Position Description

1. General Information

Name of the position	**High energy Metal-ion batteries developed with electrolytes based on Organic Ionic Plastic Crystals and stabilized solid-solid electrode-electrolyte interfaces**
Foreseen enrolment date	Between July and November 2024
Position is funded by	• COFUND, Marie Skłodowska-Curie Actions (MSCA), Horizon Europe, European Union • Centre National de la Recherche Scientifique (CNRS) • Deakin University
Research Host	Centre National de la Recherche Scientifique - Institut de Chimie de la Matière Condensée de Bordeaux (UMR5026)
PhD awarding institutions	Université de Bordeaux & Deakin University
Locations	Primary: Pessac, France Secondary: Melbourne, Australia
Supervisors	Laurence Croguennec and Jacob Olchowka (ICMCB, Bordeaux University) Jenny Pringle (IFM, Deakin University)
Group of discipline	Electrochemical energy storage, batteries, inorganic electrode and organic electrolyte materials for energy, material sciences

2. Research topics (only one of these projects will be funded)

Project 1: *High energy Metal-ion batteries developed with electrolytes based on Organic Ionic Plastic Crystals and stabilized solid-solid electrode-electrolyte interfaces*
It is critical today to explore other strategies to increase the energy density delivered by Lithium-ion batteries and thus meet the ever-increasing needs of applications (transport, storage of renewable energies etc.) in terms of autonomy. All solid state batteries appear as the technologies of choice, by replacing the liquid electrolyte by a solid electrolyte

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and the graphite negative electrode by lithium metal. However, the challenges remain numerous, the main one being the control of chemical and mechanical properties at solid-solid interfaces.

The aim here is to use spinel type manganese-rich compounds, bare or modified at their surface, at the positive electrode and new organic ionic plastic crystals (OIPC) as electrolytes. Indeed, the OIPC type solid electrolytes are in their pristine state rather gels, greatly facilitating the shaping of electrochemical cells and the shaping/wettability of the electrode-electrolyte interfaces. This point is crucial to maintain both conduction and mechanical properties over long range cycling. The objective of this project is to study and understand the reactions occurring at the interfaces between electrode materials and OIPCs in all-solid batteries, and to optimize both the electrode material and the electrolyte for improved battery performance and extended life.

The project will be performed in close collaboration between IFM at Deakin university (Australia) and Tecnalia (France), both expert in development of electrolytes, and ICMCB at Bordeaux University (France) expert in the development of electrode materials for batteries.

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Project 2: *Development of stable lithium ion batteries utilizing high voltage cathodes and solid state plastic crystal electrolytes*

Increasing energy demands throughout society, e.g. for transport, renewable energy storage etc., requires a continued improvement in the energy density of lithium ion batteries. Improving the safety of these devices is also critical, particularly for EV applications. In the drive to develop stable, high energy density lithium ion batteries it is essential to explore both new electrode materials, such as lithium metal anodes and high voltage cathodes, combined with new electrolytes, and to overcome the current challenges associated with control of the interfaces between these different components.

This project will use spinel type manganese-rich compounds, bare or modified at their surface, as the positive electrode to allow realization of high voltages. These will be combined with new solid-state electrolytes because solid electrolytes are highly advantageous for safety and stability. The new electrolyte materials, based on organic ionic plastic crystals (OIPCs), are composed entirely of ions and thus have the advantage of being inflammable and having negligible vapor pressure. The chemical, physical and electrochemical properties of the OIPCs can be modified by changing the nature of the cation and anion and thus there is significant scope for optimizing the materials and the device performance.

In order to utilize the combinations of novel cathode and electrolyte materials, this project will address the challenges of maintaining both conduction and mechanical properties over long range cell cycling. This will be achieved by studying the interfacial reactions occurring at the electrode/electrolyte interface, how this evolves with cycling, and how it changes depending on the nature of the electrode and electrolyte materials. This strategy will allow us to optimize both the electrode material and the electrolyte for improved battery performance and extended life.

The project will be performed in close collaboration between IFM at Deakin University (Australia) and Tecnalia (France), both experts in the development of electrolytes, and ICMCB at Bordeaux University (France) expert in the development of electrode materials for batteries.

