Electrical conductivity of monolithic and powdered carbon aerogels and their composites

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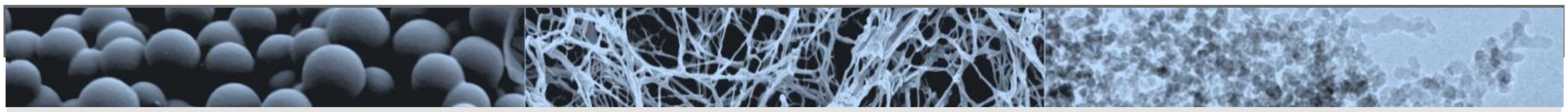
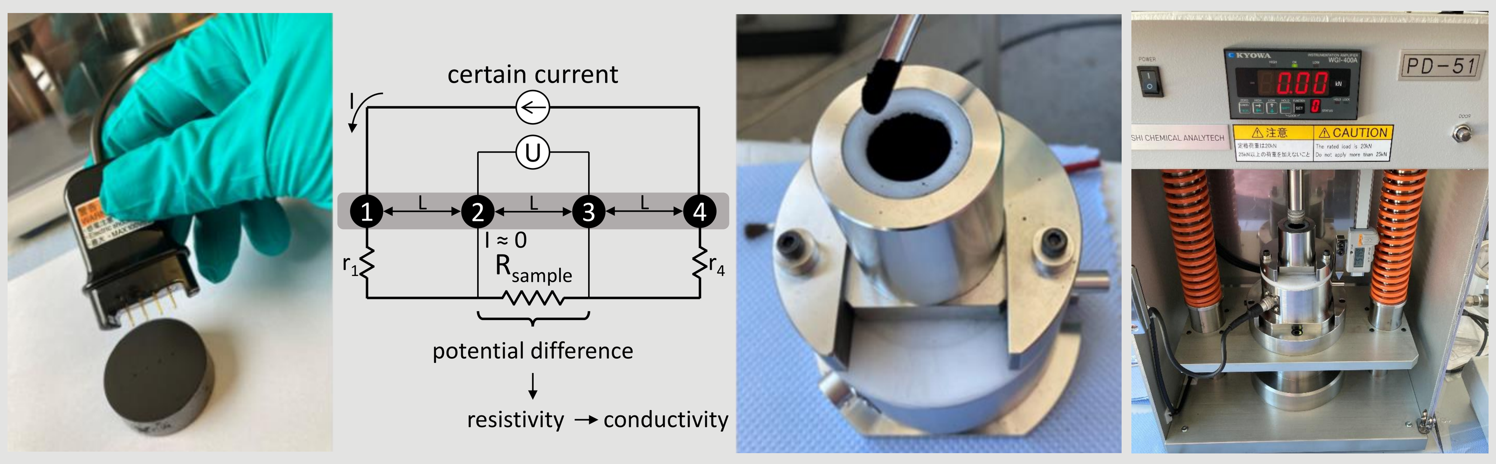


INTRODUCTION

Carbon aerogels (CA) are promising materials for applications in adsorption, catalysis, supercapacitors, or as cathode hosts in lithium-sulfur battery cells due to their unique properties such as well-controllable porosity, large specific surface area, high electrical conductivity, and low envelope density. Their electrical conductivity, remarkable for porous materials, is one of the key factors for electrochemical applications. The electrical conductivity of amorphous carbon materials is related to their electronic structure, the size of graphitic lattices or graphitic character, heteroatoms and so-called bulk electrical conductivity.

