEM can also be performed with the collaborating teams of the CSE. Then, based on the CSE experience, impedance to measure ionic conductivity and galvanostatic charge-discharge in all-solid-state cells to test the material in battery configuration will be performed.

Previous experiences in inorganic chemistry, crystallography, or electrochemistry will be appreciated.
Highly motivated, eager to learn and hardworking students that can speak English are solely welcome.

1. Janek, J. & Zeier, W. G. Challenges in speeding up solid-state battery development. *Nat Energy* **8**, 230–240 (2023).
2. Tanaka, Y. *et al.* New Oxyhalide Solid Electrolytes with High Lithium Ionic Conductivity >10 mS cm^{-1} for All-Solid-State Batteries. *Angewandte Chemie* **135**, e202217581 (2023).
3. Hou, W. *et al.* Deciphering Key Features Determining Electrochemical Stability and Conductivity of Halide Solid-State Electrolytes. *Advanced Functional Materials* **n/a**, e24886.