Superhydrophobic Microporous Layers for Improved Water Management in PEFCs

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Introduction

- Polymer Electrolyte Fuel Cells (PEFCs) are promising, highly efficient renewable energy technologies for next generation energy conversion devices.[1]
- **Problem:** Excessive water accumulation inside of the microporous layer and gas diffusion layer under the high current density operation conditions hinders oxygen transfer to the catalyst layer and decreases PEFC performance drastically.
- **Solution:** To increase water removal speed with superhydrophobic fluorinated carbon (SHFC) as MPL material.

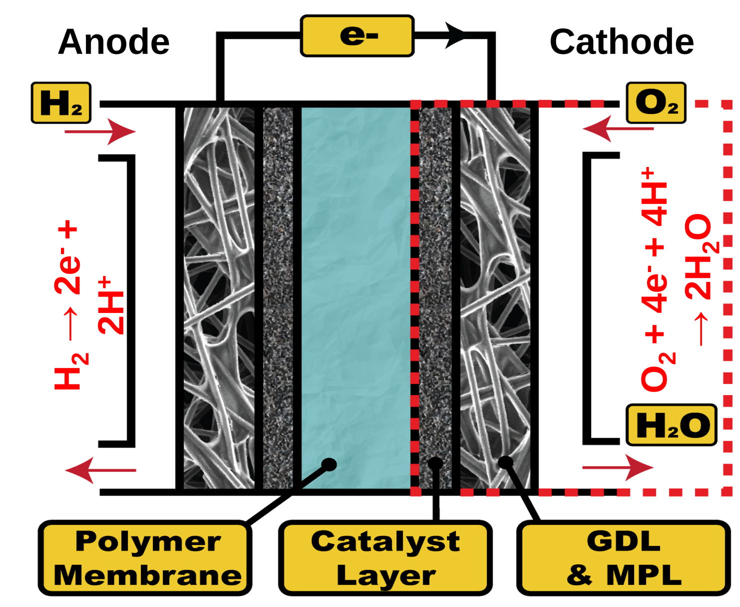

Fig.1a Schematic diagram of a PEFC

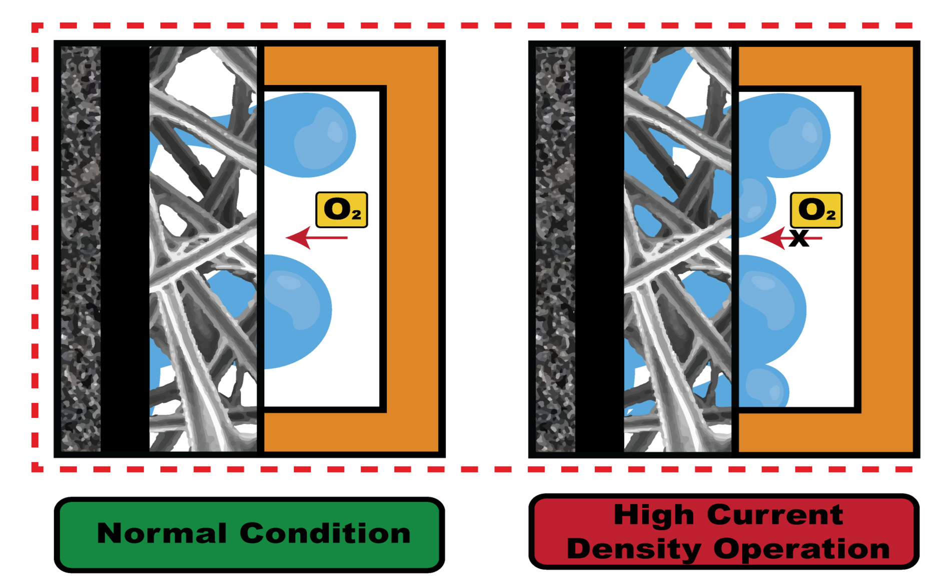

Fig.1b Schematic illustration at the cathode side of PEFC under normal and high current density operation conditions.

Materials Synthesis

Fluorinated Alcohol + Sodium (Na) ⟶ Fluorinated Carbon CF_x + By-product HF + NaF etc

Fig.2 Superhydrophobic fluorinated carbon's synthesis procedures [2]

- Sodium and fluorinated alcohol reacted in a sealed PTFE crucible at 150° C for 24 hours.
- After this reaction, the precursor is already carbonized and by-products are removed by washing it with a water and ethanol mixture.
- The yield of the reaction was 20wt%.

