Synthesis of Hard Carbon-Sn composites for negatives for Na-ion batteries

Towards developing a high energy density Sn based anode for Na-ion batteries

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Abstract

Carbon-Sn (Sn/C) composites as anode active materials are becoming of great interest for the battery research field. However, most Sn/C composites work over a wider voltage window of 0.05V-2.5V and have low tap density due to porous carbon architecture. This work aims to evaluate denser Hard carbon as host of Sn metal.

Synthesis mechanism of Hardcarbon-Sn (HC/Sn) composites is evaluated by performing synthesis at various temperatures and changing the precursor amounts. The Sn loading and size of Sn particles play a significant role in the electrochemical performance of HC/Sn composites.

Motivation

Sodium-ion battery technology is potentially cheaper than Li-ion battery technology. It offers comparable energy density to Li-ion batteries and is posed to complement Li-ion battery technology in various energy storage applications. Alloy-based anodes can help push the energy density of Na-ion batteries further, thus Sn was chosen for this study.

Methods

- Synthesis of the HC-Sn active material and electrode preparation:

1. Mixtures of 1:1 or 1:0.2 of HC:$SnCl_2$ were heated up in a tube furnace at a wide range of temperatures between 350-1100℃ in Ar or Ar/H_2 atmosphere.
2. Electrodes were prepared with slurries with ratios of 80:10:10 AM:Carbon:CMC (in water) and 95:5 AM:CMC(in water) and then coin cells were assembled in the glovebox using Kishida (carbonate based) as the electrolyte.

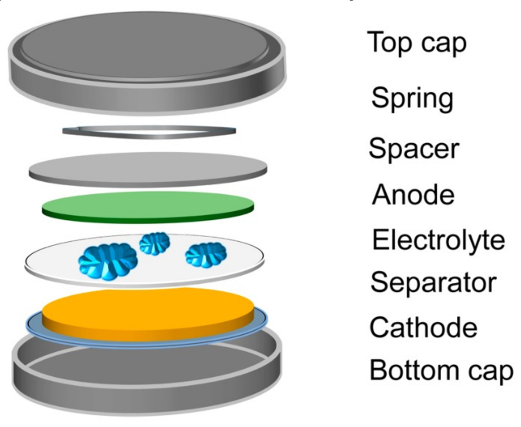


Fig. 1 Schematic representation of a coin cell[1]

Section 1 – Structure of active material (XRD and SEM)

- SnO forms at temperatures below 700 °C in Ar atmosphere.
- Sn can be formed at lower temperature (500 °C) by using a reducing atmosphere (Ar/H2).
- Sn metal exists in spherical form due to its lower melting temperature, the size of the Sn balls becoming larger as the temperature is increased as it can be seen in the SEM images

