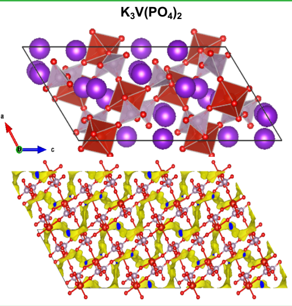
Spray-dried $K_3V(PO_4)_2$ and $K_3V(PO_4)_2$/carbon as new cathode materials for potassium-ion batteries

Jérôme Bodart, Nicolas Eshraghi, Thomas Carabin, Bénédicte Vertruyen, Frédéric Boschini, Abdelfattah Mahmoud
GREEnMat, UR CESAM, University of Liège, Quartier AGORA – B6a, Allée du Six-Août 13, BE-4000 Liège (Sart-Tilman), Belgium.
jerome.bodart@uliege.be

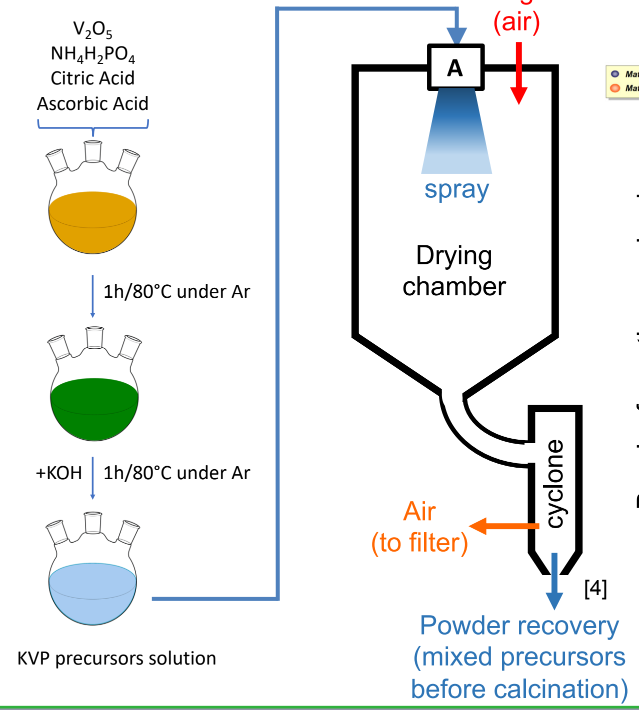
Introduction

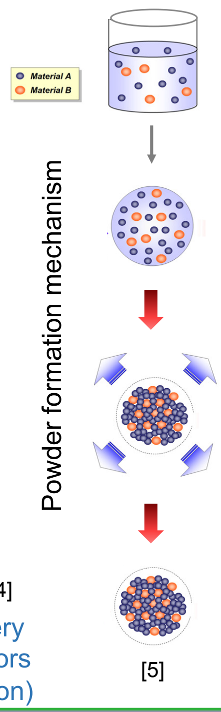
Potassium (K) is a highly abundant element, distributed homogeneously on earth and much cheaper than lithium with similar reduction potential to Lithium (Li), thus K-ion batteries (KIBs), for similar specific capacity, are expected to deliver higher energy density than Na-ion batteries (NIBs) with no difference compared to Li-ion batteries (LIBs). One main advantage of potassium making it a favorable candidate to combine the advantages of NIBs and LIBs is its reversible insertion/deinsertion capacity in graphite [1-3]. Phosphate-based compounds have many advantages such as a high structural stability upon cycling, high insertion potential and good ionic conductivity. However, these materials exhibit low intrinsic electronic conductivity. In this work, we study $K_3V(PO_4)_2$ (KVP) that combines a high working potential of 3.5-4V and a high theoretical capacity of 150 mAh.g^{-1} (for 2 K^+) and 225 mAh.g^{-1} (for 3 K^+). This material is synthesized by spray-drying, which is a cost effective and versatile method to produce large quantities of the desired material in one step. To solve the issue related to the electronic conductivity in KVP, conductive carbon allotropes (carbon nanotubes (CNT) and reduced graphene oxide (rGO)) were added during the preparation of KVP/carbon composites.



