Modularization of Ceramic Hollow Fiber Membrane Technology for Air Separation

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Projection Objective and Tasks

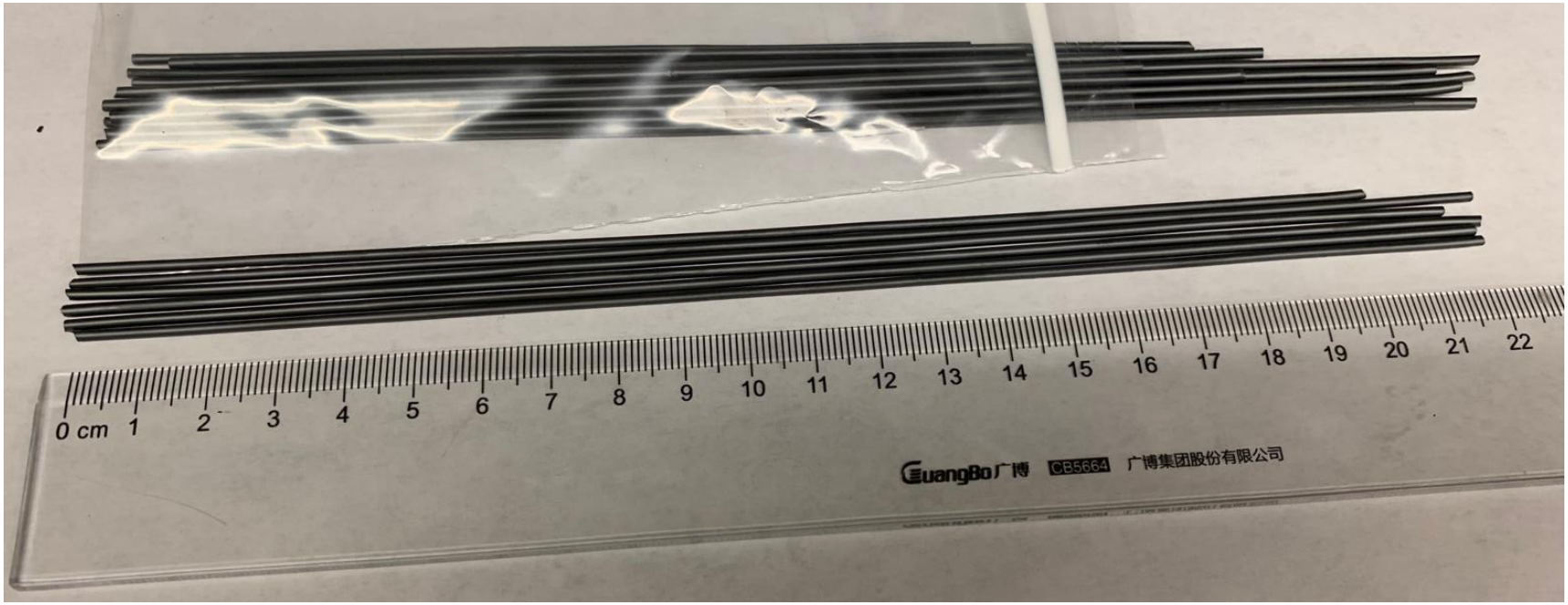
Objective:

Develop membrane stack and module for air separation and oxygen production using ceramic hollow fiber membrane technology

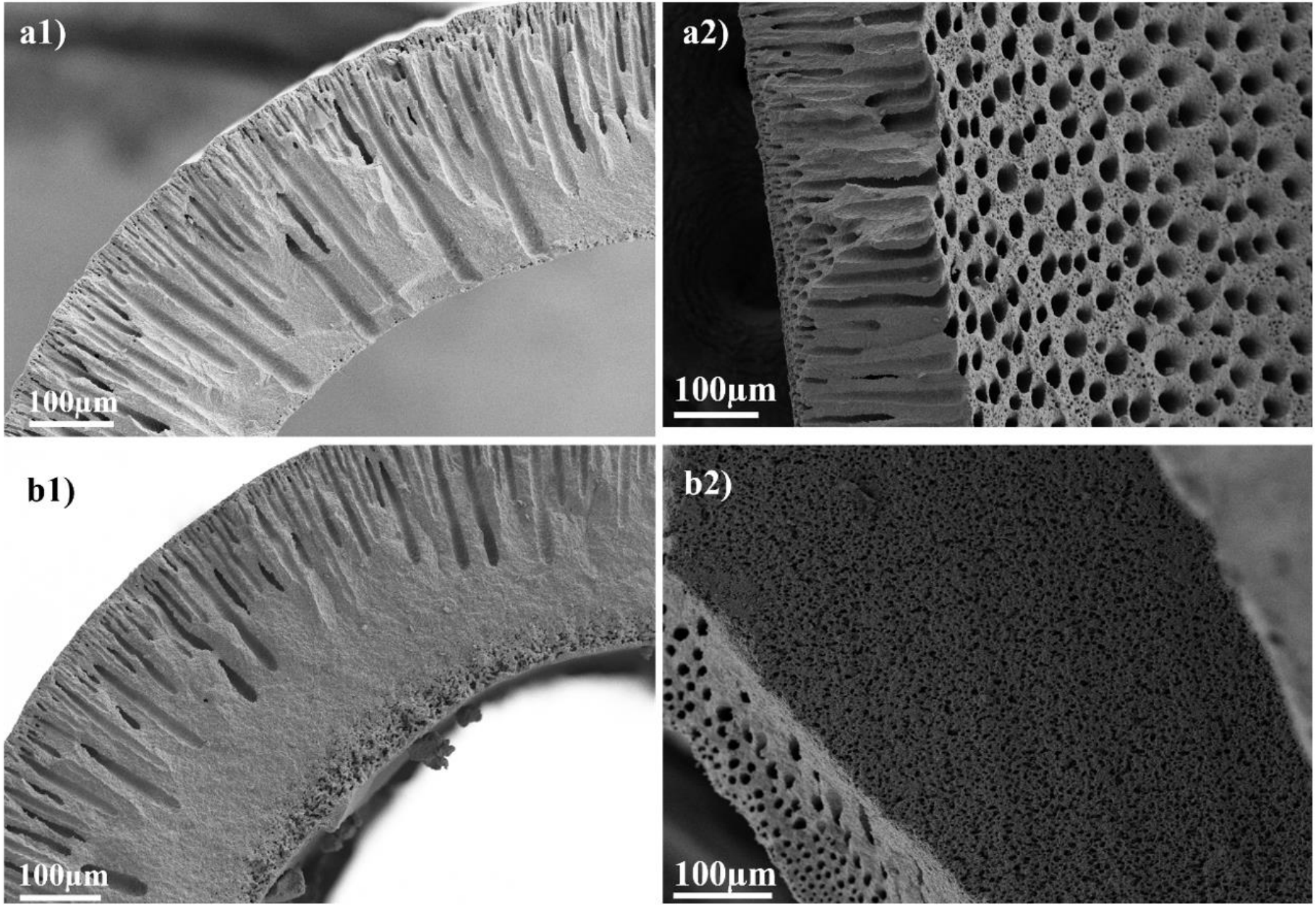
Strategic alignment of project to Fossil Energy objectives

- **Cost of Energy and Carbon Dioxide (CO2) Capture**
  - Using pure oxygen instead of air for combustion of power plant produces CO2, no need to separate nitrogen from down stream;
  - Can reduce the cost and simplify the system for CO2 capture.
- **Power Plant Efficiency Improvements**
  - Pure oxygen instead of air increases efficiency of power plant;
  - Cost-effective, reliable technologies to improve the efficiency of coal-fired power plants.