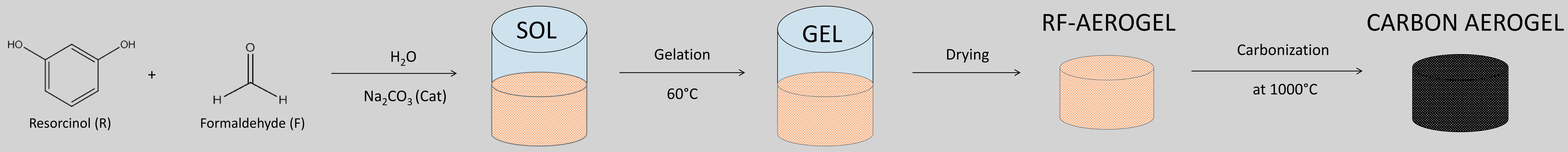
In most electrochemical applications, the carbon aerogels are used as powders for e.g. electrode materials. Therefore, the measurement of the electrical conductivity of powder materials is of great importance. For powders, conductivity consists of: 1) the conductivity of individual grains and 2) the conductivity of the powder.

The conductivity of individual grains depends only on conductivity of the material (monolithic conductivity) while the conductivity of powder depends on several factors e.g. the shape of grains, their packing, compressibility, and the contact between the grains.