Characterization

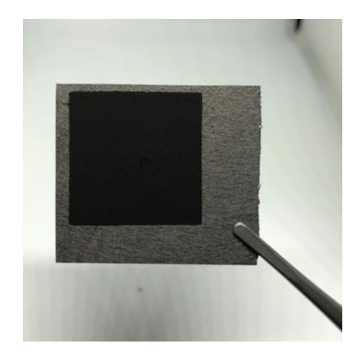

Fig.7 Images of MPL coated GDL

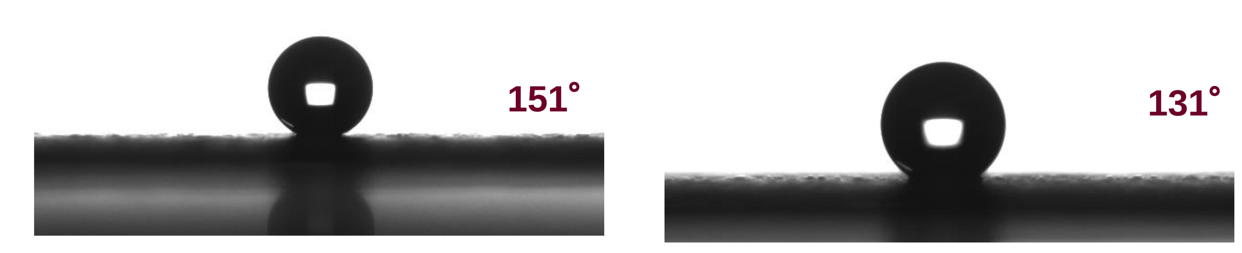

Fig.8 Surface contact angle measurement of SHFC and carbon black-based MPL with 5wt% PTFE loading.

- Two different types of MPLs are coated on GDL: SHFC-based and CB-based.
- To prepare MPLs, carbon material (SHFC or CB), methyl cellulose, deionized water, Triton-X and PTFE are mixed with a homogenizer. Then MPL slurry is coated on the GDL with a doctor blade. The final MPL thickness is 35 µm.
- To sinter PTFE and decompose methyl cellulose and Triton-X, MPL coated GDLs are heat treated at 380 ° C.
- Contact angle measurement shows that SHFC-based MPL's water contact angle is higher than 150 ° .

