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# Cheap and easily processable electrode/electrolytes for next-generation sodium-ion batteries

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**Abstract.** Electrochemical energy storage is of increasing importance to allow large-scale integration of intermittent renewable sources. State-of-the-art lithium-ion batteries suffer from relevant problems, including strategic materials supply (e.g., Li, Co), high environmental impact, high cost, low safety. Cheaper and safer batteries based on sodium-ion chemistry can answer to these issues. In this work, we demonstrate how we aim at developing new materials for next-generation, highly performing and sustainable, all-solid-state, secondary Na-ion batteries. We will explore the entire value chain, starting from the development of carbonaceous electrodes obtained by pyrolysis of biosourced waste to the development of advanced, polymeric electrolytes, also including computationally-assisted investigation of electrode/electrolyte materials and their “green” fabrication and assembly/testing in lab-scale cells.

**Key words.** energy storage, sodium-ion battery, carbonaceous anode, solid polymer electrolyte, electrochemical characterisation.

## 1. Introduction

Energy storage is a key challenge of the 21th century. In fact, renewable energy production is expected to grow largely in the coming years, and efficient massive storage is required to improve large-scale grid integration of intermittent electricity sources (e.g. solar, tides, wind) [1]. At present, the state-of-the-art in the field is represented by Li-ion batteries. However, near future global battery market might be so large that problems regarding materials supply will rise not only for lithium (*viz.* Li<sub>2</sub>CO<sub>3</sub>), but also for electrode raw materials (e.g. Co-based). Cheaper batteries based on Na-ion chemistry can refresh the renewable energy sector and supply more balancing to the grid, providing proper back up to intermittent renewable sources. Sodium exhibits suitable electrochemical properties, close to those of lithium, and it is very abundant. These features make Na-based batteries proficient candidates to replace LiBs, particularly when large-scale energy storage is envisaged [2]. This chemistry

might be strategic for electrified road transportation as well, which has stringent requirements in terms of safety and durability. In general, development of new Na-ion based technologies requires: i) the discovery/investigation of new materials/components being widely distributed in large amount and without strategic contingencies, and ii) the search for high energy/power density, and safe battery configurations.

In this context, in this work we will deliver a fully integrated innovation chain based on the material-to-end-use approach. In particular, the target in our research group is to develop new materials for next-generation, highly performing and sustainable, all-solid-state, secondary Na-ion batteries, by exploring the entire value chain that includes “green” fabrication of nanostructured electrode (e.g., iron and/or vanadium phosphates eventually supported on electrospun carbon fibers at the cathode and biosourced derived hard carbons at the anode) and solid electrolyte materials (crosslinked polyethyleneoxide with specific plasticisers and additives), and their assembly and electrochemical testing in lab-scale test cells with the best materials, validated upon prolonged cycling at ambient temperature. Concerning sustainability, recyclable and naturally abundant materials are processed to give energy storage components with minimum environmental impact.

## 2. Overview of the research work

Below, new materials for next-generation, highly performing and sustainable, solid-state Na-ion batteries under development in our labs are briefly detailed.

### A. Nanostructured electrode materials

Different kind of electrode materials for Na-ion batteries are under development in our laboratories, which include sodium iron phosphate specifically mixed with reduced graphene oxide or vanadium phosphates eventually supported on electrospun carbon fibers at the cathode and