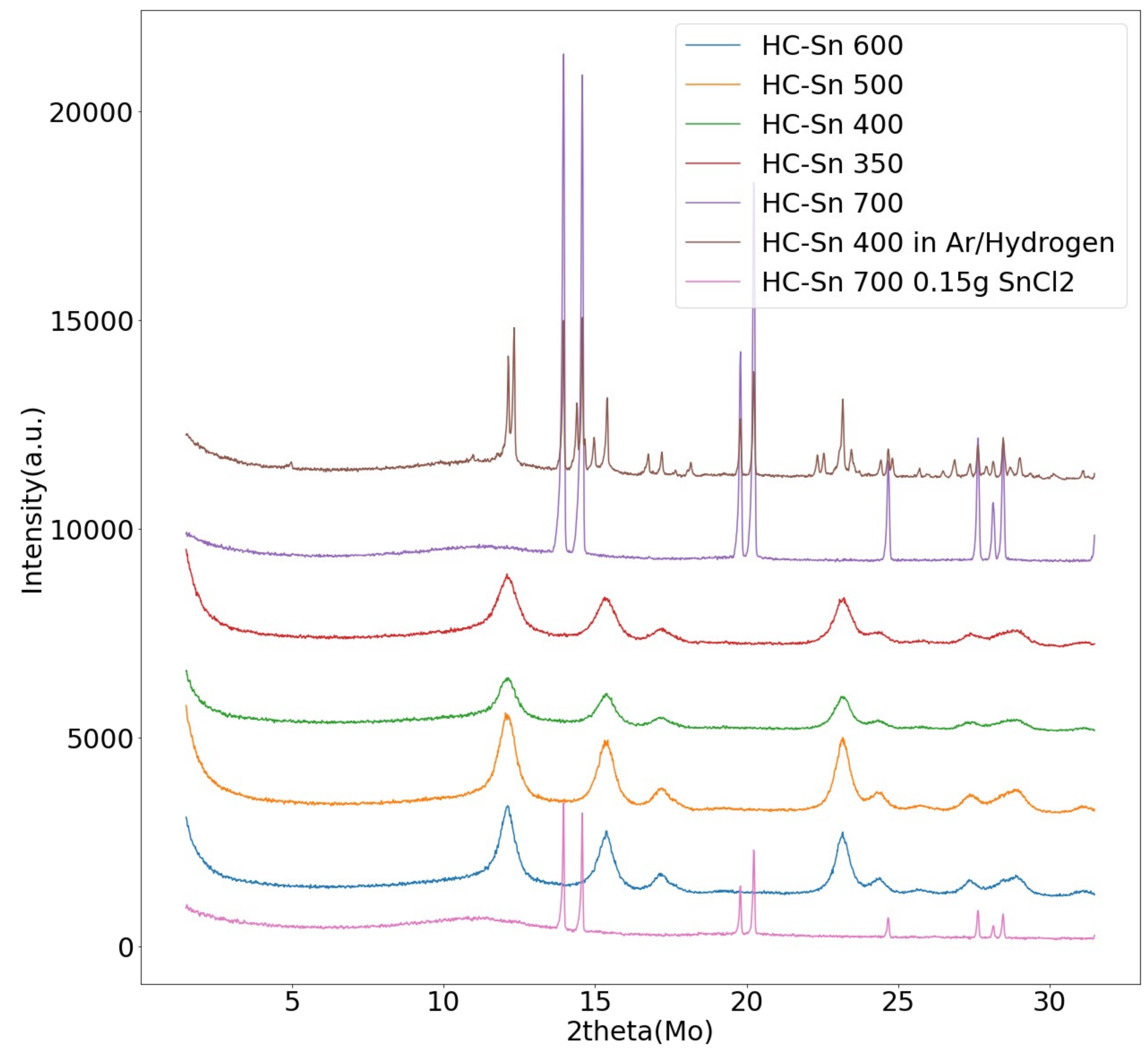
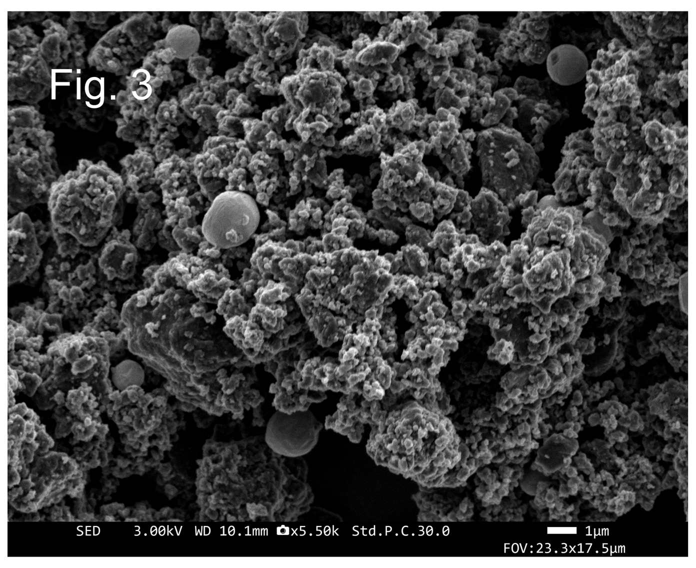


Fig. 2 XRD spectra of HC-Sn materials at different temperatures



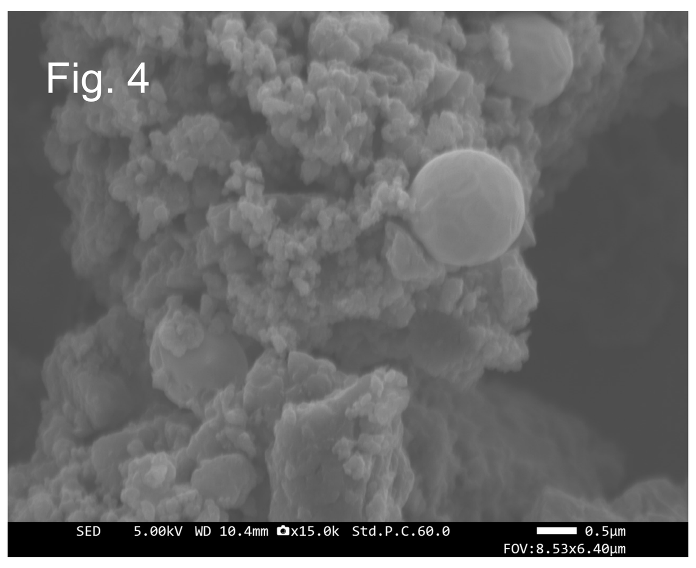


Fig. 3 SEM image of the HC-Sn 1100℃ material
Fig. 4 SEM image of the HC-Sn 700℃ material

Impact / Next steps

- Synthesis conditions can significantly change the electroactive materials in terms of chemistry and physical properties.
- The understanding of synthesis conditions is essential in designing better HC/Sn composite. The size and amount of Sn particles depend on both the synthesis conditions and target Sn loading.
- Next steps could be changing the Sn precursors and trying synthesis at different temperatures in a reducing atmosphere.

