Programa de Doctorat
Electroquímica Ciència i Tecnologia

PhD PROJECT

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Research line: Electroquímica Aplicada: Acumulació d'energia, corrosió, electrosíntesi, dispositius electroquímics

Thesis name: Sustainable batteries for portable devices

1. Introduction

The explosion of the internet of things concept (iOT) has caused an increasing demand of batteries. This fact, coupled with a trade model based on lineal economy results in the proportional generation of electronic compounds and batteries waste (e-waste). The unsustainable e-waste generation has raised an alarm due to the wide variety of their compounds[1] –specially heavy and non-ferrous metals– that end up in the landfills causing hazardous consequences to human health and environmental damage.

Despite the efforts of the European Union (EU) to implement regulations and social awareness to encourage safe disposal and e-waste recycling (e.g. RoHS Directive[2] , EuP Directive[3] and WEEE Directive[4]), only 45.7% of the batteries sold in the EU were collected for recycling during 2017, with the remaining ones being disposed of in an uncontrolled way. The situation is not better in other parts of the world, the United States of America do not even have an specific legislation at federal level. Each state applies its own approach, leaving to an inefficient reclining method (i.e. less than 30% of e-waste recycled in 2012). Same lack of regulation can be observed in other parts of the world like Australia, Africa or South America.[5,6]On the other hand, recovering these valuable metals (e.g. Au, Pt, etc.) has become a lucrative activity, gaining popularity in emerging economies such as China's, who is the biggest importer of globally generated e-waste. China holds three national-level legislative documents that were drafted to the problem of e-waste management. Despite this, there is a perceptible lack of effective enforcement and supervision, leading to the majority of imported e-waste being processed by the informal sectors with inappropriate infrastructures (i.e. small and backyard workshops).

Nowadays lithium-ion batteries are the mainly use energy storage systems for portable applications. Although, lithium is considered a low abundance resource and it has a high environmental impact during its extraction, in consequence its usage is only suitable in secondary batteries.[7] Oppositely, zinc-air and alkaline batteries –zinc-manganese oxide– are the commonly used primary batteries. The consumption of this type of batteries is expected to rise significantly in the following years, and proportionally the number of discarded batteries, due to the wide range of applications constantly increasing. The most unhopeful fact, is that primary batteries are designed in an unspecific way, meaning that usually the application adapts to a standardized battery format, which is in many cases oversized. Consequently, batteries are disposed of before its completely depletion.

Beyond doubt, rethinking the current battery production paradigm becomes mandatory, towards a more sustainable and eco-design batteries. Focusing efforts on finding rarely used biocompatible, biodegradable and environmentally friendly abundant materials alternatives.[8,9] Besides adapting the design, development and fabrication to the needs of an exhaustible resources planet, with the aim of preventing the environmental impact of the uncontrolled disposed of uncompleted depleted batteries.[10,11]

2. Objectives

Conceived under the sustainability standards this PhD aims to be completely align with the circular economy principle. Regarding this, the PhD main goal is to develop alternatives to the current batteries and electronic devices production by taking advantage from the intrinsic capabilities of natural abundant materials, imposing the requirements of small amount of energy to be produced and breaking free the necessity of toxic products in this area. In order to do this, new batteries concepts will be developed to adapt the energy storage to the user needs, from prototypes which can autonomously work and bring energy to remote areas (i.e. countryside, rural areas, farmlands, …) to new market applications of biodegradable batteries. In essence, the work here proposed aims to enrich the humanity's path towards a more sustainable way of living and producing.

3. Working plan and timeline

The development of PhD is involved inside the biodegradable and sustainable batteries research line from the SPEED research group.[10] Because of this reason, the origin point will be enhancing the PhD student knowledge from the previous *know-how* of the group. This will be done through the elaboration of a bio-friendly redox species catalogue. An exhaustive bibliography research will complete the already identify redox species and via an electrochemical characterization the potential species will be studied and its suitability to form a battery will be evaluated.

After a first classification of potential sustainable materials and the acquisition of the pre-settled group experience in batteries characterization, hydrogel preparation, eco-design and prototype fabrication the student is proposed to work in the development of different generic batteries prototypes.

This second part will be initiated with the development of an autonomous flow battery which will work as a result of the evaporation flow of its reactants. In first place, in order to demonstrate the possibility of mature this idea, a fluidic study of the evaporation flow will be done, in order to identify the variables which affect it and find how to control it. Afterwards, with the well-known flow, the evaporation flow battery performance will be properly characterized. Subsequently, the real prototype will be developed concentrating the efforts in using completely sustainable and biodegradable materials. Finally, tests will be performed under real atmospheric conditions and biodegradability analysis will be carried out to show the feasibility of the prototype.

Simultaneously, a new hydrogel material will be studied and tested, being the starting point of the fabrication of a hydrogel battery. This battery will be form by to redox hydrogel electrolytes and a separator supported on carbon paper. The enrichment of the group knowledge in this area will be necessary during the first months, then the improvement of the conductivity, stability and humidity effects on the hydrogel matrix will done by the student. The development of a separator, which acts at the same time as ion exchange membrane, will be also necessary.. Moreover, the possibility of using other materials (different chemistries, redox polymers, carbon electrodes…) will be explored in order to achieve a versatile battery suitable of being adapted to many applications. Always bearing in mind that biodegradability analysis and life-cycle-assessment will be executed to evaluate the sustainability of the approach.


2018-2019
2019-2020
2020-2021
September - February
Reproduce previous group results
October - December
Study electrochemically eco-friendly species in different pH's
November - January
Configure eco-friendly species catalogue
February - March
Increase hydrogel knowledge
March - August
Demonstrate the possibility of developing a evaporation battery
April - August
Improve hydrogel electrolytes
May - August
Work on the hydrogel coin-cell performance
September - November
Improvement of the coin cell membrane
October- November
Evaporation battery prototype development and testing
October– December
Biodegradable coin cell prototype design and fabrication
November-December
Humidity and temperature test in a climate chamber
January- February
Biodegradability tests
February – August
Testing other materials to adapt the hydrogel battery to any possible applications
November-September
Search real specific applications of the developed batteries
December-September
Writing the thesis

4. Bibliography

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