Porous Carbon-rich SiOC Ceramic Aerogels as Anode Materials for Rechargeable Lithium-ion Batteries

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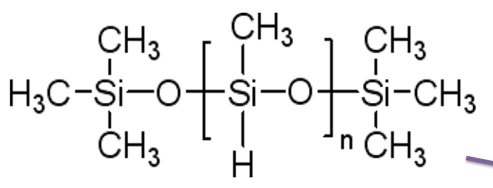
Introduction

- **Silicon oxycarbides, SiOC**, are amorphous ceramic materials with silicon bonded to oxygen and carbon simultaneously. Produced by pyrolysis in controlled atmosphere from crosslinked siloxane resins at T < 1200°C. Presence of >25 % of free carbon phase enhances the electrochemical properties.
- **Aerogels**, Produced by drying wet gels under supercritical conditions
- **SiOC aerogels**, Tailor made hierarchically porous networks, candidates for gas sensing applications [2]

Motivation

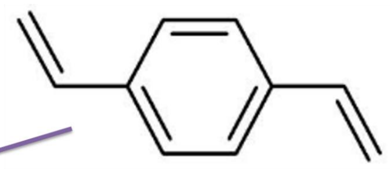
- Dense SiOC ceramic anodes able to deliver capacities up to 700 mAh g^{-1}[1]
- High-rate capability of porous carbon based anodes [1]
- High-porosity materials perspective for high-rates applications

Experimental Setup



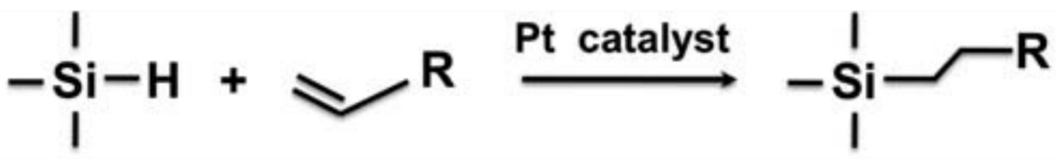
Poly(methylhydrosiloxane)