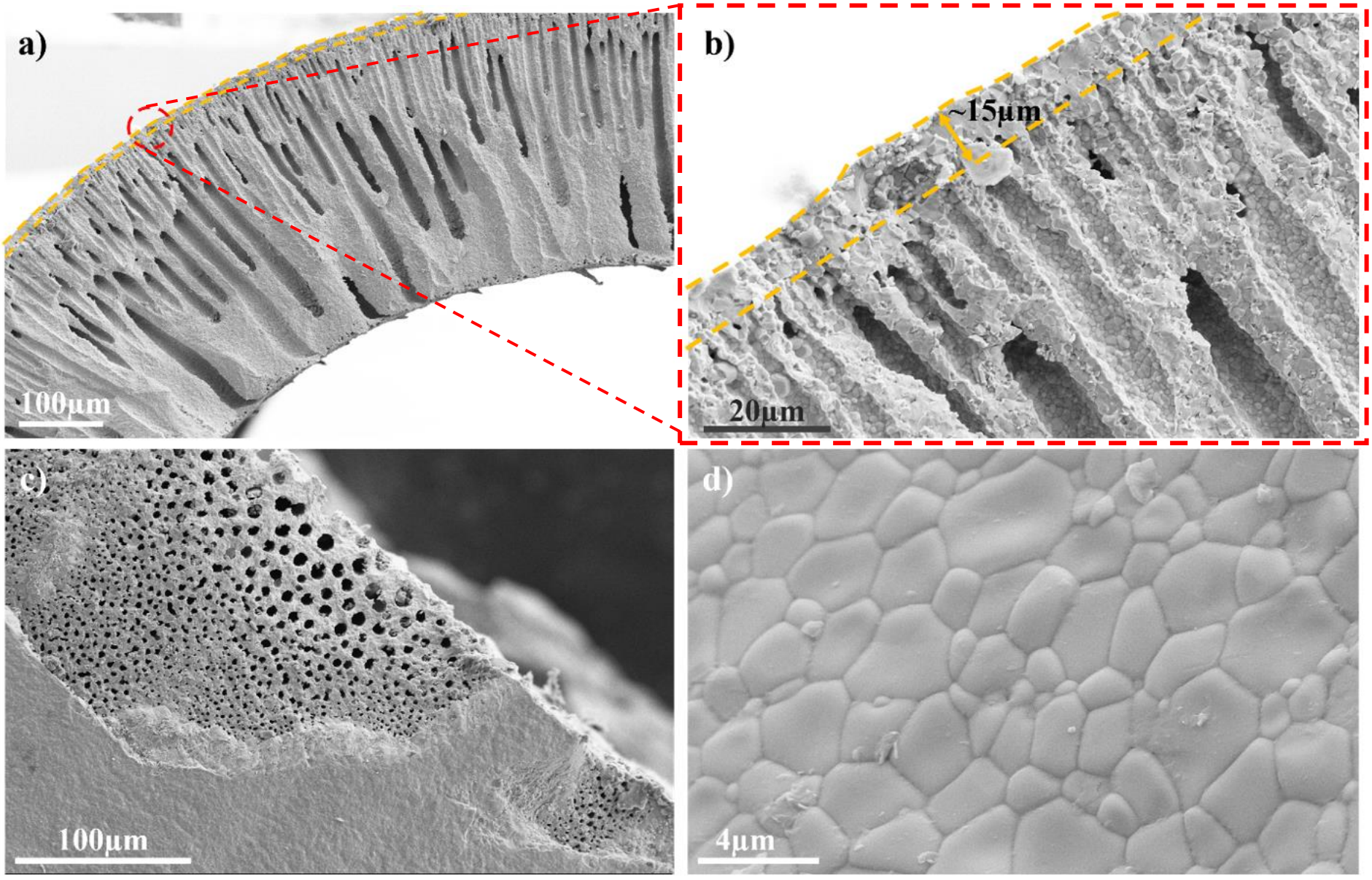
Fabrication of Membranes



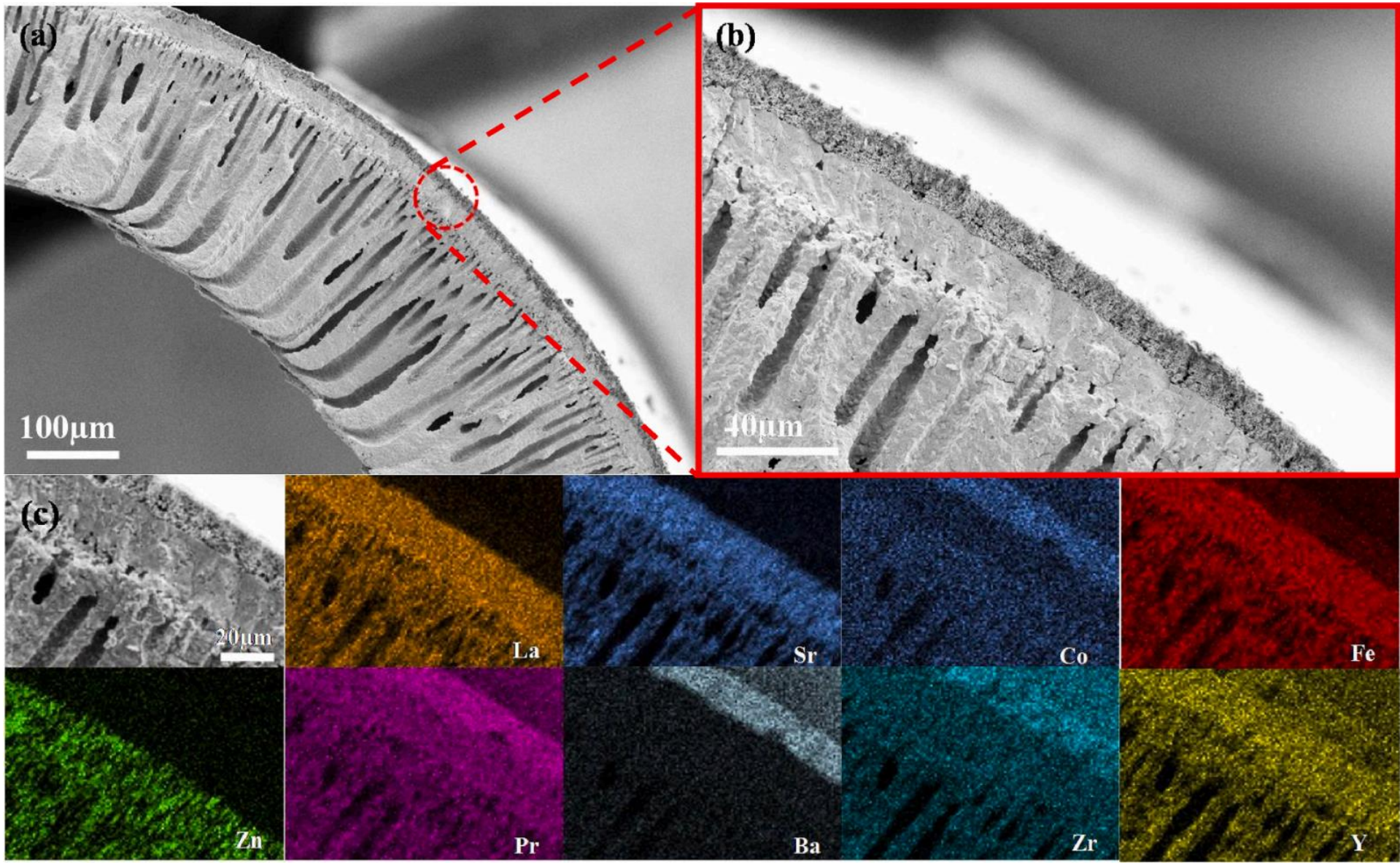
Characterization of Membranes



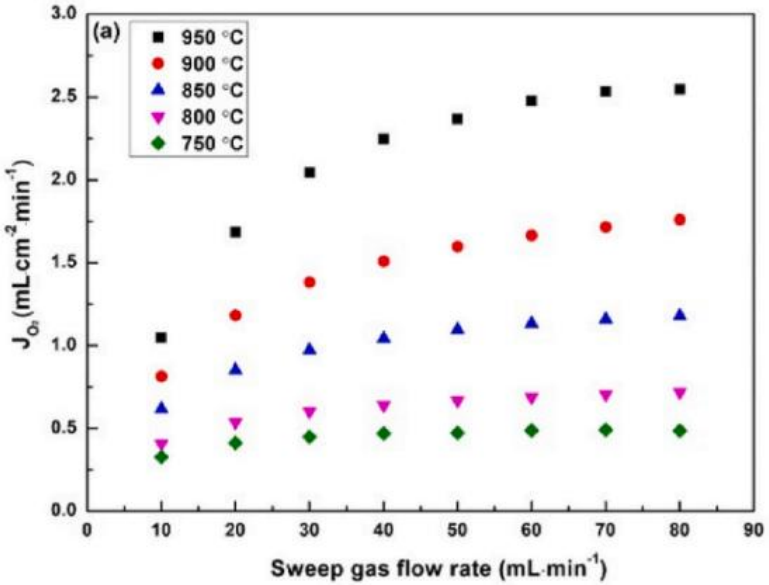
Microstructure of Membrane Device

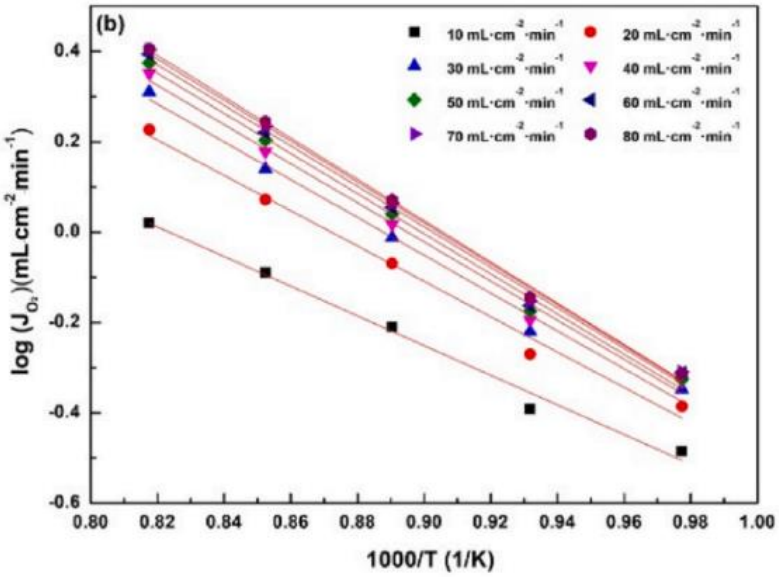


