FACILE SYNTHESIS OF V_2O_3/CARBON CORE/SHELL HYBRIDS AS AN ANODE FOR LITHIUM-ION BATTERIES

Öznil Budak,[1,2] Pattarachai Srimuk,[1,2] Aura Tolosa,[1] Simon Fleischmann,[1,2] Juhan Lee,[1,2] and Volker Presser[1,2]

[1] Energy Materials Group, INM - Leibniz Institute for New Materials, Saarbrücken, Germany
[2] Department of Materials Science & Engineering, Saarland University, Saarbrücken, Germany

INTRODUCTION

Fossil fuels are currently humankind's major energy source. However, their use leads to environmental issues, such as air pollution, CO_2 emission, acid rain, and global warming. A more sustainable alternative is the widespread use of **renewable energy**, such as solar and wind. However, the generation of renewable energy is uncontrollable and intermittent, which mandates reliable electrical energy storage systems for stable and consistent power delivery. Among them, **Lithium-ion batteries (LIBs)** are the most promising candidates because of their high energy density and efficiency.[1]

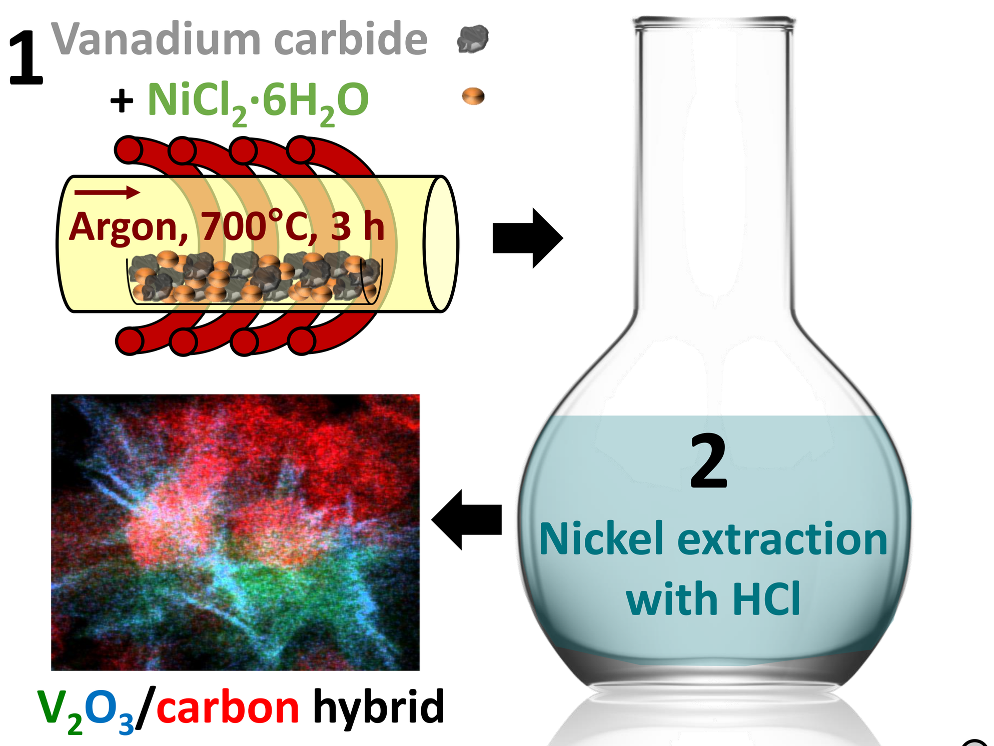
V_2O_3 is a **promising** LIB electrode material but there have been only very few studies exploring V_2O_3 as an **anode** for LIBs so far.[2-5] The current state of the art assumes that V_2O_3 undergoes structural volume change during cycling; this effect and the **low electronic conductivity explain the poor cycling stability.**[4] For example, there is a 50-60 % capacity loss of bulk V_2O_3 after 50-100 charge/discharge cycles.[2, 4]

So how can we overcome these limitations?