Pt catalyst
+
Acetone



Divinylbenzene

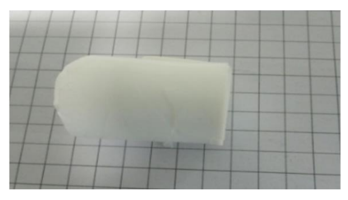
Acetone as solvent- 80 Vol% of solvent

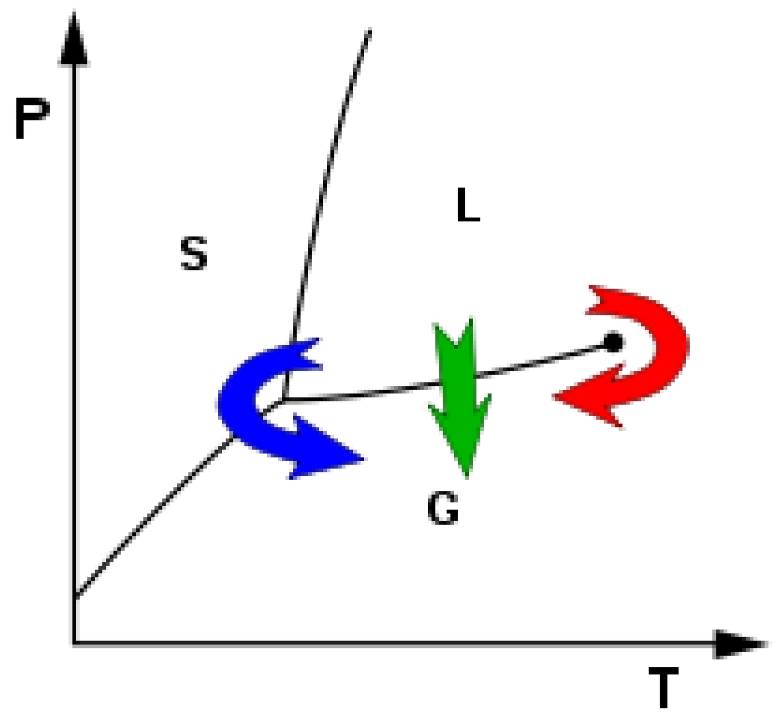


Hydrosilylation reaction – 2h at 180 °C

Wet gels are dried using a hypercritical CO_2 reactor

Preceramic Aergoel



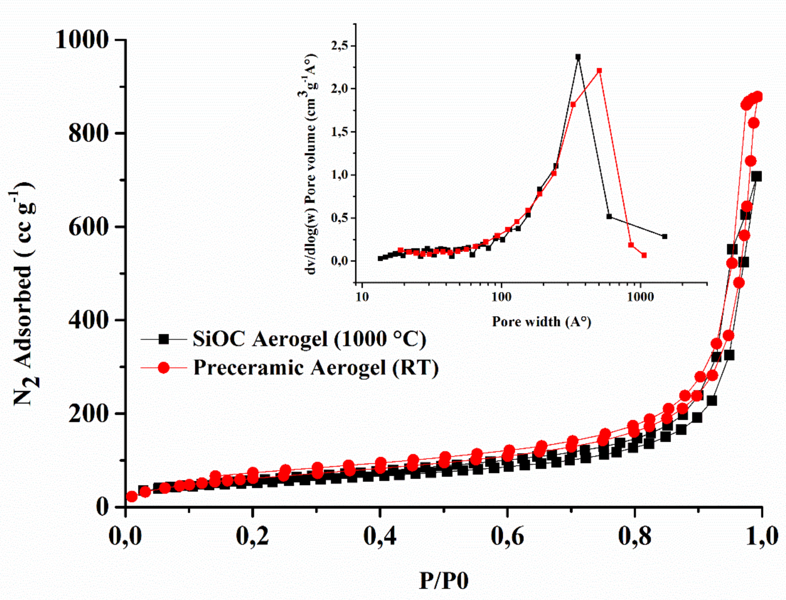


PC: Wikipedia

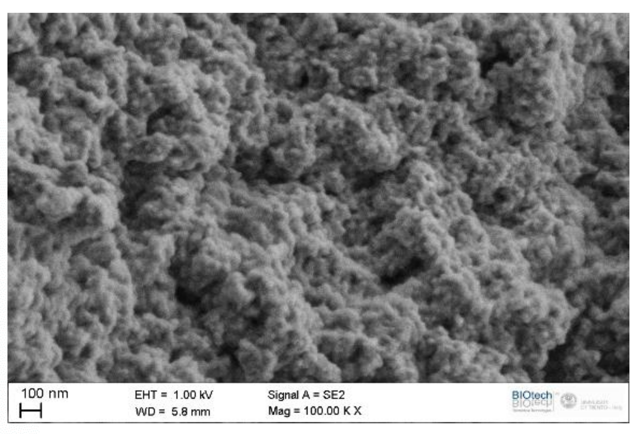
Super critical drying approach

Results and Discussions

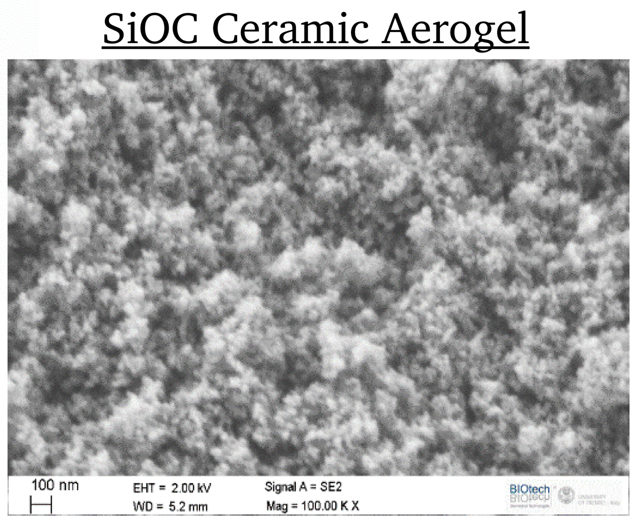
BET and SEM



Preceramic Aerogel



SiOC Ceramic Aerogel



	Surface area (m^2 g^{-1})	Pore volume (cc g^{-1})	Pore size (nm)
Pre-ceramic Aerogel (RT)	227	1.37	52
SiOC Aerogel (1000 °C)	180	1.09	24