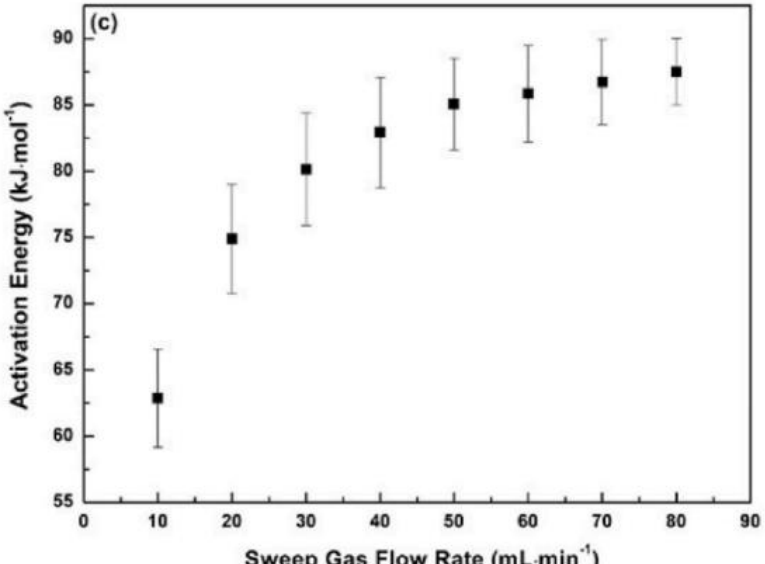
Characterization of Membrane



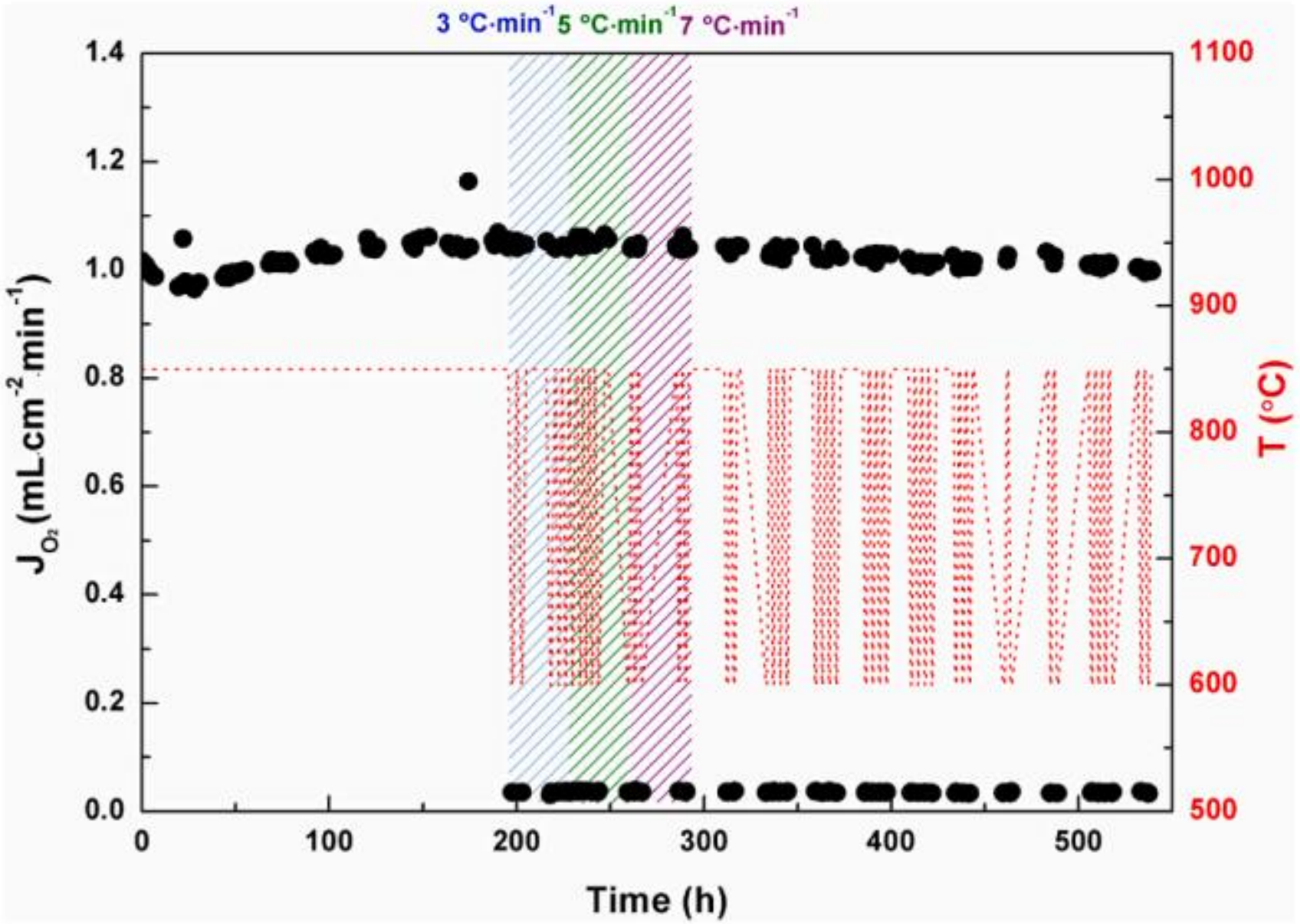
Oxygen Permeation Performance



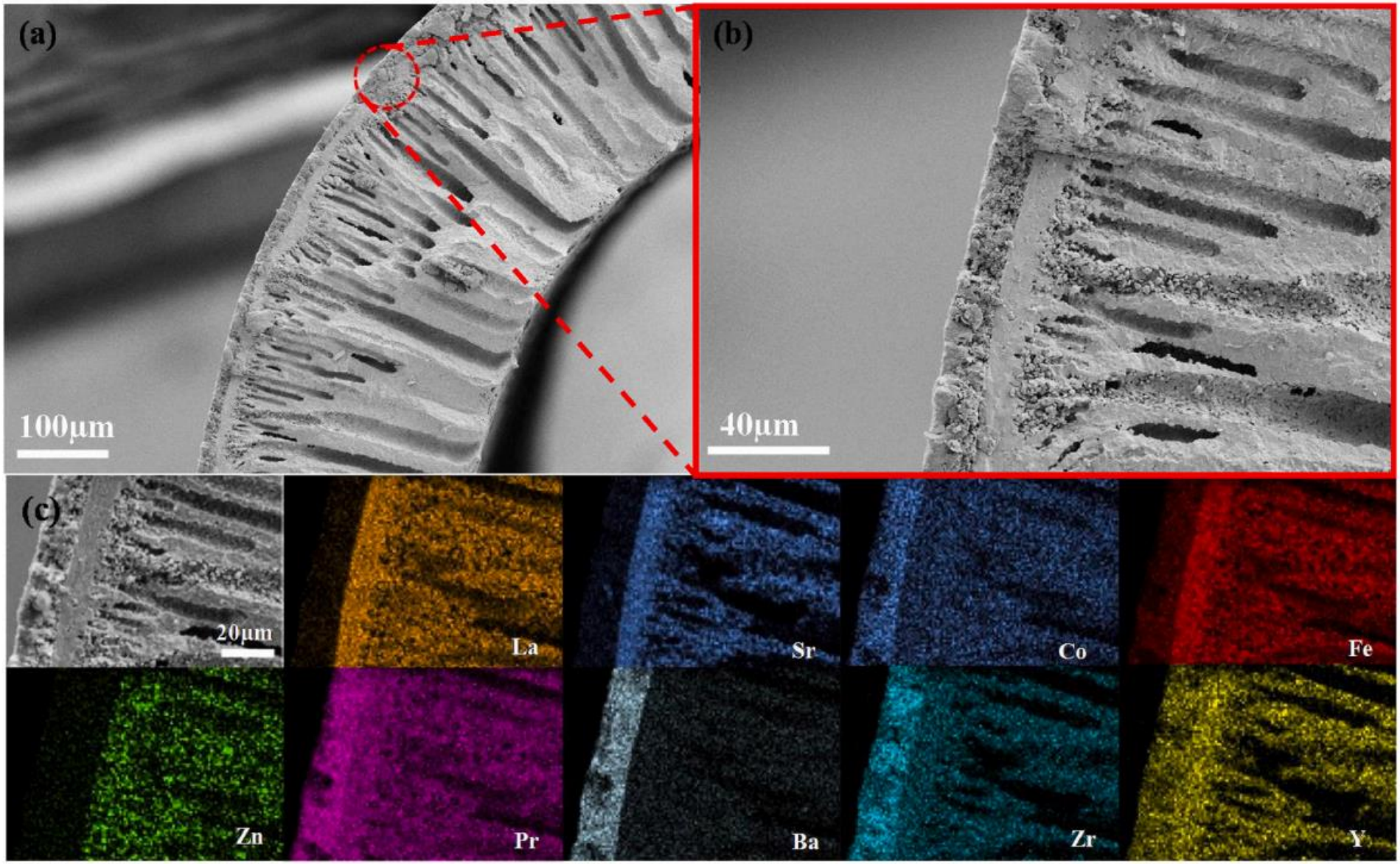




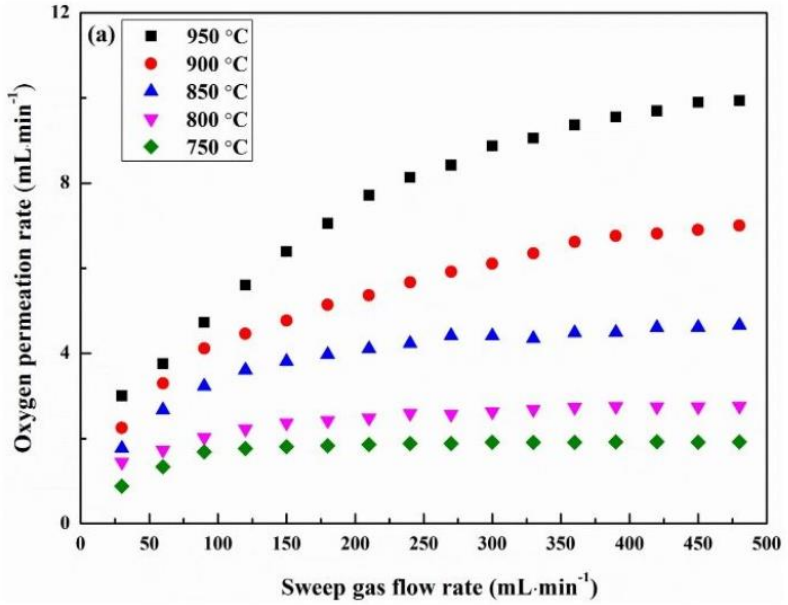
