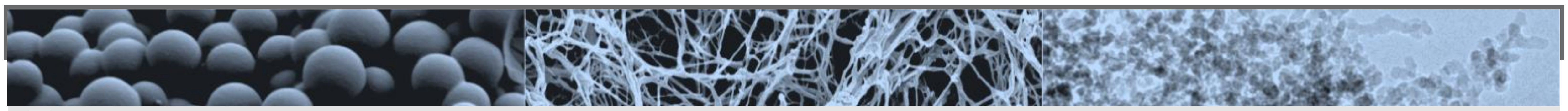
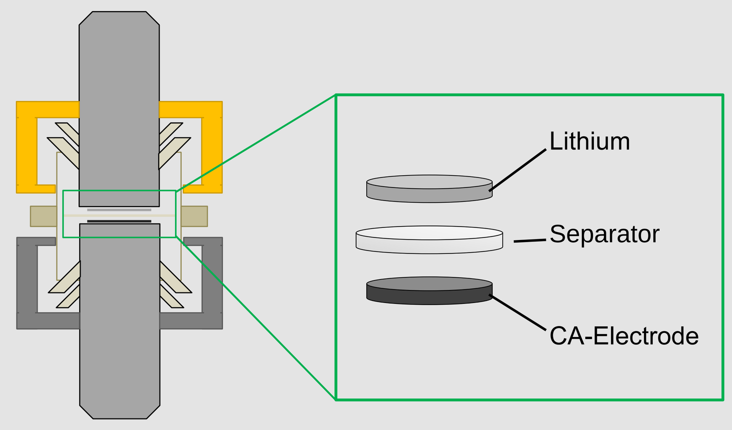
Highly microporous carbon aerogels encapsulating sulfur as cathodes for lithium-sulfur batteries

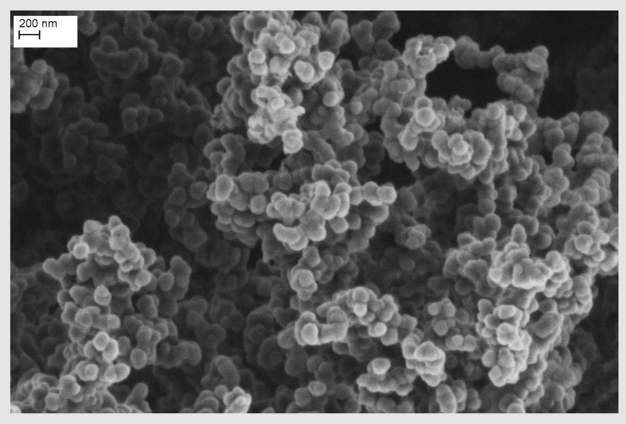


INTRODUCTION

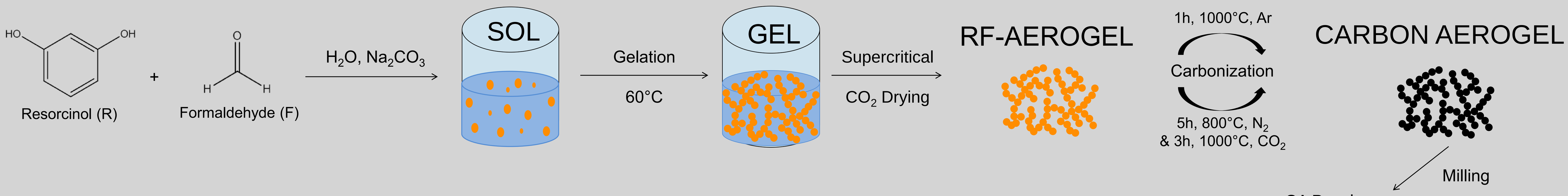
Carbon aerogels (CAs) are highly promising materials as matrices for sulfur to act as cathodes in metal-sulfur batteries. Resulting from organic resorcinol-formaldehyde aerogels, CAs exhibit highly porous structures with porosities up to 97%, high surface areas of about 500-3500 m²/g, large pore volumes of about 0.1-2.5 cm³/g, and significant electrical conductivities of about 80-150 S/m.
Additional important advantages of CAs are their tunable porous structures and pore size distributions. Their microstructures are adjustable during the synthesis of organic aerogels and their subsequent carbonization. Moreover, the elastic compressibility of CAs prevents the formation of cracks as a result of changes to the sulfur volume.