We introduce V_2O_3/C core/shell hybrids where vanadium carbide serves as the precursor for the metal oxide and carbon.[6]

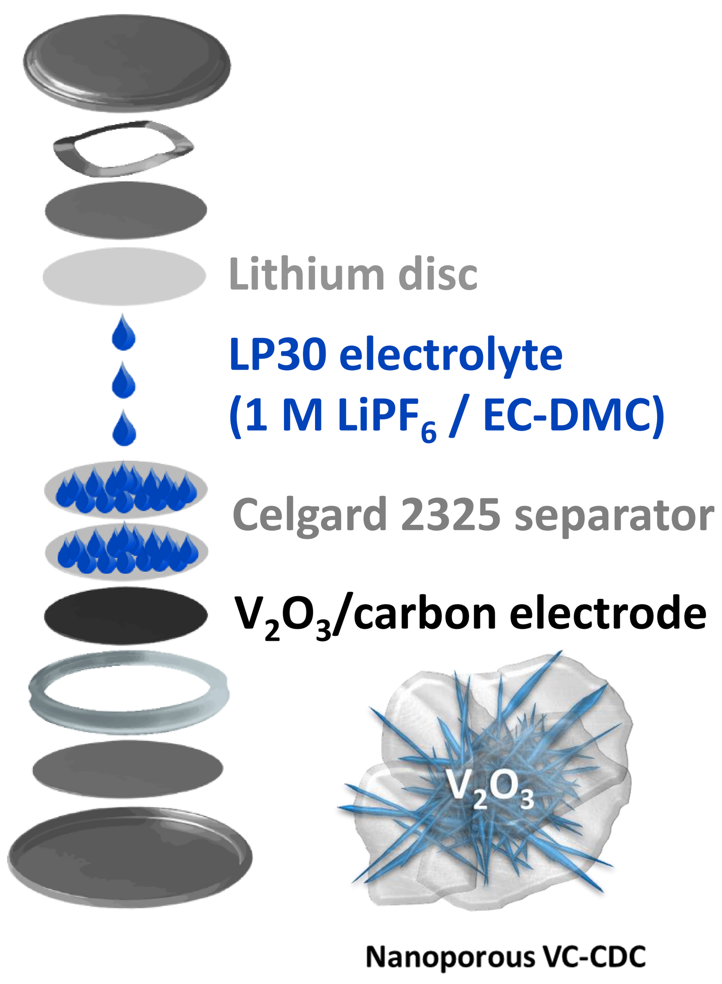
METHODS

Two-step synthesis



Simplified: $4VC + 8(NiCl_2 \cdot 6H_2O) = 2V_2O_3 + 3C + 8Ni + 40H_2O + 16HCl + CO_2$