Stability

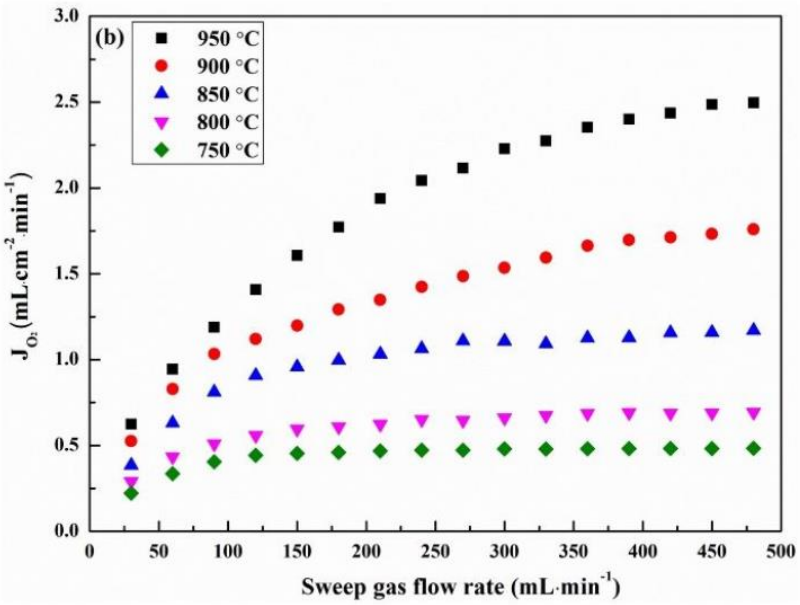

3 °C·min-1 5 °C·min-1 7 °C·min-1
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
J O2 (mL·cm-2·min-1)
0
100
200
300
400
500
Time (h)
1100
1000
900
800
700
600
500
T (°C)

