Understanding the microwave-thermal pretreatment effect on holey graphene fabrication

Yan Dou, Materials Science and Engineering
Mentor: Qiong Nian, Assistant Professor
School for Engineering of Matter, Transport and Energy

What is the electrochemical difference of holey graphene with different microwave pretreatment condition?

Experimental Methods:

According to MACE method, holy graphene can be fabricated by follow steps:

1) Pretreatment:

The graphene oxide(GO) solution is pretreated by irradiating in a microwave reactor to form defected graphene oxide(dGO) with different power(0W, 200W and 600W).

2) MACE process:

The dGO is mixed with hydrogen peroxide in a reaction tube and irradiated in the microwave reactor to further etch and extend the dGO to holey graphene oxide(hGO).

3) Reduction:

The hGO is reduced to holey graphene (rhGO) by microwave, and the holes can provide abundant ion transport channels and achieve charge transfer.

Figure 1 | three-electrode experiments

Results: Electrochemical characterization of rhGO-EC with power of 0W, 200W and 600W in 1 M Na_2SO_4

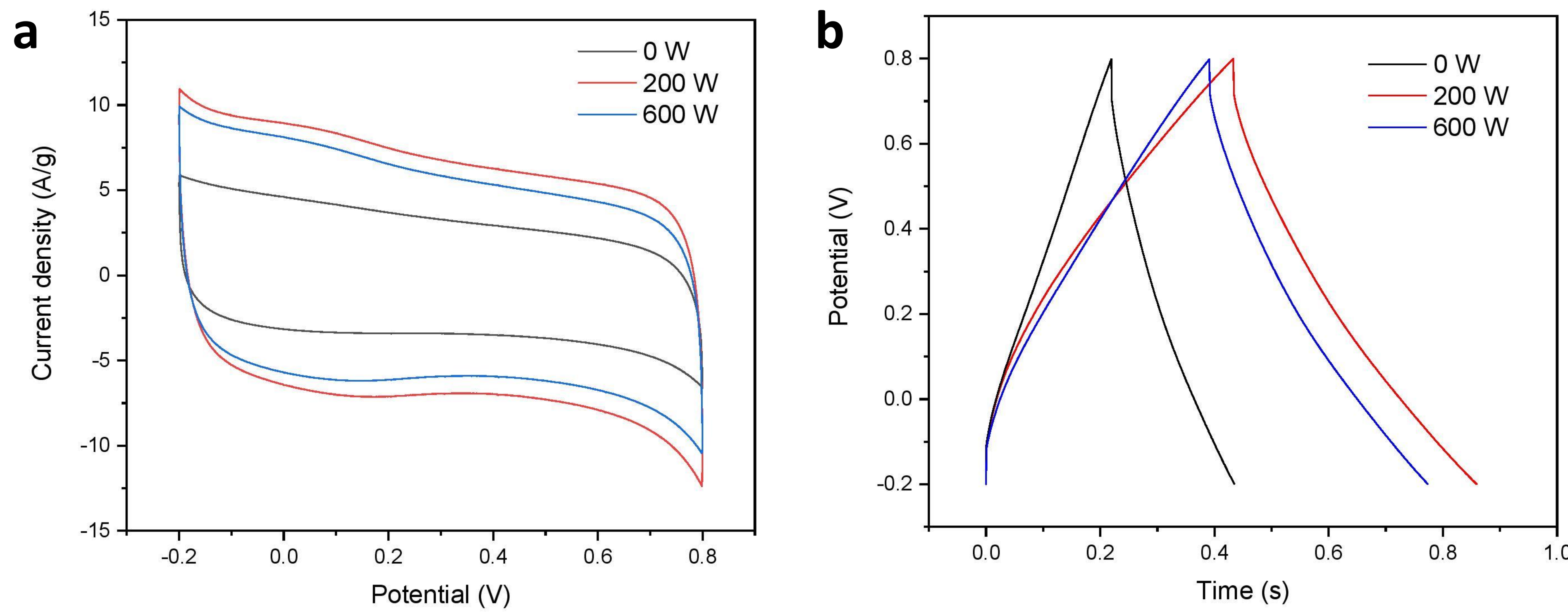

Figure 2 | (**a**) CV curves of rhGO-EC at a scan rate of $100 mVs^{-1}$. (**b**) Galvanostatic charge/discharge curves of rhGO-EC at a current density of $100 Ag^{-1}$.