Testing battery cell


Microstructure of carbon aerogel

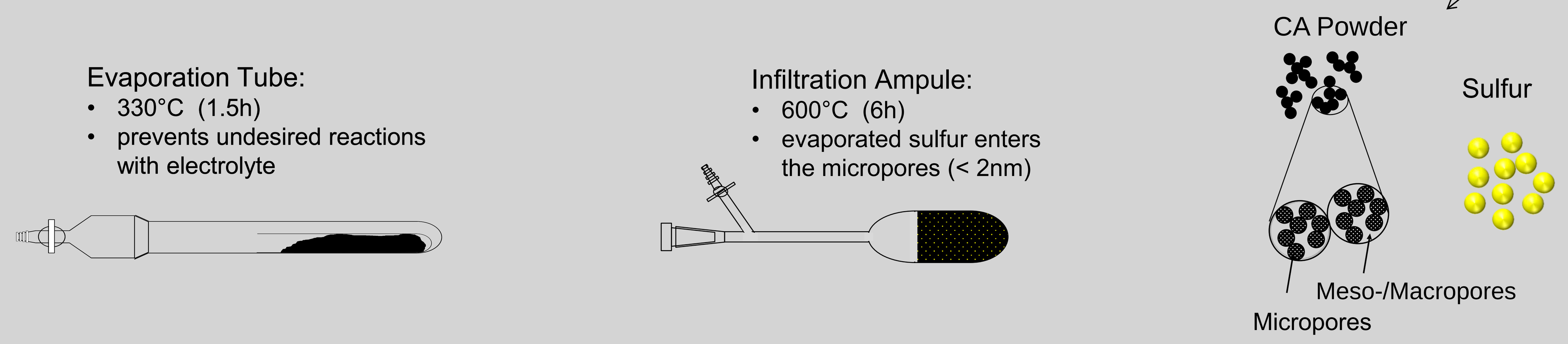
SYNTHESIS & INFILTRATION



Molar ratios:	Reaction conditions:
Resorcinol:Formaldehyde = 0.5 Resorcinol:Water = 0.008 Resorcinol:Catalyst = 50	stirring time 60 min at room temperature

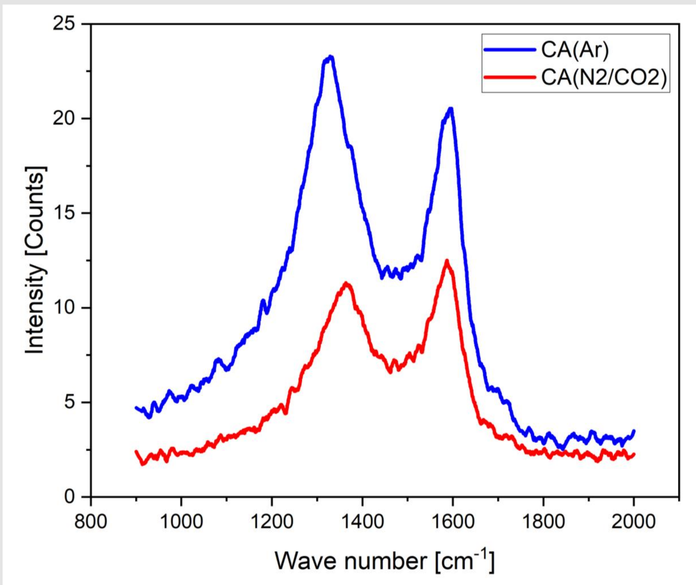
Evaporation Tube:
- 330°C (1.5h)
- prevents undesired reactions with electrolyte