Characterization

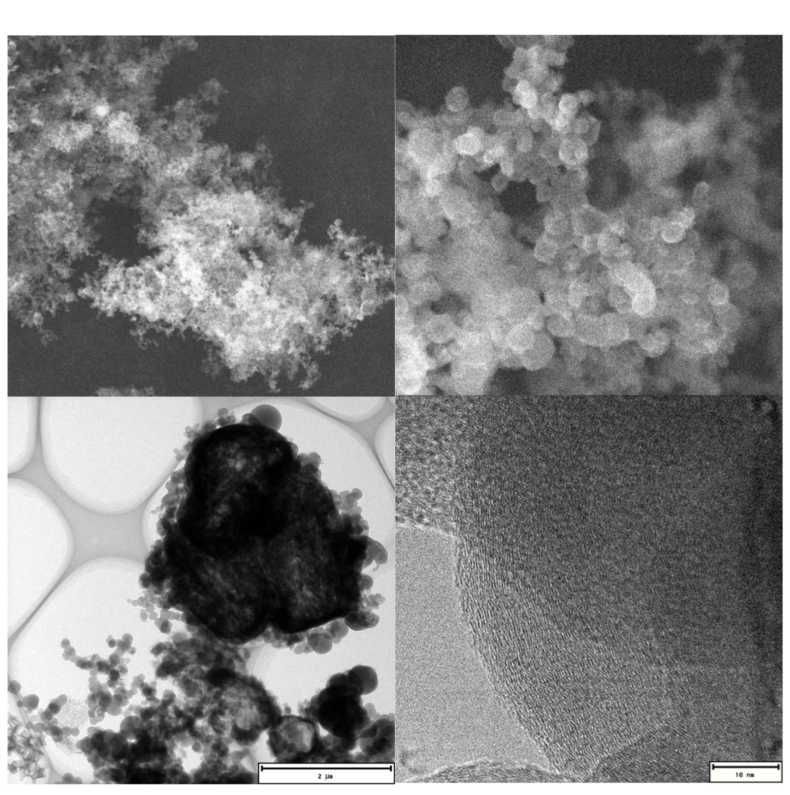

Fig.3 SEM and TEM images of SHFC

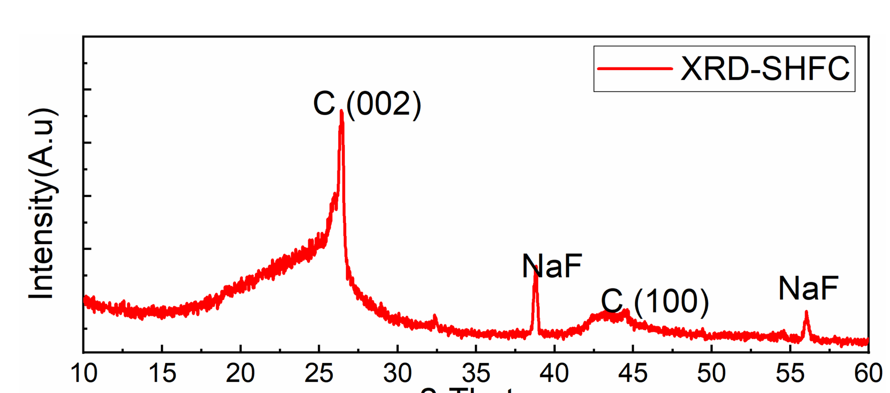

Fig.4 XRD analysis result

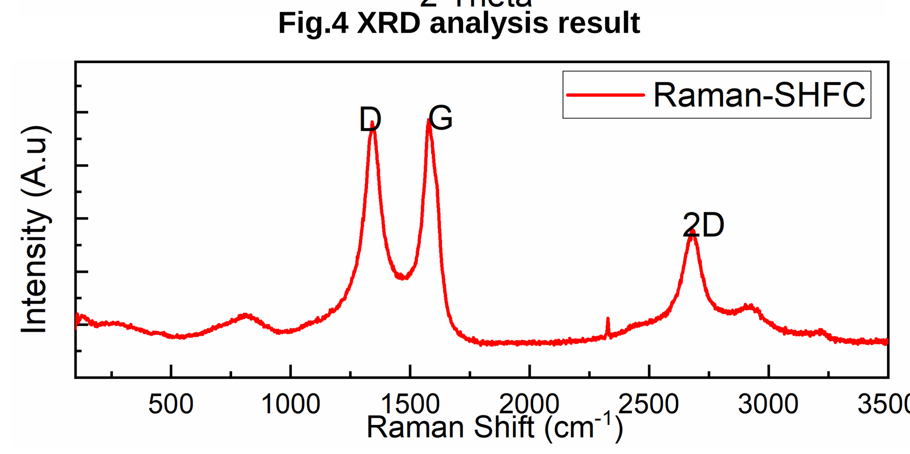

Fig.5 Raman spectroscopy analysis result

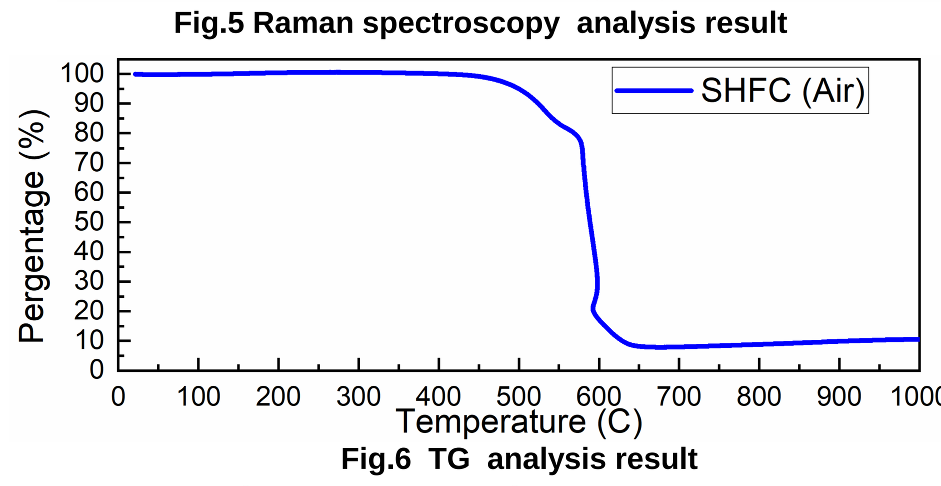

Fig.6 TG analysis result

- SEM reveals that the structure of SHFC is similar to carbon black.
- BET specific surface analysis shows that SHFC has low surface area ($40 m^2/g$) compared to carbon black ($100 m^2/g$)
- TEM shows that SHFC contains high ordered graphitic structure.
- XRD analysis revealed sharp peaks at 25.9° and 26.5° , corresponding to fluorine dopped graphene and graphene formations respectively.
- Raman spectroscopy analysis results support TEM and XRD results, and show that SHFC has multi layered graphene formation.
- TG analysis results show that SHFC is stable until to 500° C under air.