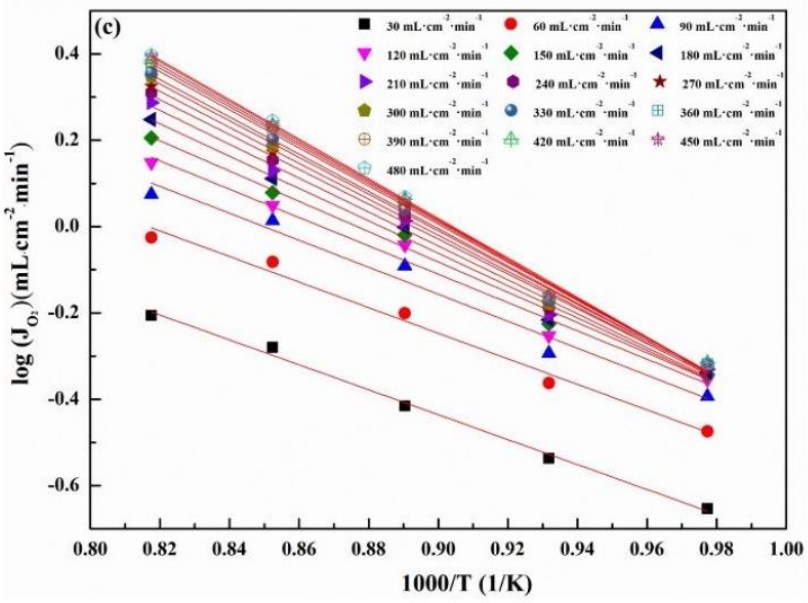
Post test characterization

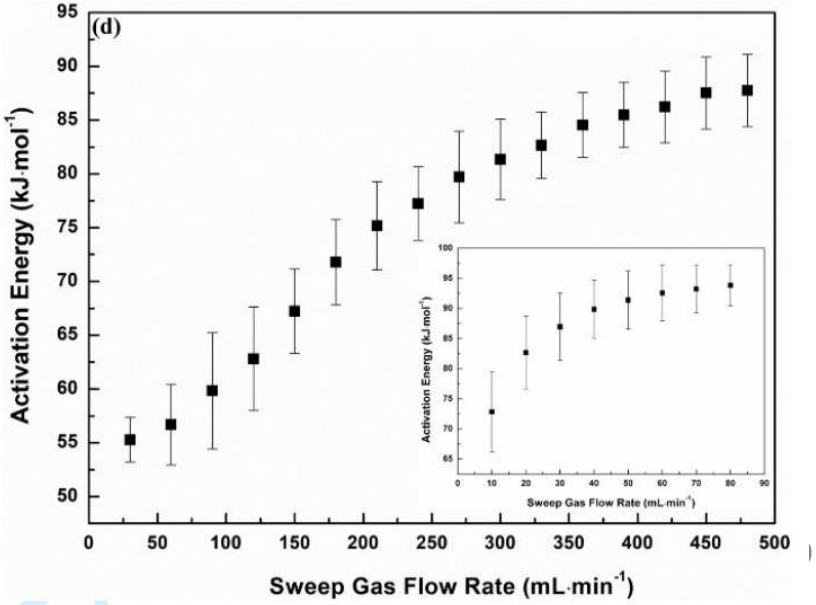


Upscaling: Membrane Stack-Proof of Concept