- The CV(Fig. a) and GCD(Fig. b) indicate that rhGO with pretreatment shows a **significantly improved electrochemical performance** beyond the rhGO without pretreatment. The approximate rectangular part of CV curves and the triangular GCD curves reveal **an almost electrical-double-layer capacitive behavior** as well as **efficient electrolyte ion transport** throughout the rhGO.
- The GCD curves also can derive the specific capacitance values(Fig. c**). A good gravimetric capacitance of 172 F g-1** at a current density of 1 A g-1 is exhibited by rhGO-Ecs(200W). On the contrary, the gravimetric capacitance of **rhGO without pretreatment(81 F g-1) electrodes is about half of the rhGO(200W, 600W).**

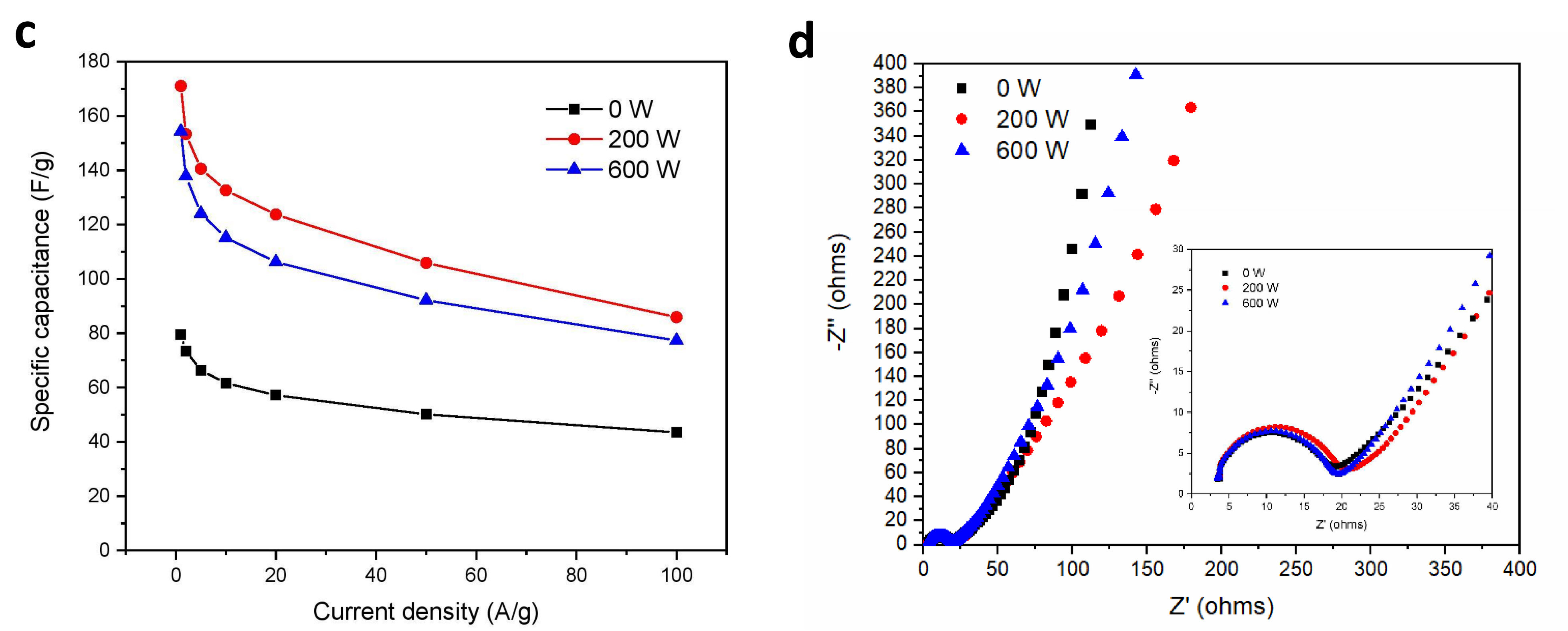

Figure 3 | (**c**) Comparison of specific capacitances versus different current densities for rhGO-EC. (**d**) Niquist plots of rhGO-EC as well as the close-up view of the high-frequency regime.

- Increasing the current density up to 100 A/g(Fig. c), the rhGO(0W, 200W, 600W) displays **a similar capacitance retention**(around 50%).
- The ion transport properties within the rhGO further probed using EIS. A frequency response analysis over the frequency range from 100 kHz and 10 mHz yields the Nyquist plots (Fig. d). The vertical curves of rhGO(200W, 600W) in low-frequency regime **exhibit a nearly ideal capacitive behaviour (but not better than 0W)**.
- A close-up observation of the high-frequency region reveals a transition from a vertical curve to a semicircle part. The rhGO(200W) exhibits a slightly larger diameter semicircle, indicating **a higher charge transfer resistance** within the rhGO(200W) electrodes.

Conclusion:

Through this project, the relationship between pretreatment conditions and electrochemical performance of rhGO have been studied. The microwave pretreatment improves the capacitance of rhGO effectively. In addition, the pretreatment with lower power(200W) shows a better property of capacitance compared with the pretreatment with higher power(600W).

But the reduction process by microwave doesn't make a full reduction of hGO, which brings about a higher charge transfer resistance in rhGO with microwave pretreatment. So, the next step should focus on researching a better reduction method.

Acknowledgements

This project is supported by the "MORE" program. I thank Professor Nian for insightful discussions and advice. Also appreciate Ira A. Fulton Schools of engineering for providing this chance.

MORE
Masters Opportunity for Research in Engineering

ASU Ira A. Fulton Schools of Engineering
Arizona State University