Characterization

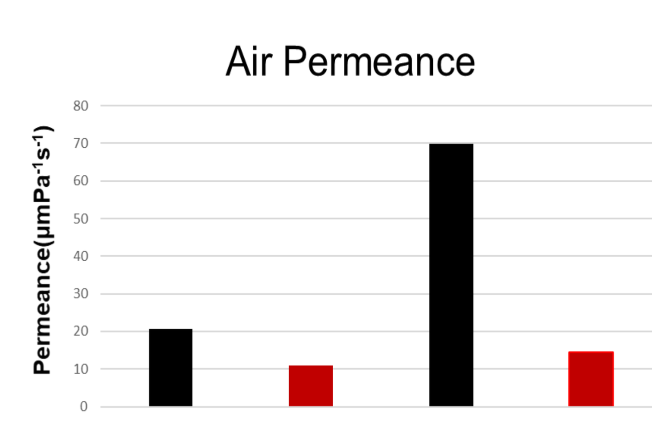

Fig.9 Air permeability at room conditions [3]

- Air permeabilities of CB-based and SHFC-based MPLs are measured at room conditions.
- Compared to SHFC-based MPLs, CB-based MPLs are more air permeable at low relative humidity conditions.

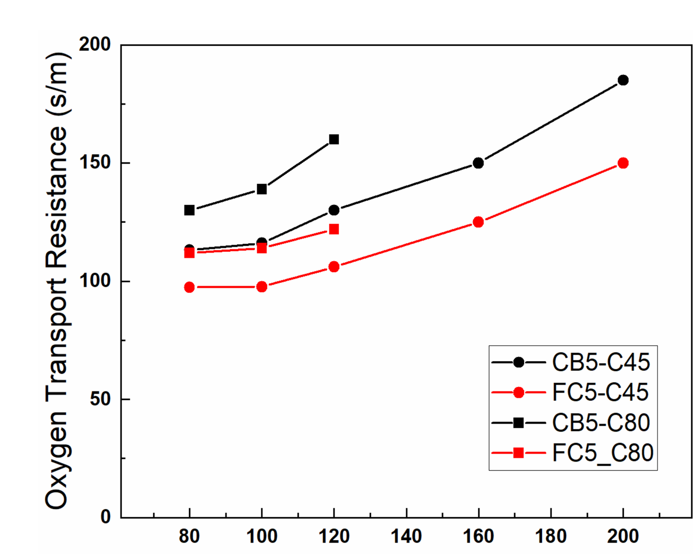

Fig.10 Oxygen transport resistance [4]

- Oxygen transport resistances at 45 ° C and 80 ° C with different high humidity conditions were measured.
- Opposite to the air permeability test, when relative humidity is high, at low and high cell temperatures, SHFC-based MPLs have lower oxygen transport resistance.

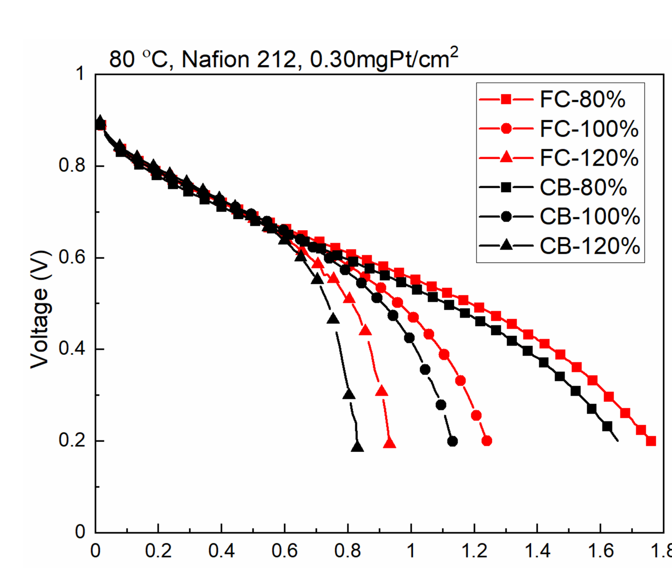

Fig.11 Single fuel cell performance test results

- Performance of SHFC-based MPL and CB-based MPL were compared with single fuel cell test results.
- The single fuel cell tests were conducted at 80 ° C cell temperature and high relative humidity conditions (80,100,120%).
- The results are showing that when SHFC-based MPL employed in the cell, fuel cell performance increasing dramatically in all high relative humidity conditions.

Conclusions

- Superhydrophobic fluorinated carbon was synthesized at a low reaction temperature with the decomposition reaction of fluorinated alcohol with sodium metal.
- SHFC and commercially used MPLs were manufactured and characterized.
- The water contact angle measurement results showed that SHFC-based MPL has a contact angle higher than 150 ° .
- The oxygen transport resistance tests and the single fuel cell performance test results signified that SHFC-based MPL has significantly higher performance at high current density operation conditions.

References

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[2] Lyth S.M., Ma W., Liu J., Daio T., et al., Solvothermal synthesis of superhydrophobic hollow carbon nanoparticles from a fluorinated alcohol, Nanoscale, 2015, 7, 16087-16093

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[4] Mashio, T., Ohma, A., Yamamoto, S. & Shinohara, K. Analysis of Reactant Gas Transport in a Catalyst Layer. *ECS Trans.* **11**, 529–540 (2019).