Conclusions

- Changing the synthesis conditions (temperature and gaseous atmosphere) for the HC-Sn composites, the composition and structure can change and affect the performance of the anode in the sodium-ion battery.
- High-temperature synthesis reveals the formation of Sn metal balls that show a better performance of the batteries, the possible reasons for this needing more research.

Section 2 – Performance of battery (Cycling capacity and the Galvanostatic curve)

- Presence of SnO leads to poor first cycle coulombic efficiency.
- HC/Sn composites perform better than HC/SnO composites in terms of capacity (mAh/g) and first cycle coulombic efficiency.
- Reducing the amount of Sn precursor leads to better performance. Most likely due to the smaller size of Sn metal.

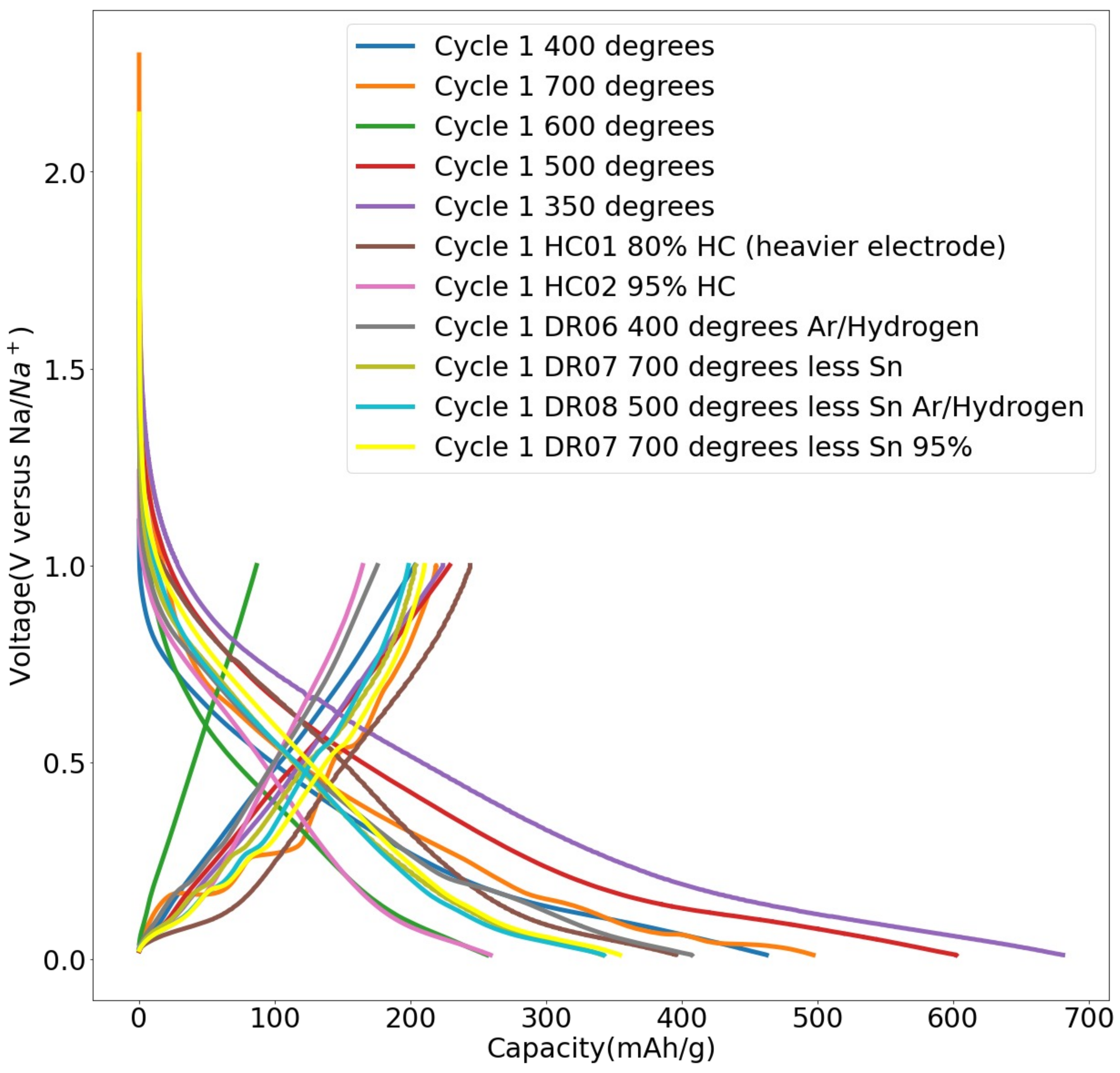


Fig. 5 Galvanostatic curve for the first cycle of the materials synthesised