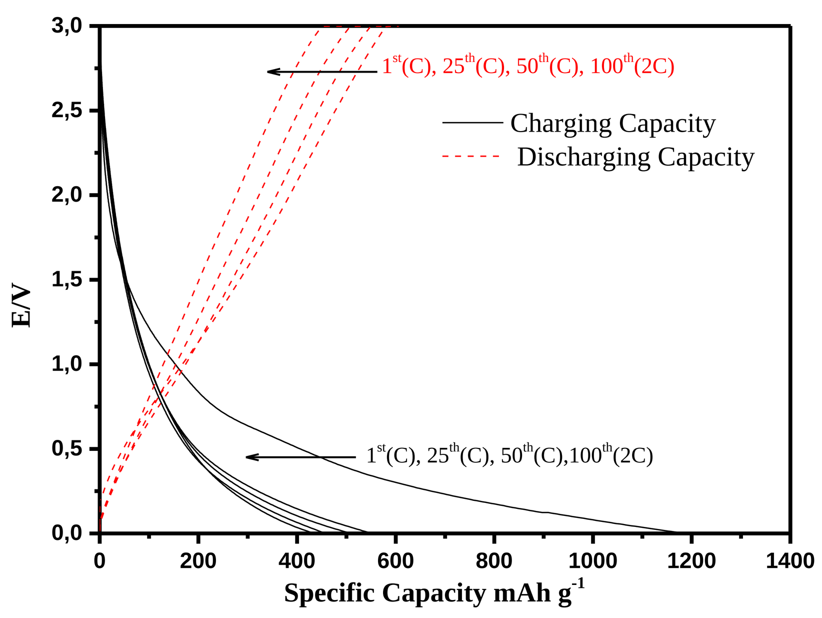
- Hierarchical porosity with pore size ranging from micro- meso and macro pores
- SiOC ceramic aerogels maintain porosity after thermal treatment at 1000 °C

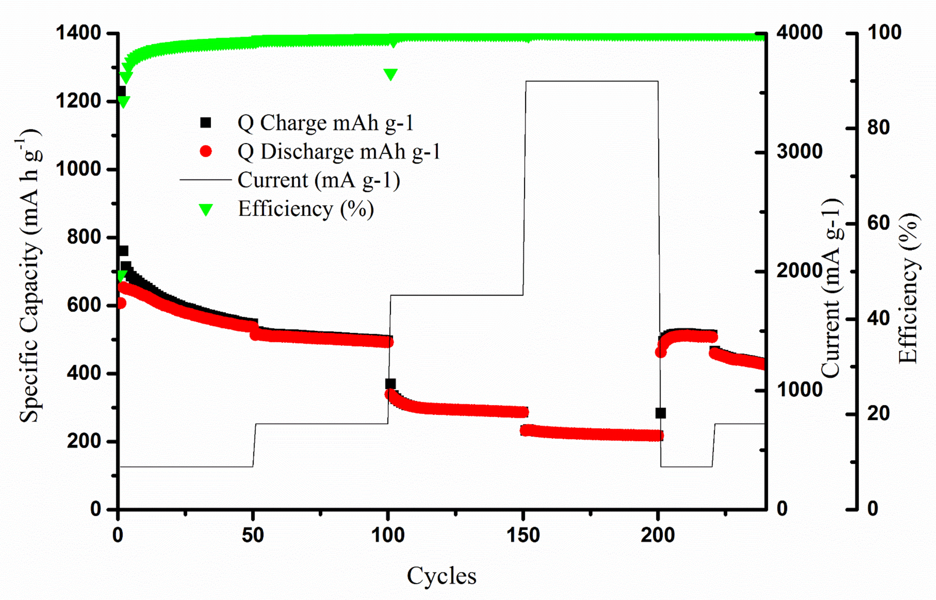
Elemental Analysis – SiOC Composition

C (wt. %)	O (wt. %)	Si (wt. %)	Si C_x O $_{2(1-x)}$ (wt. %)	Free Carbon (wt. %)
43.04	27.08	29.88	60	40

$SiO_{1,58} C_{0,21} + 3,15\ C_{free}$

GCPL / Cell Cycling





Charging rate	Q $_{Insertion}$ (mAh g^{-1})	Q $_{Extraction}$ (mAh g^{-1})	Q $_{Irrev}$(mAh g^{-1})	Efficiency (%)
C (360 mA g^{-1})	1280	600	680	49
C_{100} th (2C, 720 mA g^{-1})	500	490	10	98
10C (3600 mA g^{-1})	233	232	1	99

- Efficiency jumps to 98-99 % from second cycle.
- Significant first cycle irreversibility: high surface of the active material, still remains a challenge for the future work.

Conclusions

- Successful synthesis of SiOC ceramic aerogels with high surface area of 180 m^2g^{-1}
- Initial capacity of 650 mAh g^{-1} at a rate of C (360 mA g^{-1})
- Specific capacities of 200 mAh g^{-1} at a rate of 10C
- Excellent high-rate capability compared to dense SiOCs
- Post-lithiation studies required to understand more about intercalation mechanism.

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References

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