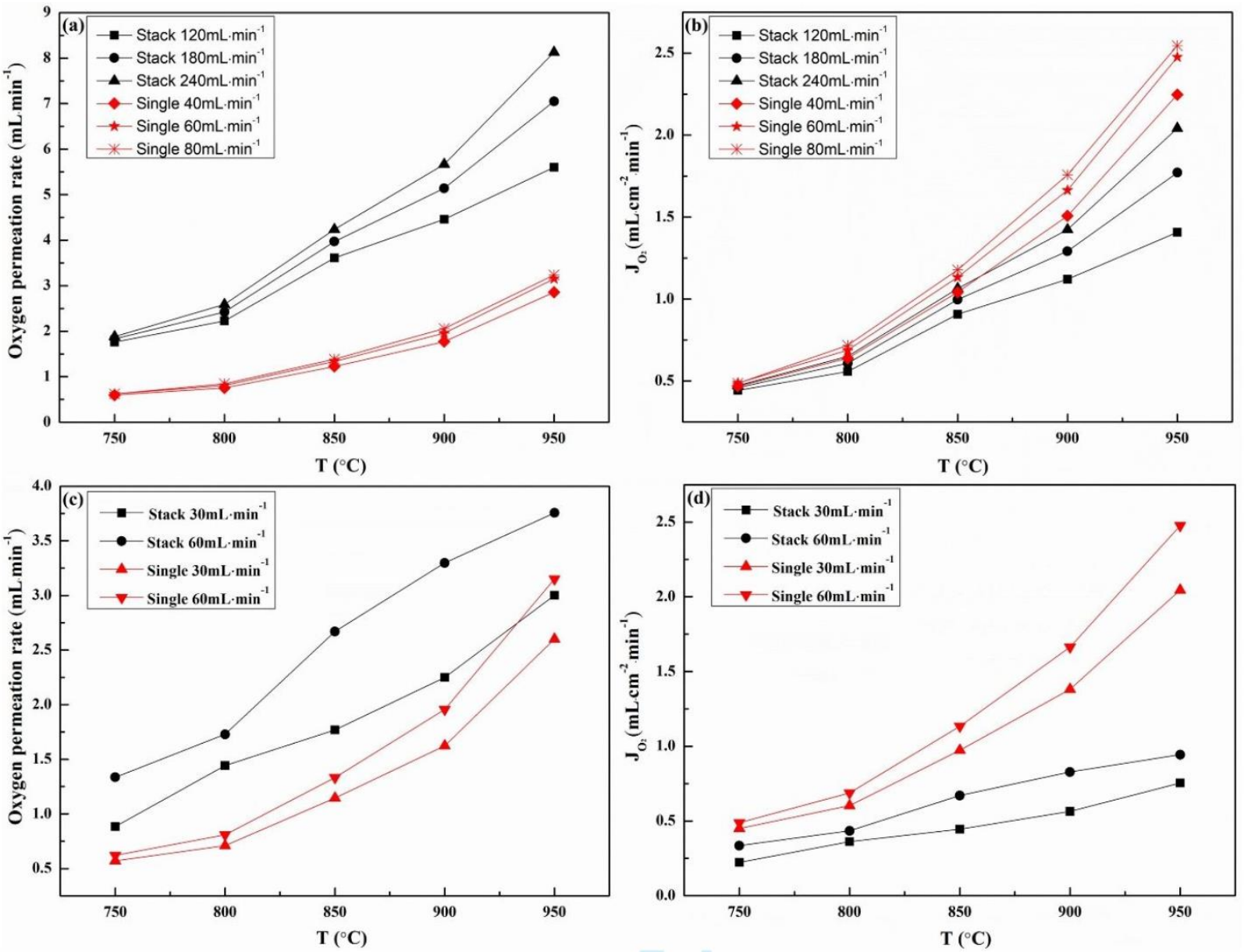




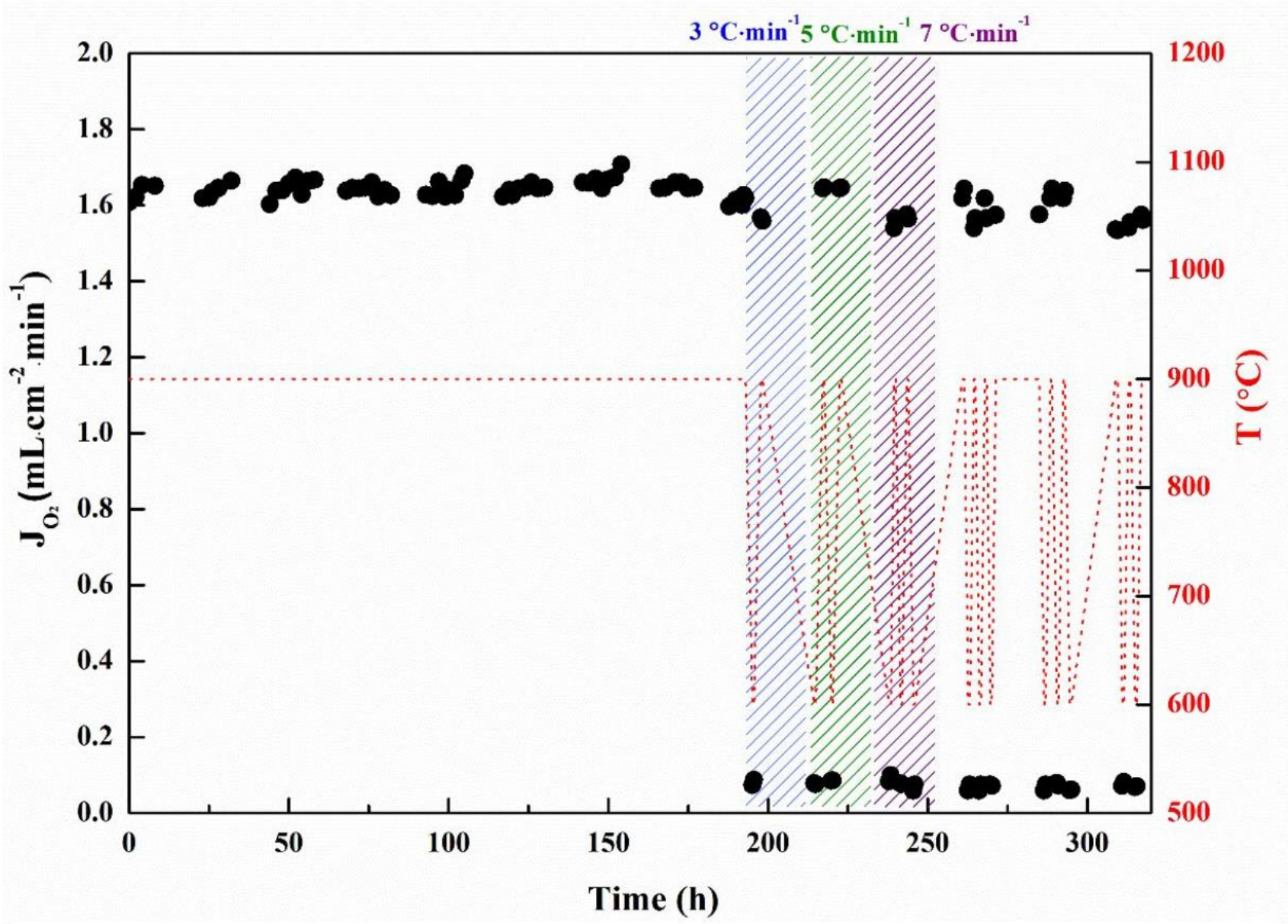




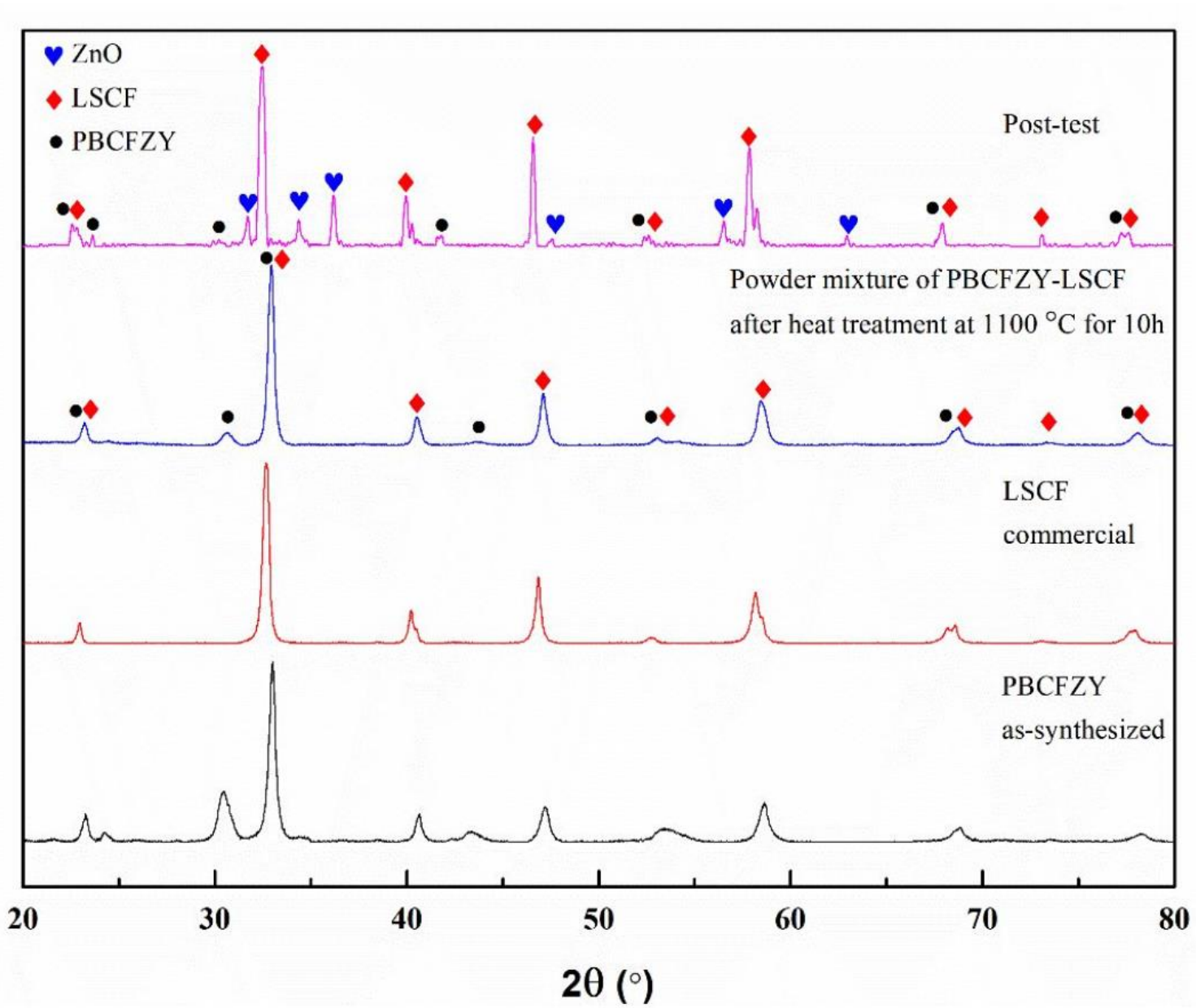
Upscaling: Membrane Stack-Proof of Concept