Setup of the measurement of the electrical conductivity of monoliths and powders

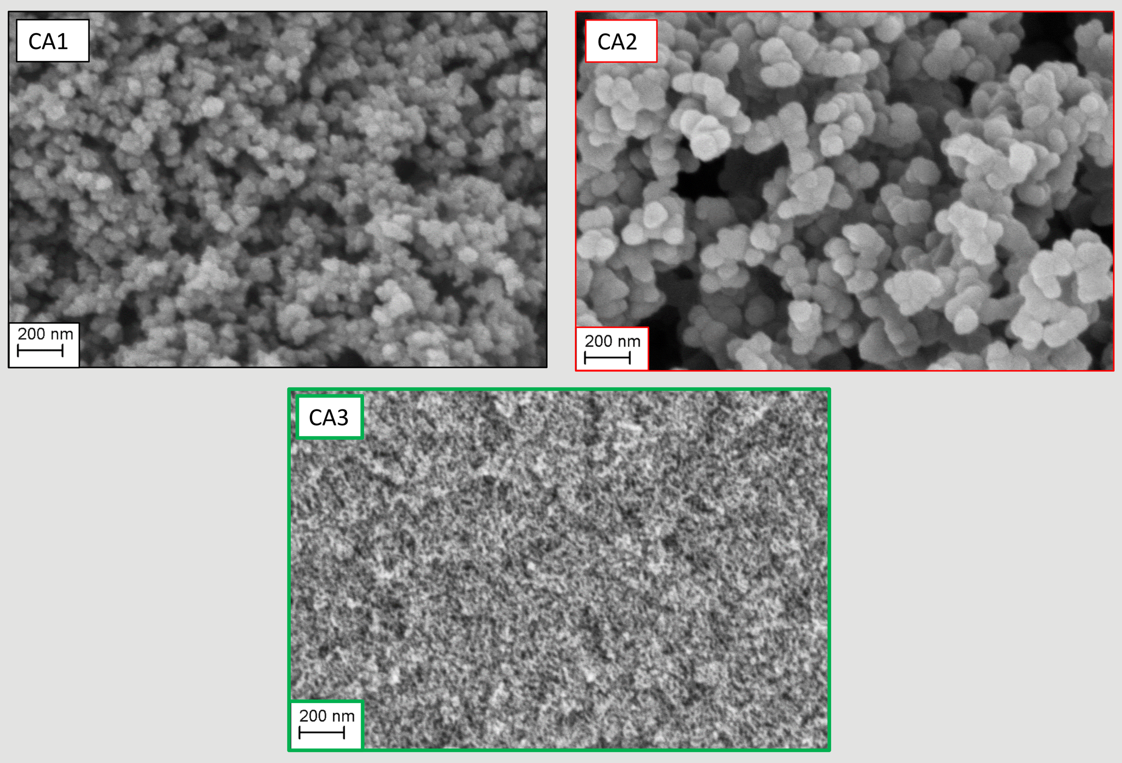
SYNTHESIS

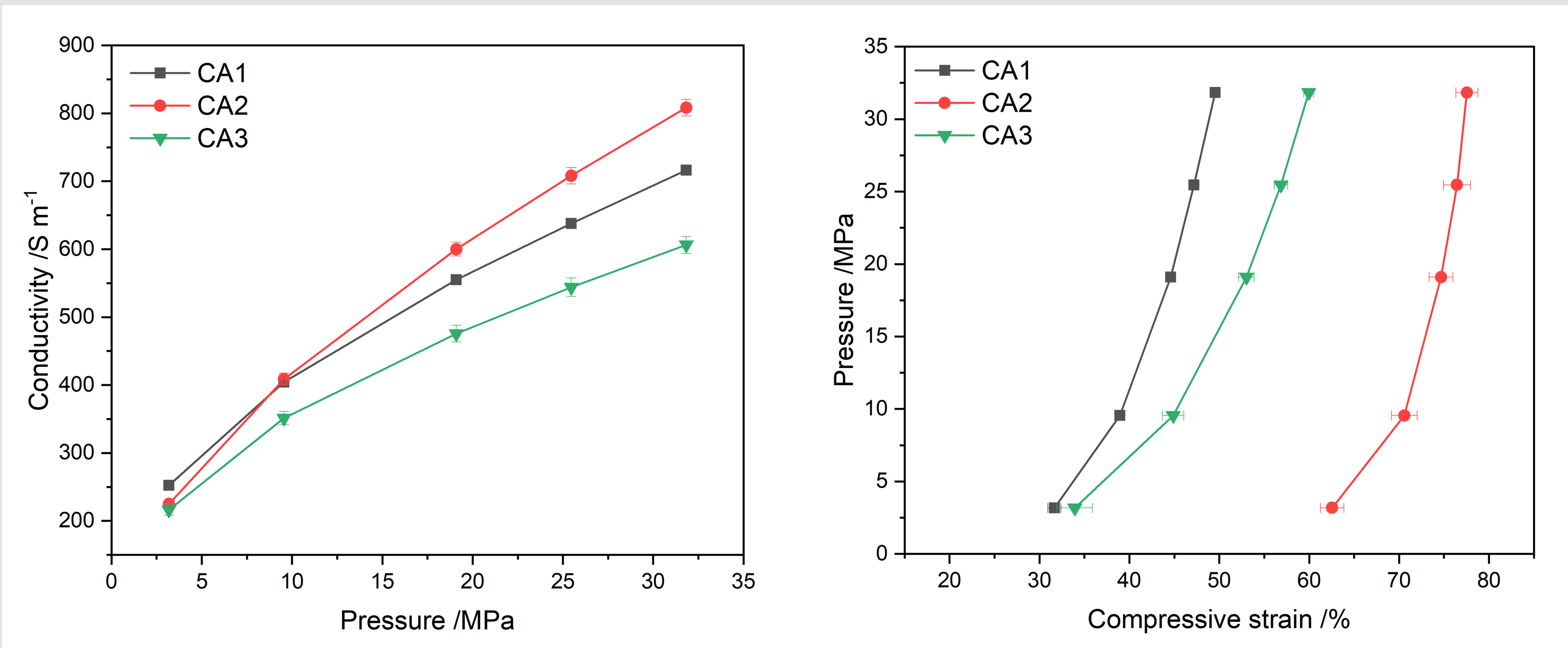


Synthesis parameters of the different carbon aerogels:

Carbon aerogel	R:Cat molar ratio	R:W molar ratio	R:F molar ratio	pH of initial solution	Stirring time [min]	Gelation time [days]	Drying conditions	Carbonization conditions
CA1	1500	0.044	0.66	-	30	2	Ambient pressure 80°C	1 h, N_2
CA2	50	0.008	0.5	5.4-5.6	60	7	Supercritical CO_2	1 h, N_2
CA3	200	0.019	0.5	-	30	7	Supercritical CO_2	1 h, N_2