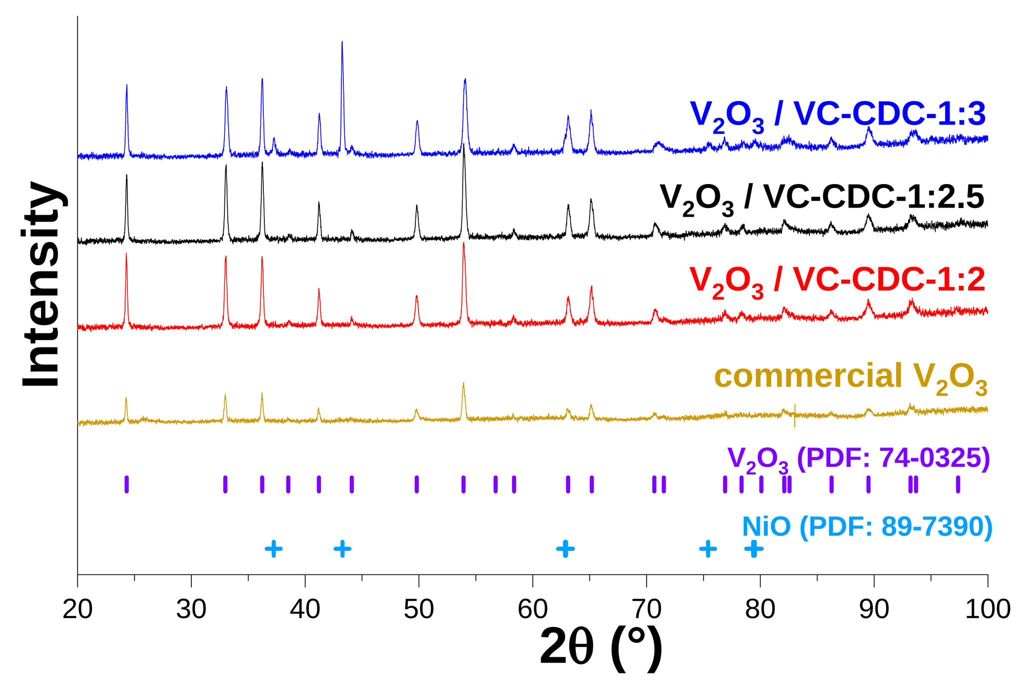
Coin cell assembling

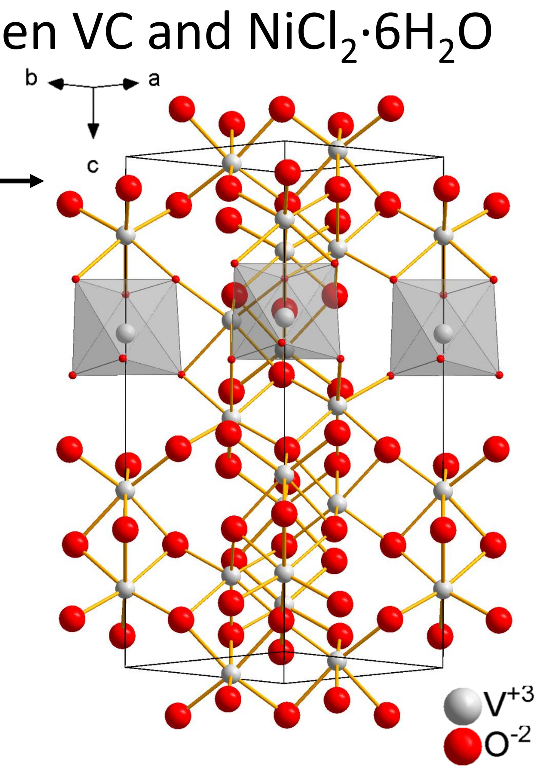


STRUCTURAL CHARACTERIZATION

X-ray diffraction (XRD)

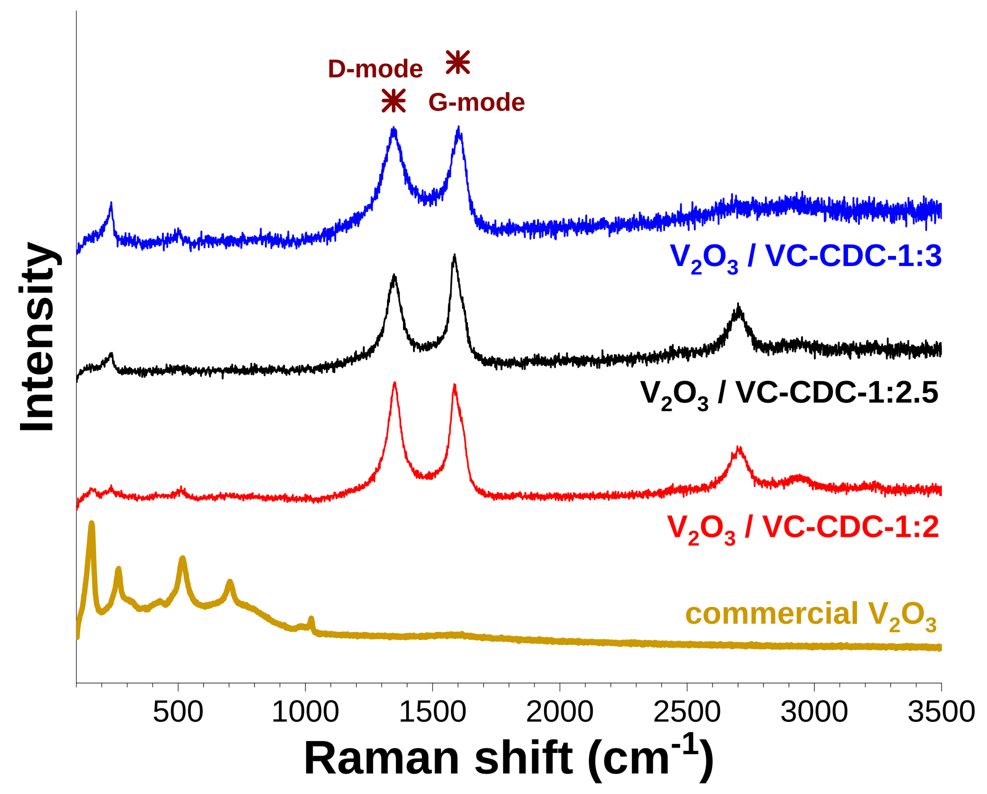
- Increasing the stoichiometric ratio between VC and $NiCl_2 \cdot 6H_2O$ leads to bunsenite-type cubic NiO
- Karelianite type rhombohedral V_2O_3