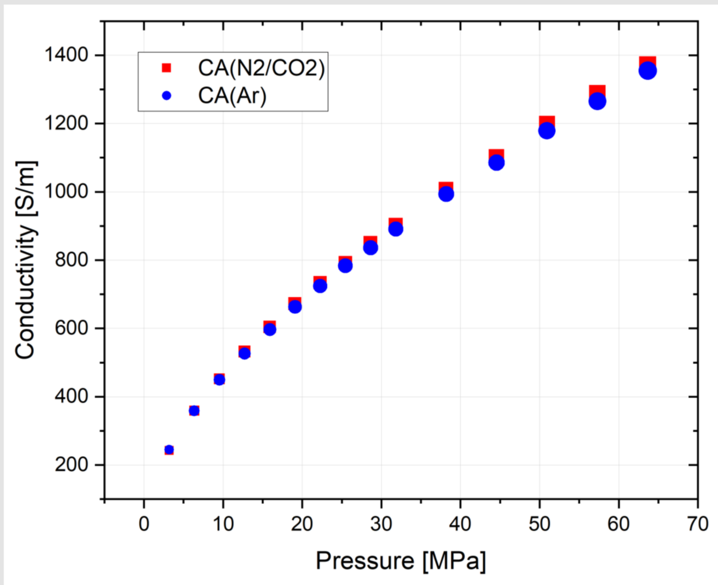
Infiltration Ampule:
- 600°C (6h)
- evaporated sulfur enters the micropores (< 2nm)