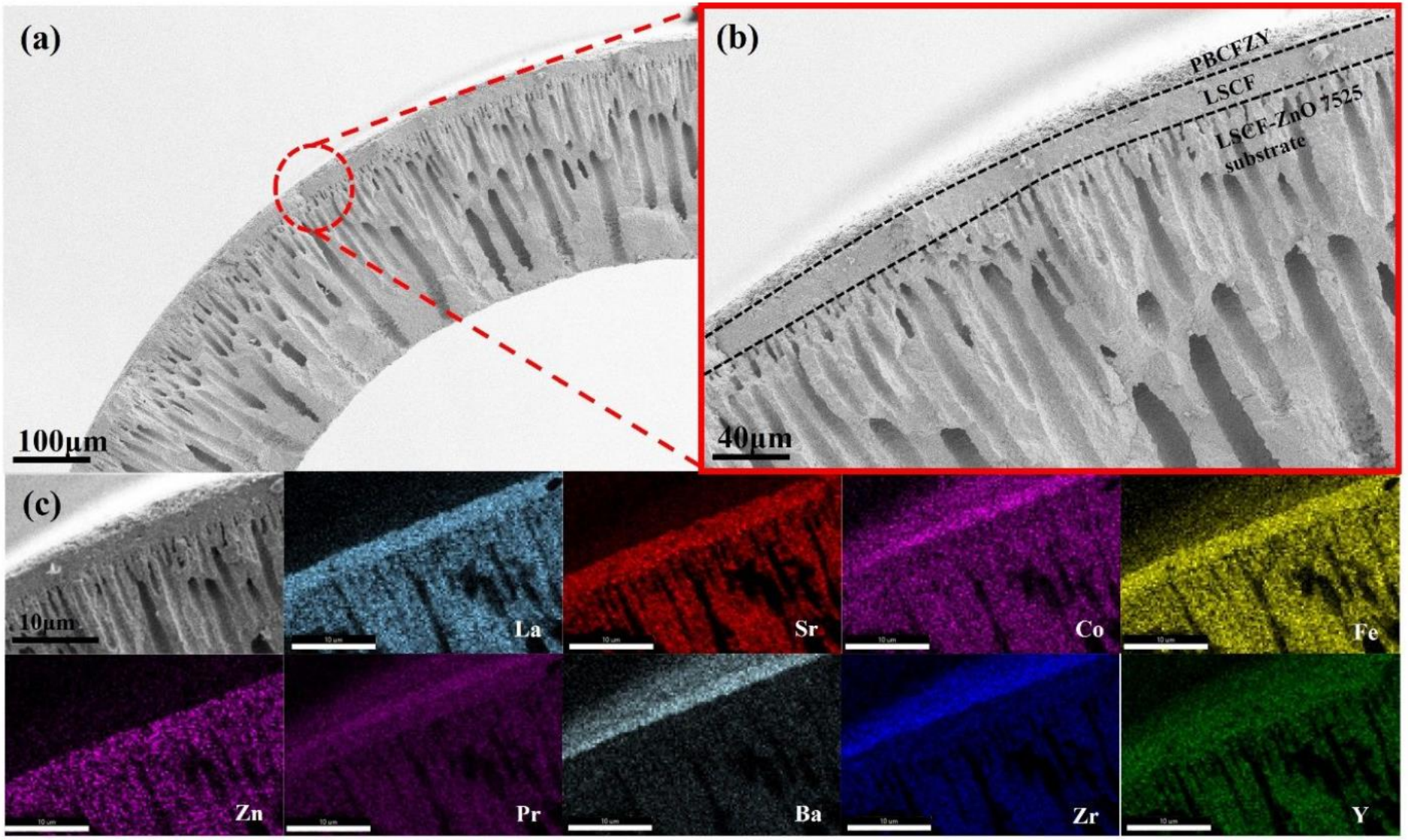
Stability


3 °C·min-1 5 °C·min-1 7 °C·min-1
J O2 (mL·cm-2·min-1)
T (°C)
Time (h)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1200
1100
1000
900
800
700
600
500
0
50
100
150
200
250
300

Stability

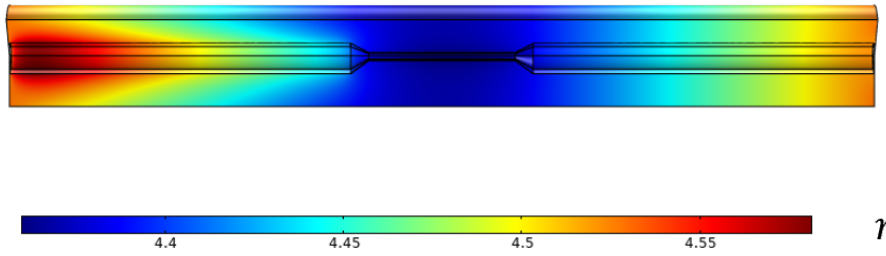

ZnO
LSCF
PBCFZY
Post-test
Powder mixture of PBCFZY-LSCF
after heat treatment at 1100 °C for 10h
LSCF
commercial
PBCFZY
as-synthesized
20
30
40
50
60
70
80
2θ (°)

Stability

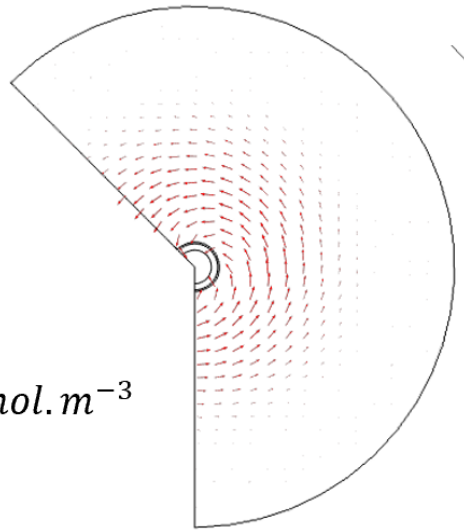

(a)
100µm
(b)
PBCFZY
LSCF
LSCF-ZnO 7525
substrate
40µm
(c)
10µm
La
Sr
Co
Fe
Zn
Pr
Ba
Zr
Y