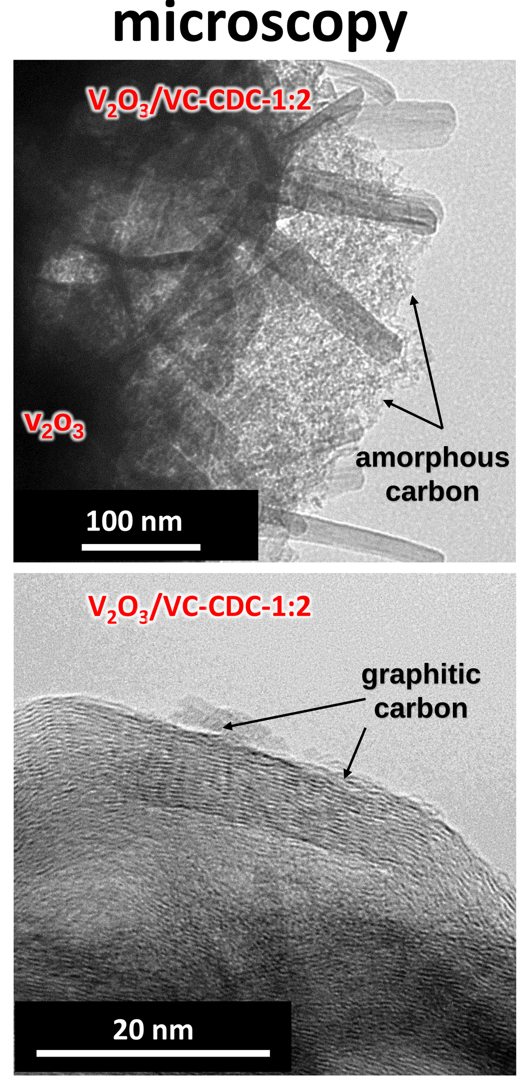


Raman spectroscopy

- Broad peaks of disordered nanocarbon (CDC: carbide-derived carbon)
- Small peaks of nanoscale V_2O_3