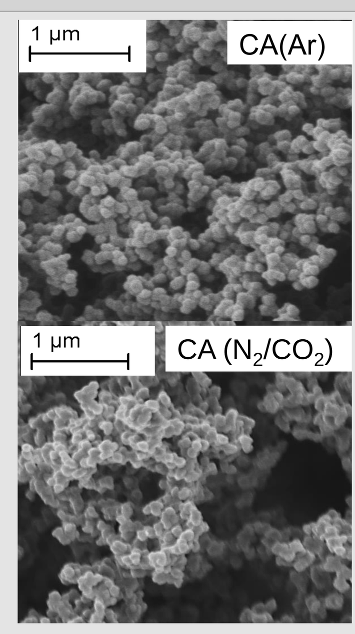


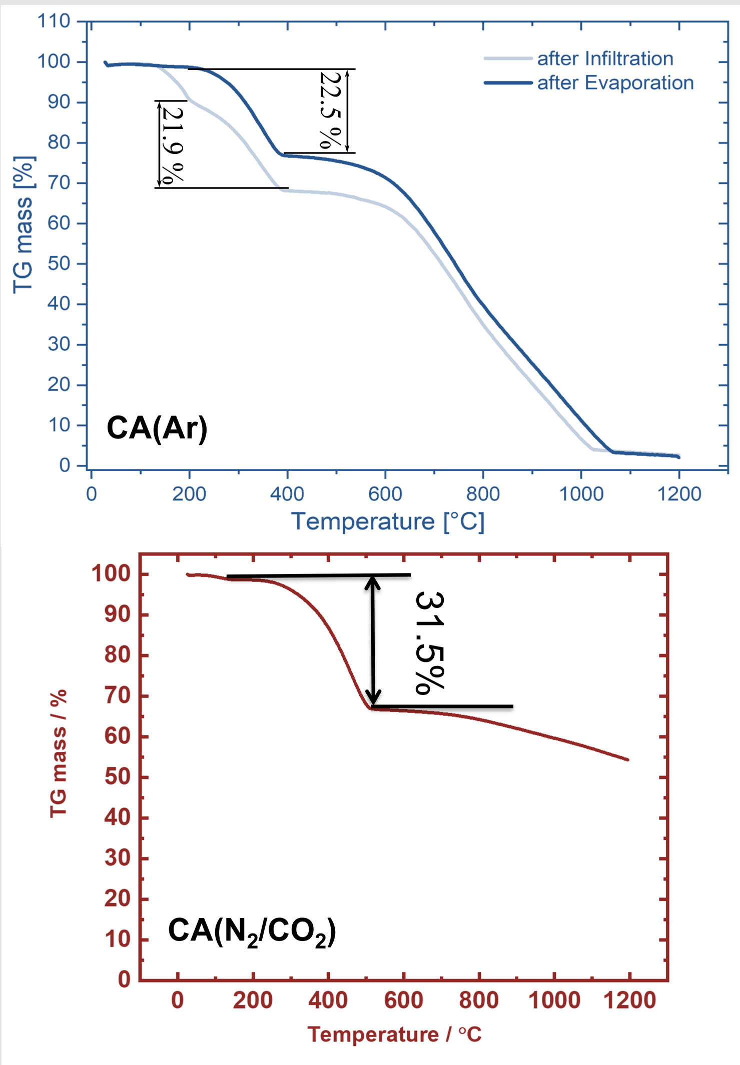
CHARACTERIZATION

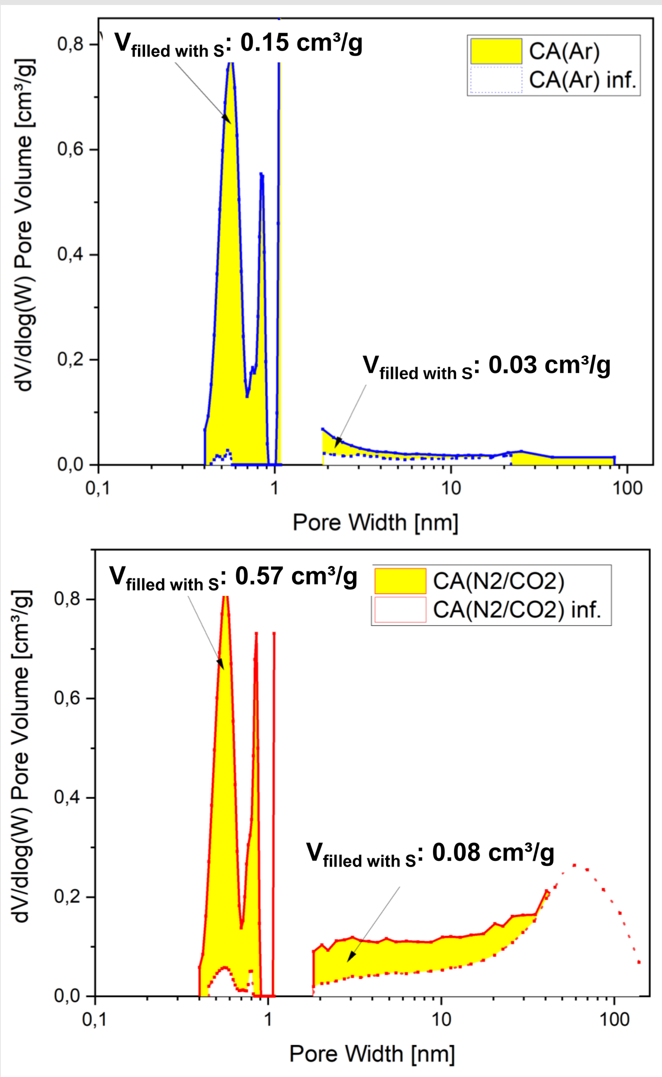
Properties	CA(Ar)	CA(N_2/CO_2)
Skel. density [g/cm³]	2.72	2.71
Bulk density [g/cm³]	0.04	0.07
Porosity [%]	98.6	97.3
Specific surface area [m²/g]	561	1912
Micropore volume [cm³/g]	0.18	0.60
Mesopore volume [cm³/g]	0.04	0.28