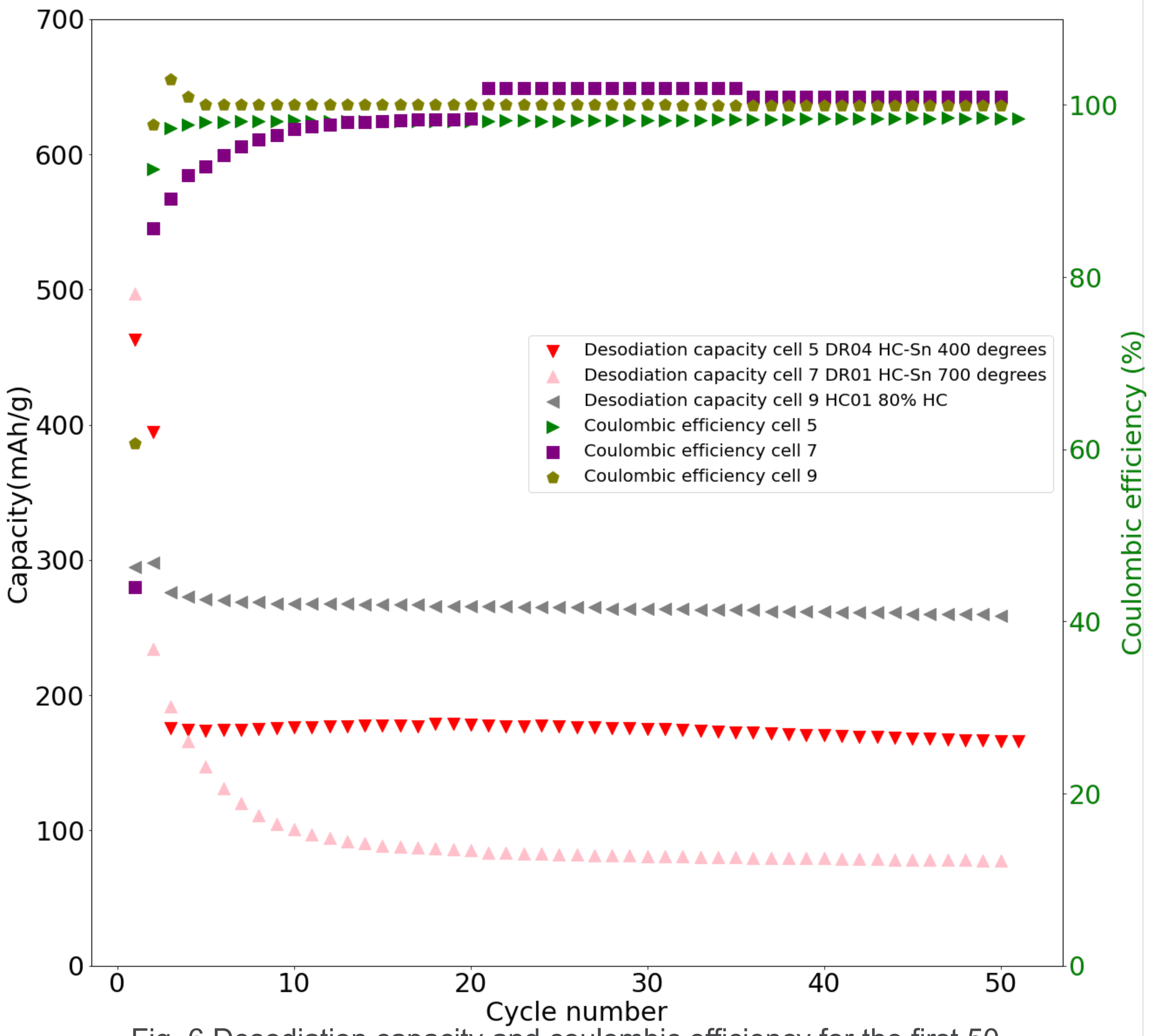


Fig. 6 Desodiation capacity and coulombic efficiency for the first 50 cycles of 3 different materials

Intern bio

Daria is studying Chemistry at The University of Oxford and is going into her fourth year of their four-year integrated Master's degree. Daria has always been interested in the ways chemistry can be applied to a wide range of research fields and by taking part in this FUSE internship, she has discovered an exciting interest in batteries. Daria is considering a future in academia and this internship helped her get a hand-on experience of conducting research and is now strongly considering doing a PhD.

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References

1. *Elahe Talaie et al. Methods and Protocols for Electrochemical Energy Storage Materials Research, Chem. Mater.* 2017, 29, 1, 90–105

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