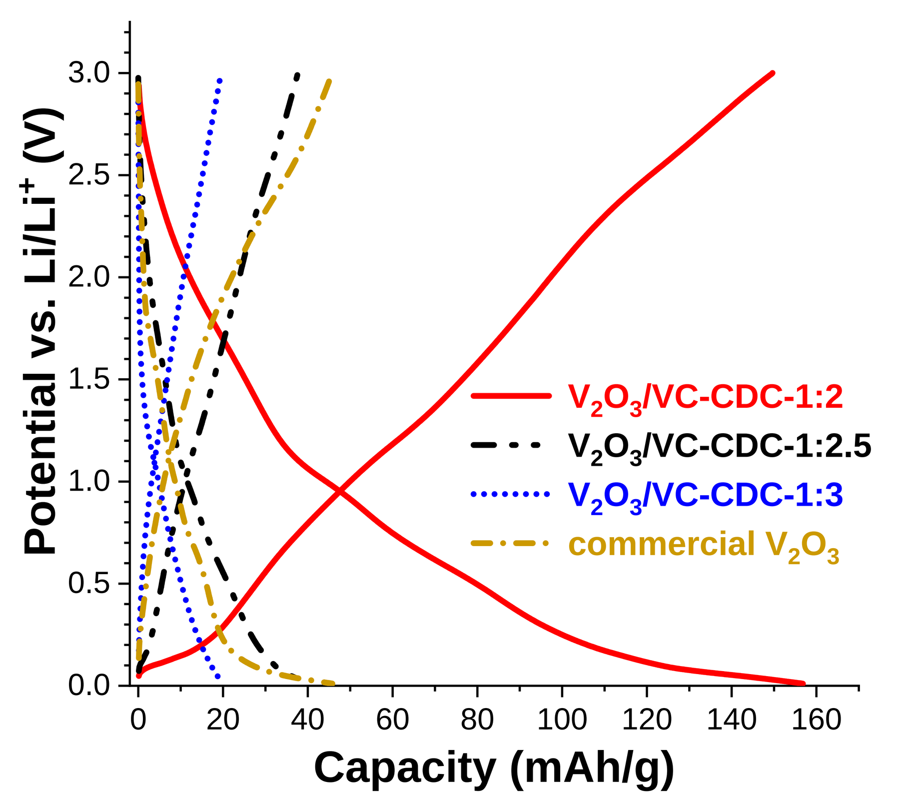


Transmission electron microscopy

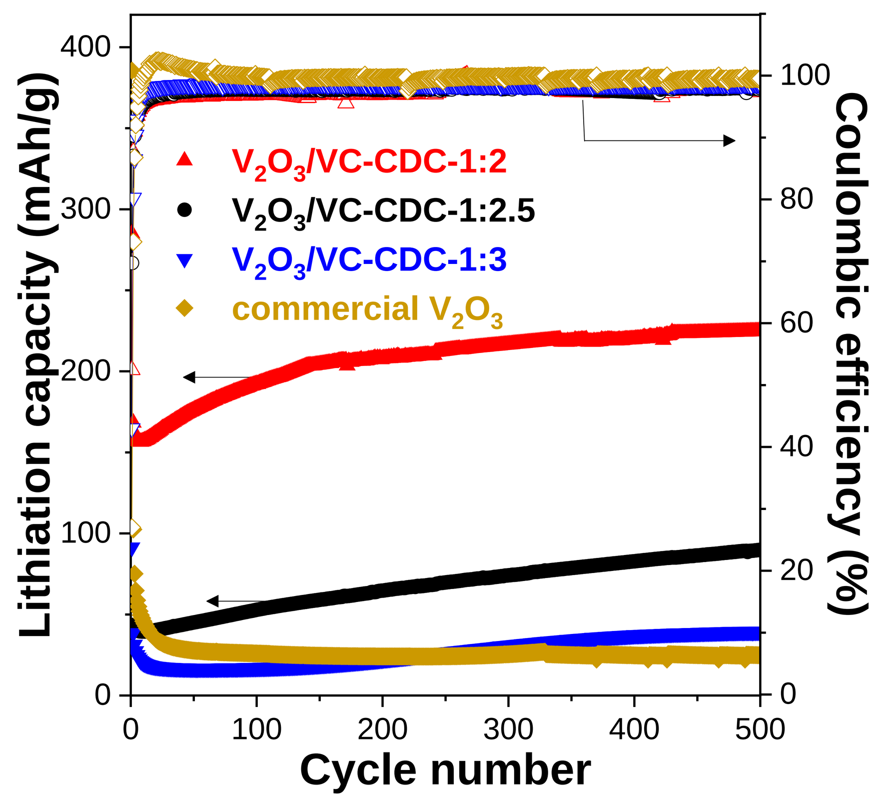


ELECTROCHEMICAL CHARACTERIZATION

Voltage profile



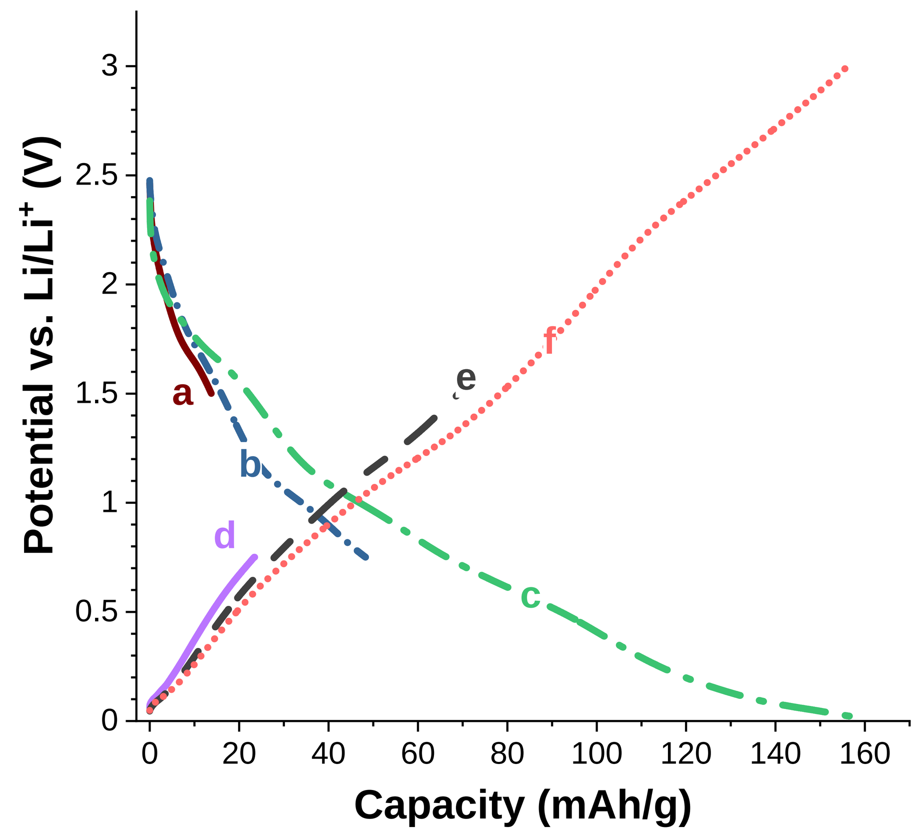
Cycling stability



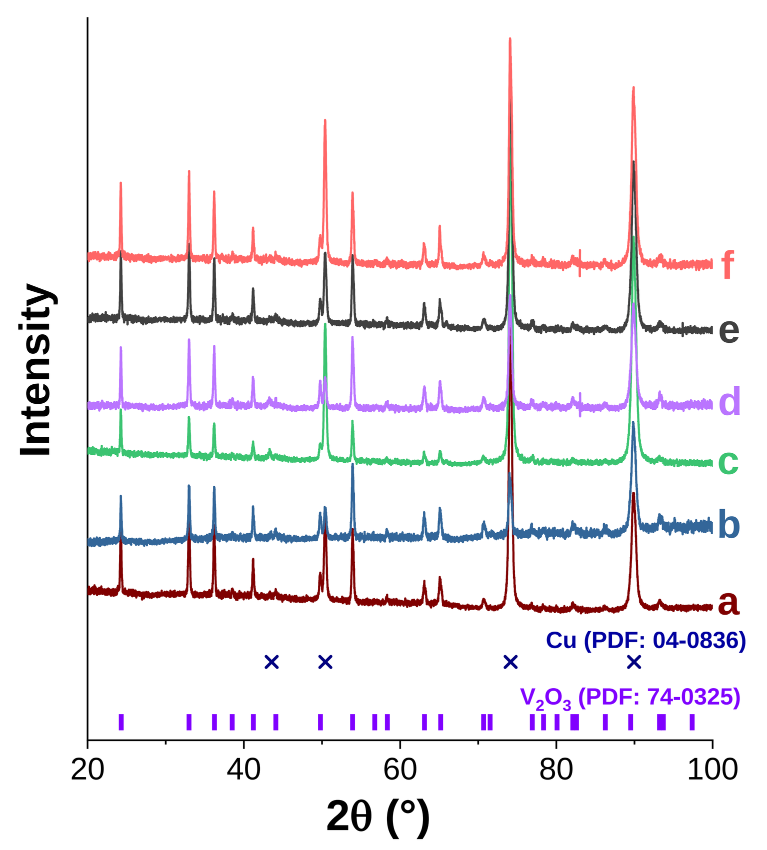
- Highest capacity and best performance stability for V_2O_3/VC-CDC-1:2

POST MORTEM ANALYSIS

Voltage profiles after 40 cycles



XRD patterns at different states



Sample	Phase	Volume (Å³)
Lithiation at 1.5 V (a)	V_2O_3	298
Lithiation at 0.75 V (b)	V_2O_3	298
Lithiation at 0.01 V (c)	V_2O_3	297
Delithiation at 0.75 V (d)	V_2O_3	297
Delithiation at 1.5 V (e)	V_2O_3	297
Delithiation at 3.0 V (f)	V_2O_3	297

- No significant crystallographic V_2O_3 volume change via electrochemical cycling
- Surprising result per the state of the art in the literature

Raman data analysis after 500 cycles

Sample	State	I_D/I_G ratio
V_2O_3/VC-CDC-1:2	Initial	1.1
	500 cycles	2.7
V_2O_3/VC-CDC-1:2.5	Initial	1.1
	500 cycles	2.3
V_2O_3/VC-CDC-1:3	Initial	2.1
	500 cycles	2.2
commercial V_2O_3	Initial	2.0
	500 cycles	0.9

- VC-CDC becomes structurally more disordered after cycling
- Ergo: carbon plays an active role in the energy storage process

FUNDING

DFG

REFERENCES

[1] Nitta et al. (2015), *Mater Today* 18, 252-264.
[2] Jiang et al. (2015), Appl. Mater. Interfaces 7,1595-1601.
[3] Shi et al. (2015), J. Power Sources 275, 392-398.
[4] Sun et al. (2011), J. Power Sources 196, 8644-8650.
[5] Yan et al. (2016), J. Power Sources 329, 148-169.
[6] Budak et al. (2019), Batteries&Supercaps, 2, 74-82.

CONCLUSIONS

- **Using an optimized precursor ratio, we synthesized a V_2O_3/VC-CDC hybrid material with a core/shell particle architecture.**
- **The material afforded a capacity of 160 mAh/g with high performance stability up to 500 cycles.**