RESULTS & DISCUSSION

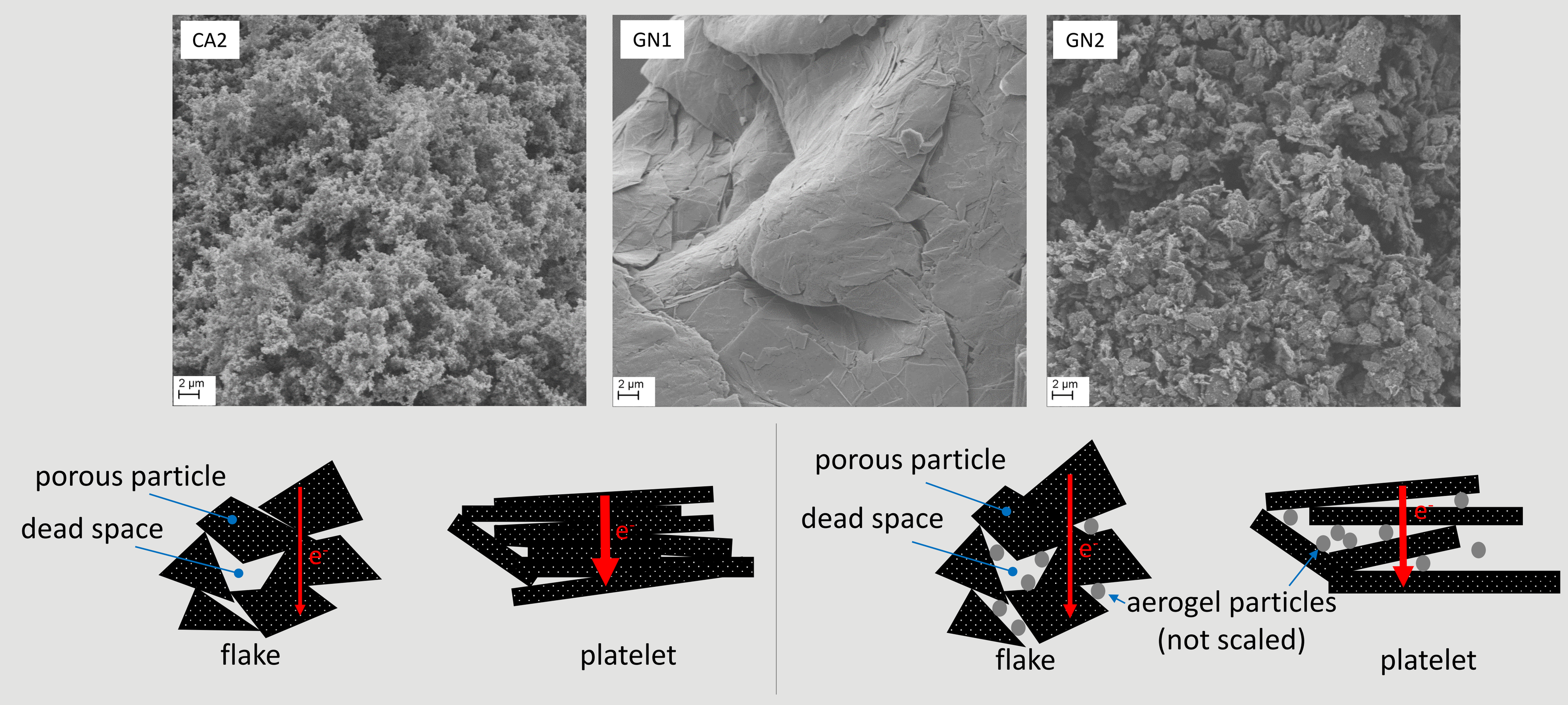


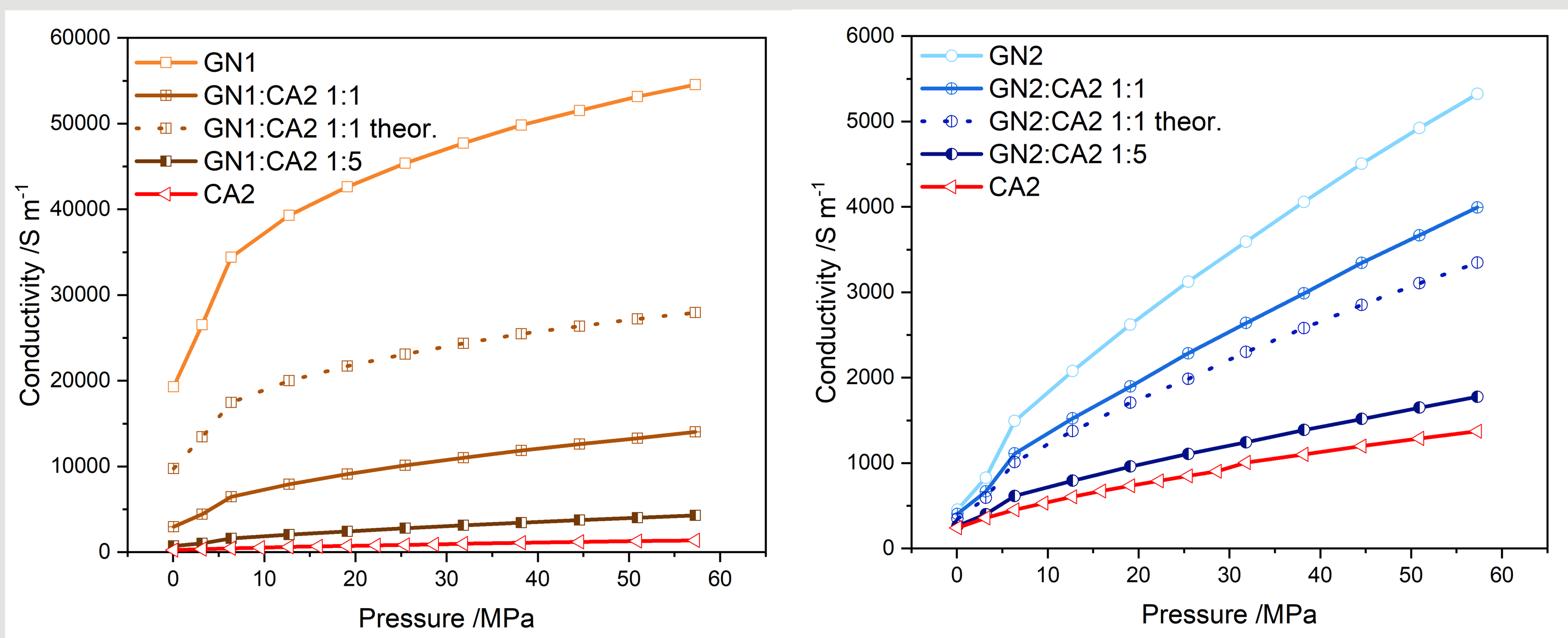


Carbon aerogel	Envelope density [g·cm⁻³]	Skeletal density [g·cm⁻³]	Porosity [%]	Specific surface area [m²·g⁻¹]	Micropore volume [cm³·g⁻¹]	Mesopore volume [cm³·g⁻¹]	Pore volume* [cm³·g⁻¹]	Average pore diameter* [nm]	Average primary particle size* [nm]	Monolithic electrical conductivity [S·m⁻¹]
CA1	0.420±0.0009	2.14±0.06	80	590±14	0.19±0.01	0.40±0.01	1.91	13.0	4.7	n.a.
CA2	0.076±0.0002	1.78±0.04	96	500±60	0.17±0.03	0.12±0.02	12.63	101.0	6.8	10.3±1.2
CA3	0.328±0.0007	2.03±0.02	84	692±22	0.10±0.00	2.62±0.08	2.56	14.8	4.3	670.8±18.6

* calculated

Carbon aerogel composites





CONCLUSIONS

- Electrical conductivity of powder strongly depends on applied pressure
  - High envelope density and strong compression provide more electron pathways
  - Electrical conductivity is highly influenced by the envelope density, the compression and densification behavior
  - The shape of the powder particles has an essential influence on the compression and densification behavior
- Monolithic electrical conductivity depends on envelope density and degree of crosslinking
- Addition of high conductive additive increases the electrical conductivity of composites
- Increase in electrical conductivity is influenced by the different particle shapes of additive

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