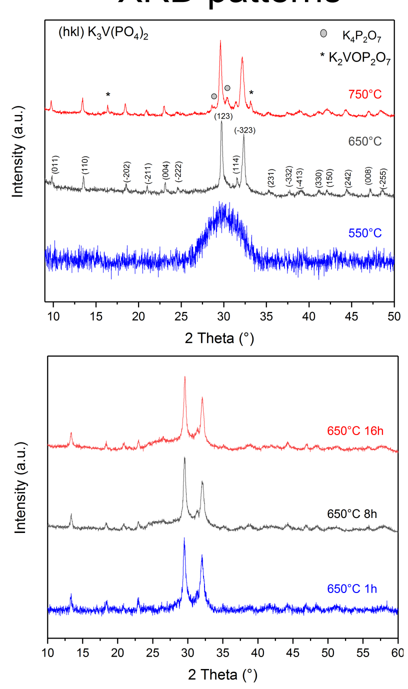
Synthesis and characterization of $K_3V(PO_4)_2$

Synthesis method

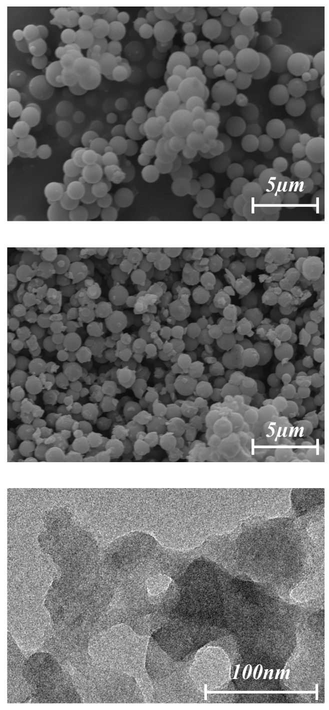




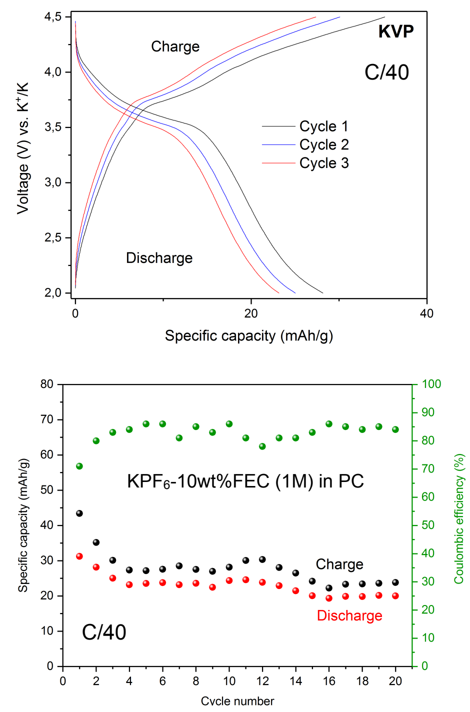
XRD patterns



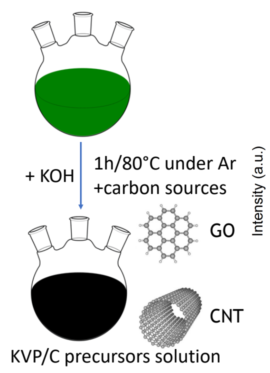
SEM and TEM



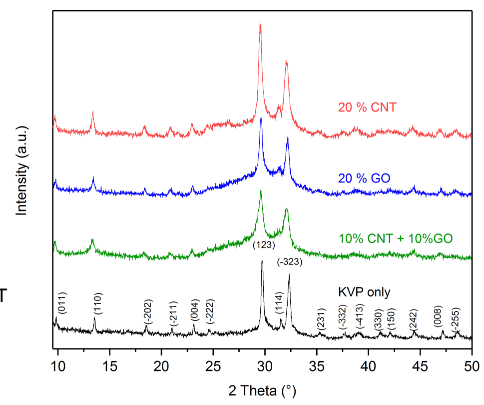
Electrochemistry

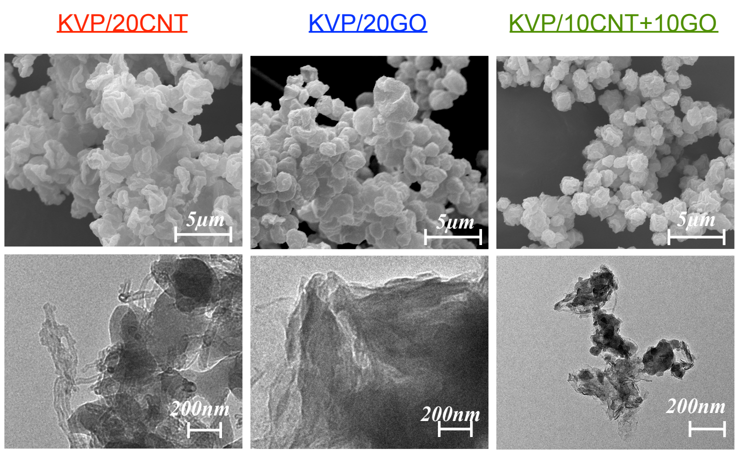


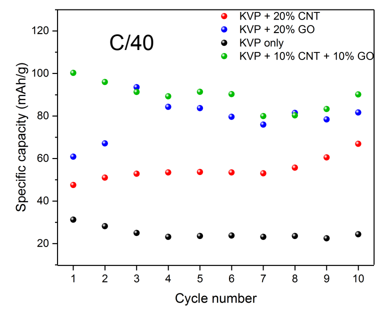
Influence of carbon addition

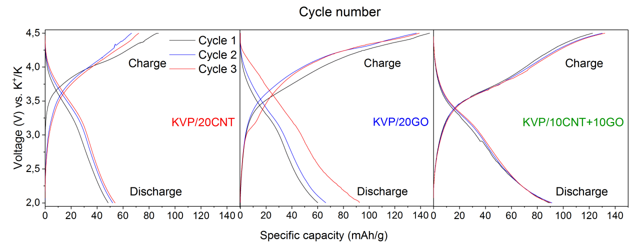


XRD patterns

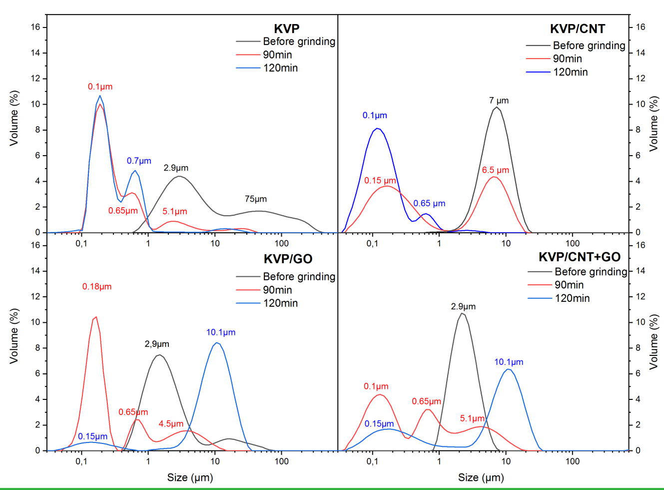


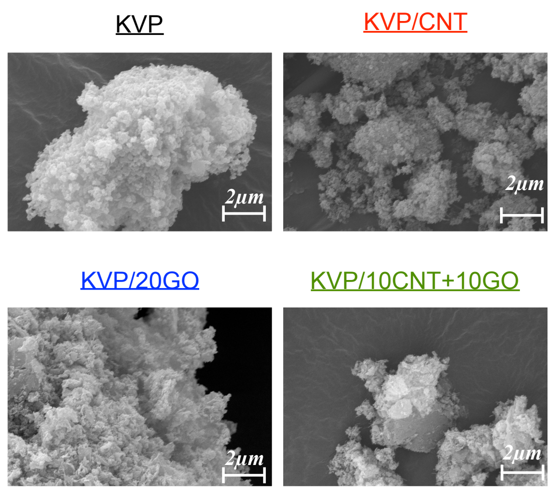


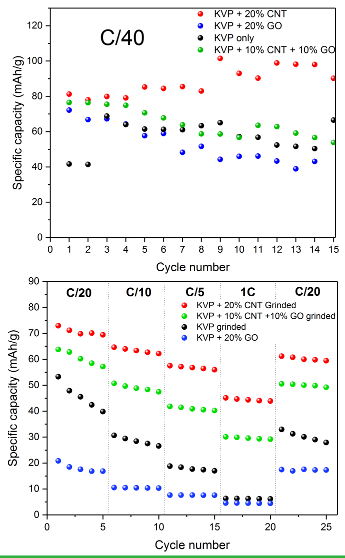


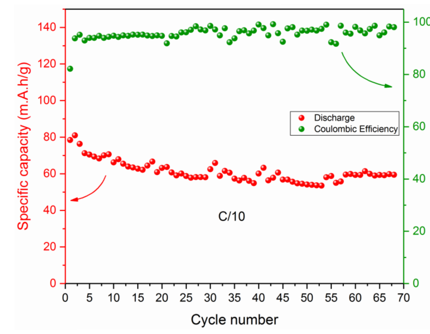


Influence of grinding









- Efficient nanosizing of samples upon grinding (~100nm)
- Electrochemical performance are improved (101mAh/g at C/40; 75mAh/g at C/20) for KVP/20CNT after grinding
- Destruction of rGO layer leading to lower performance for KVP/rGO

Conclusion

KVP and KVP/C pure materials are obtained by spray drying after calcination at 650°C for 8h under argon. KVP displays low electrochemical performance due to its low electronic conductivity and to the large particles size. The addition of carbon improved the electrochemical performance. The grinding of the KVP and KVP/C particles reduced the particle size in a homogeneously distributed manner except for KVP/20GO. The grinding step is harmful for KVP/20GO because the graphene layer is broken. KVP/20CNT delivers a high discharge capacity (101 mAh/g at C/40) and demonstrates excellent capacity retention at higher C-rate after ball-milling.

References and Acknowledgement

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