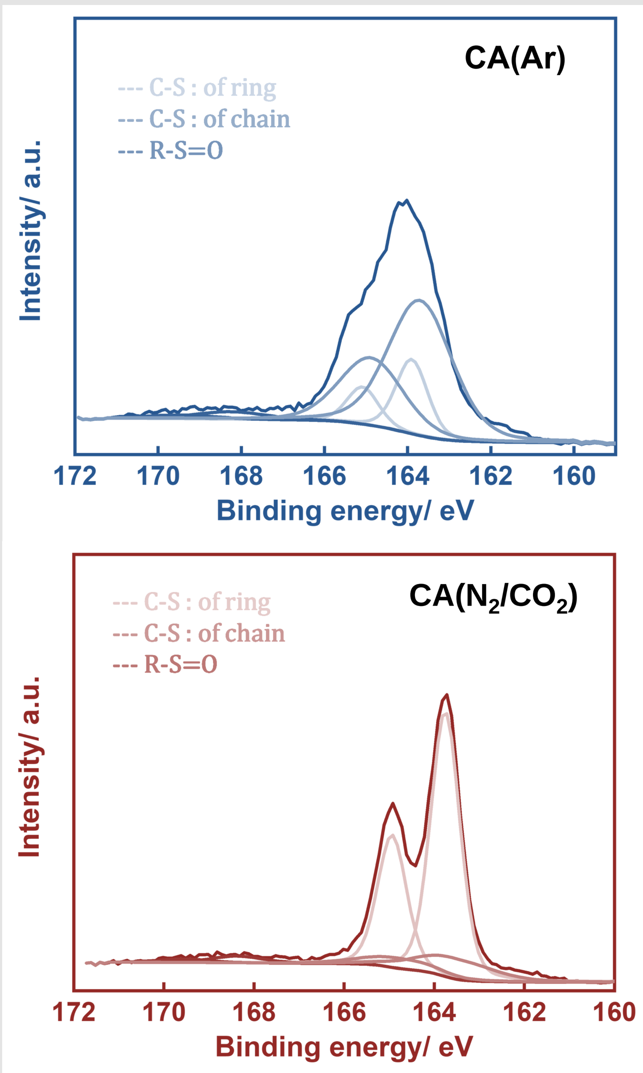












RESULTS

- CA(N_2/CO_2) shows higher level of graphitization
- Higher level of graphitization leads to higher electrical conductivity
- Higher microporosity leads to higher sulfur loading
- In mesopores 0.08cm³/g of sulfur left
- Sulfur in mesopores can be distributed as S_8 rings and lost during first cycles
- Presence of C-S bonds
- CA(N_2/CO_2) shows more bonds at graphitic ring due to higher level of graphitization
- Stable discharge capacity in carbonate based electrolytes for CA:S
- High specific capacity and coulombic efficiency for CA:S cathode materials
- No irreversible losses in rate-capability test for CA:S cathode materials

PERFORMANCE

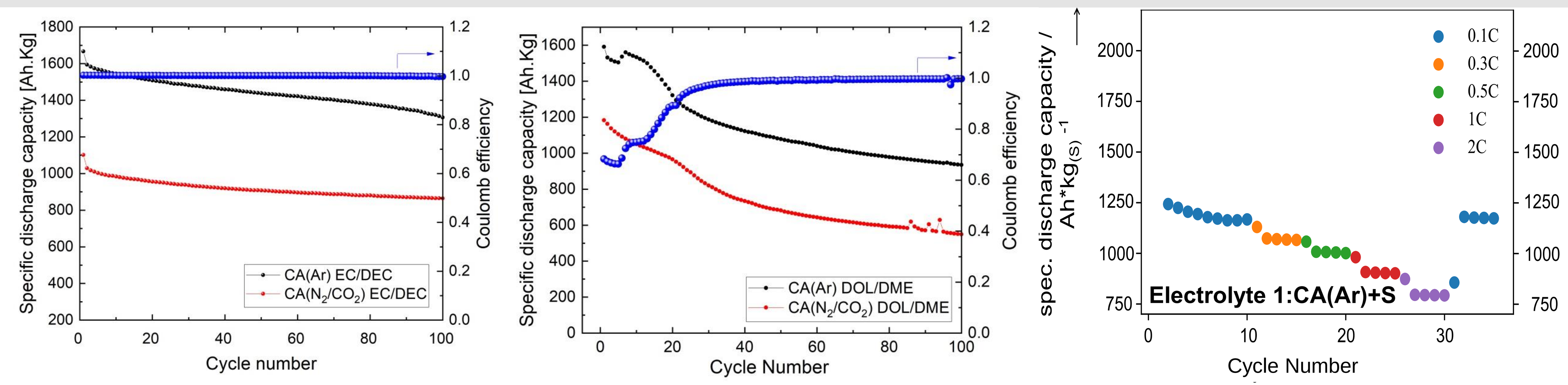
Cell Parameter:

Cell type: Swagelok

Electrolyte 1: 1M LiTFSI (lithium bis(trifluoromethylsulfonyl)imide in DOL/DME (1.3-dioxolane / dimethoxy ethane), 25°C

Electrolyte 2: 1M $LiPF_6$ (Lithiumhexafluorophosphat) in EC/DEC (ethylene carbonate / diethylene carbonate), 25°C

Sulfur-loading: 0.7–0.8 $mg_{(S)}/cm^2$



CONCLUSION

- Synthesis of the CAs with controlled and defined pore sizes and structures
- Increased surface area and micropore volume due to carbonization with N_2/CO_2
- Infiltration of short chain sulfur in the micropores through gas phase process
- Higher cyclability of the Li-S cell via the encapsulation of sulfur in carbonate- and ether-based electrolytes
- Suppression of polysulfide shuttle effect using CA:S electrode

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