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Project 3: *Advancement of the energy density and stability of solid state lithium ion batteries by investigation of novel cathode and electrolyte materials*

Lithium ion batteries have become an essential part of our everyday lives and their demand continues to increase, for use in a wide range of applications from transport to portable electronics to stationary storage for renewables. Advancement of these applications requires improving the energy density and safety of lithium batteries, which can be achieved by a number of different strategies. Lithium metal can be used as the anode, but successfully using this reactive metal requires careful selection of the electrolyte and understanding and controlling the properties of the electrode/electrolyte interface. High voltage cathodes, such as those based on manganese-rich compounds, are under development to improve the energy density of lithium ion batteries, and these require combination with high electrochemical stability electrolytes. Finally, the use of solid-state electrolytes instead of liquid electrolytes can be very advantageous for safety, reducing leakage and flammability and allowing use of more reactive electrodes. However, the challenge is to maintain good contact and ion conduction at the electrolyte/electrode interface. This project will utilise a range of materials and analysis techniques to investigate these approaches, to develop higher energy density lithium batteries.

Spinel type manganese-rich compounds, bare or modified at the surface, will be used as the positive electrode. These electrodes will be used in combination with novel quasi-solid-state electrolytes based on organic ionic plastic crystals (OIPCs). OIPCs are composed entirely of ions, with a wide range of possible chemical, thermal and transport properties depending on the type of ions used. They can be used to form quasi-solid-state electrolyte by mixing with lithium salts; these soft mechanical properties are advantageous for achieving good wettability with the electrode and maintaining good contact with cycling. However, there is much to be understood about the compatibility of OIPCs with different cathode materials and how this is affected by the nature of the two materials and by cycling. This will be investigated by studying the interfacial reactions with different electrolytes and electrodes, upon cell cycling under a range of different operating conditions. This understanding will be important for realizing the development of safer, more stable high energy density Li ion batteries.

The project will be performed in close collaboration between IFM at Deakin University (Australia) and Tecnalia (France), and ICMCB at Bordeaux University (France), supervised by experts in the development of electrolytes and electrode materials respectively.

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3. Employment Benefits and Conditions

CNRS offers a 36-months full-time work contract (with the option to extend up to a maximum of 42 months). The total working hours per week is 38.5h.

The remuneration, in line with the European Commission rules for Marie Skłodowska-Curie grant holders, will consist of a gross annual salary EUR 27,000. Of this amount, the estimated net salary to be perceived by the Researcher is EUR 1,850 per month. However, the definite amount to be received by the Researcher is subject to national tax legislation.

Benefits include

- Becoming a Marie Skłodowska-Curie fellow and be invited to join the Marie Curie Alumni Association.
- Access to all the necessary facilities and laboratories at Institut de Chimie de la Matière Condensée de Bordeaux (UMR5026) and Deakin University.
- Tuition fees exemption at both PhD awarding institutions.
- Yearly travel allowance to cover flights and accommodation for participating in AUFRANDE events.
- 10,000 EUR allowance to cover flights and living expenses for up to 12 months in Australia.
- 45 days paid holiday leave.
- French Social security coverage.
- Sick leave.
- Parental leave.

4. PhD enrolment

Successful candidates for this position will be enrolled by the following institutions and must comply with their specific entry requirements, in addition to AUFRANDE's conditions.

Applicants must hold a Master degree in chemistry, physics or a related field recognised in France or an equivalent qualification awarded following a training course.

Applicants should also meet the English Language Entrance requirement of IELTS 6.5 with no band below 6.

More information on the Université de Bordeaux' requirements

Visit the website: https://college-doctoral.u-bordeaux.fr/en/Graduate-Research-School/The-Doctoral-Schools/Chemical-sciences

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More information on Deakin University's requirements

Applicants must have completed a research project in a related area including a thesis which is equivalent to at least 25% of a year's full-time study with achievement of a grade for the project equivalent to a Deakin grade of 80% or equivalent.

Visit the website: https://www.deakin.edu.au/research/research-degrees-and-PhD/research-applications

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