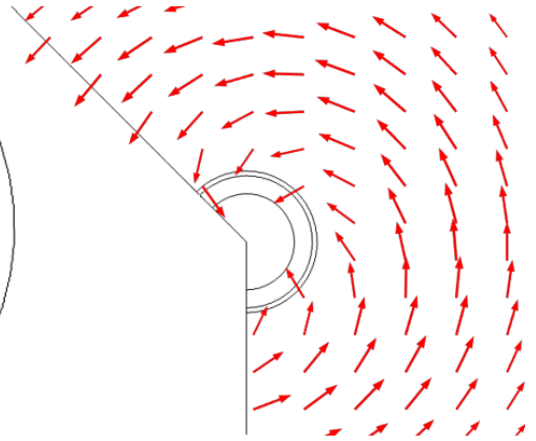
Multiphysics Modeling of Membrane

850°C

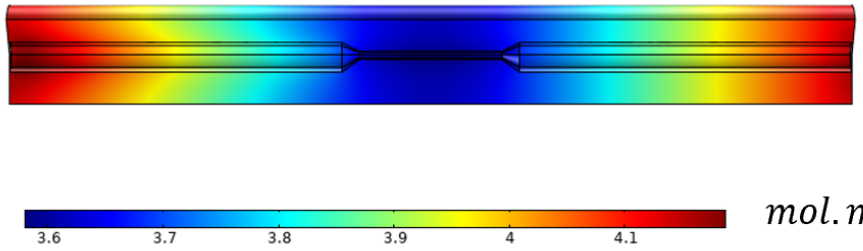


$mol.m^{-3}$

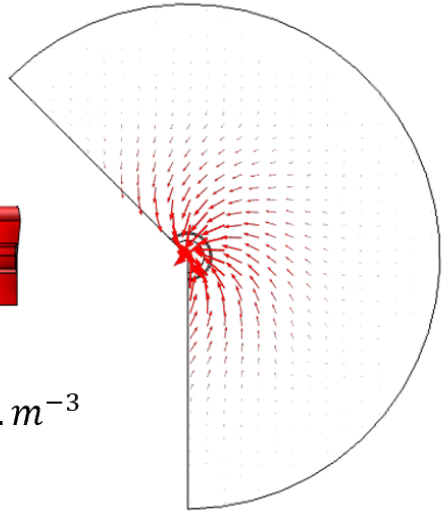


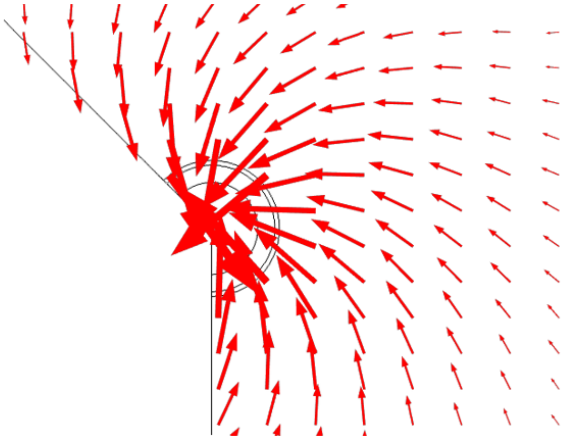


950°C

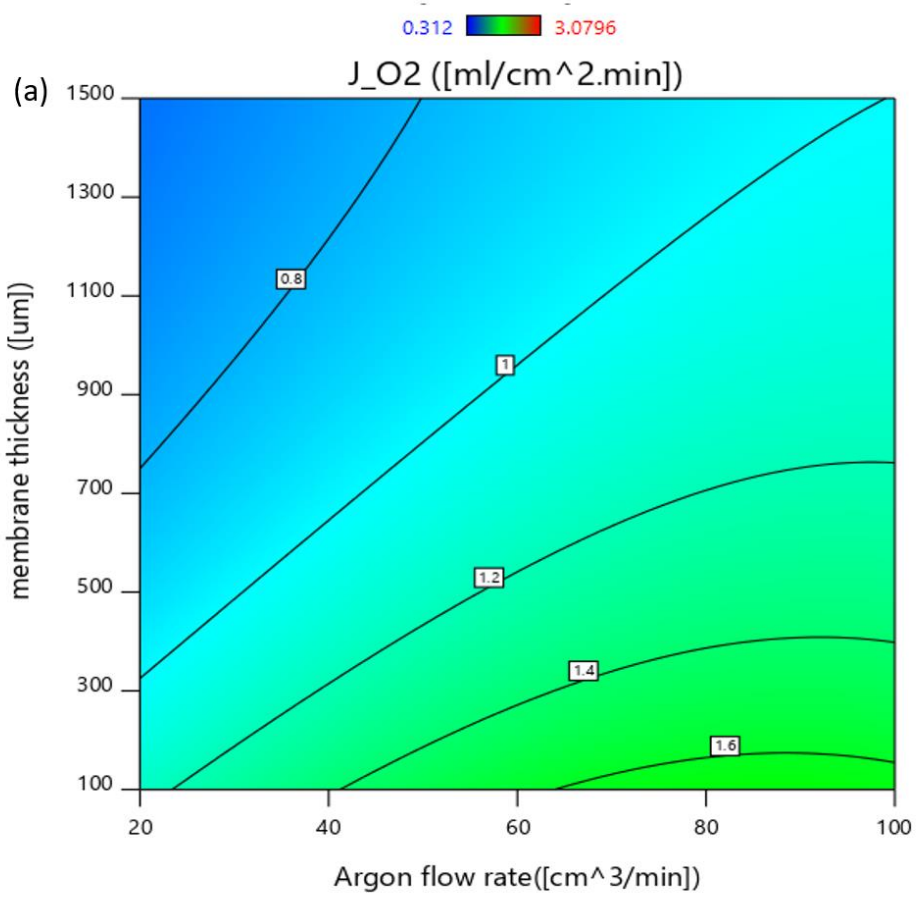


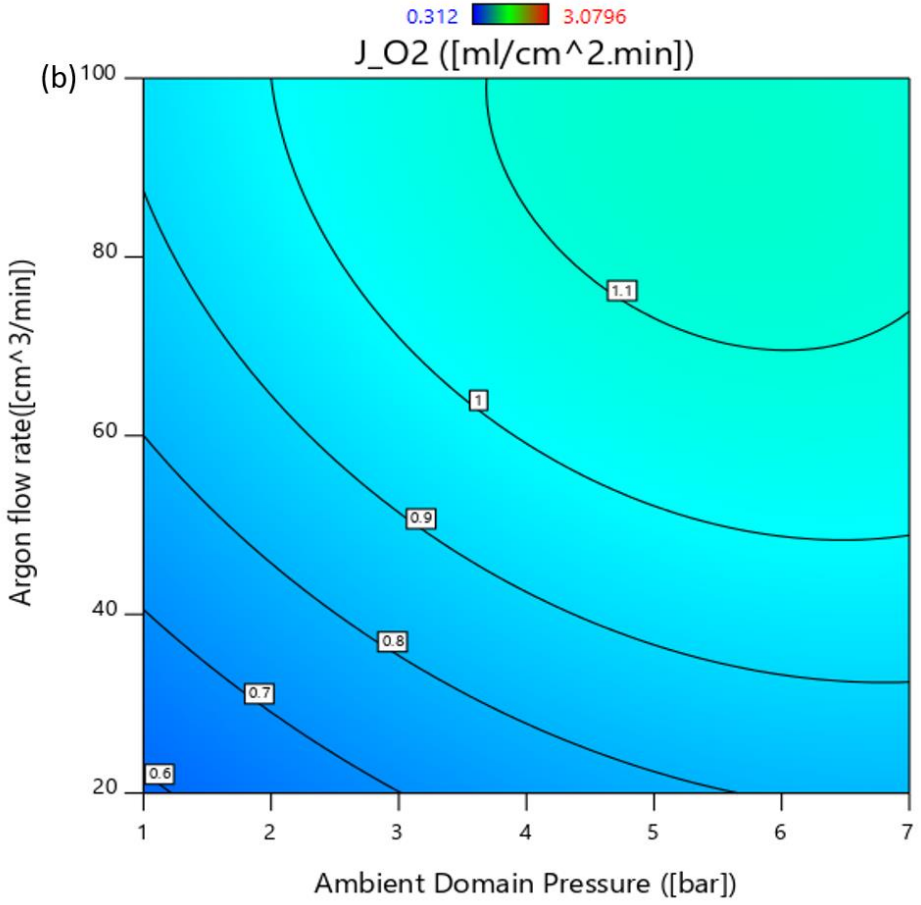
$mol.m^{-3}$



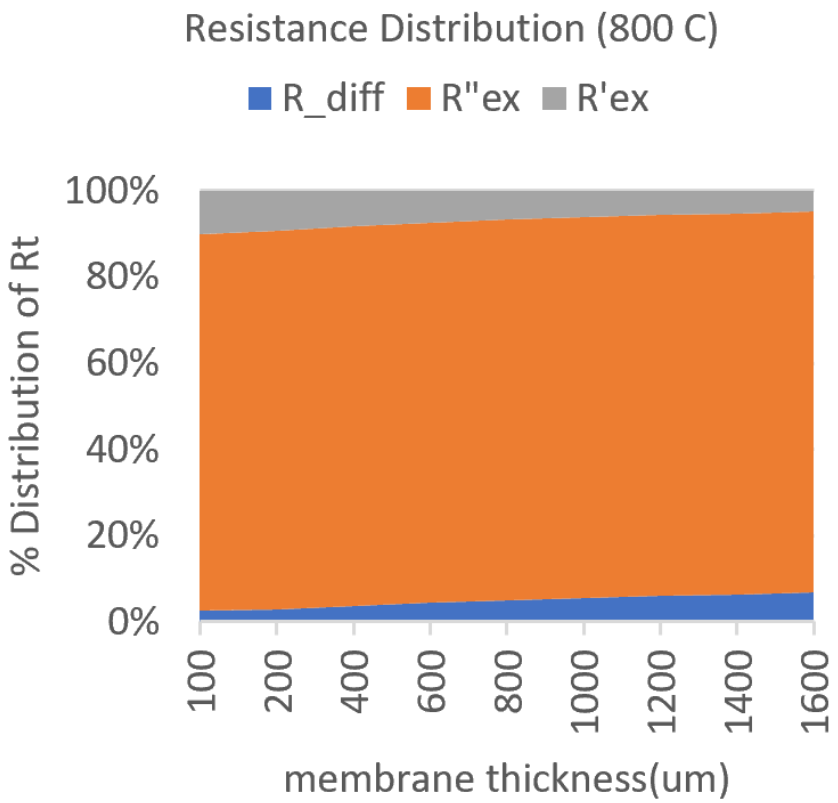


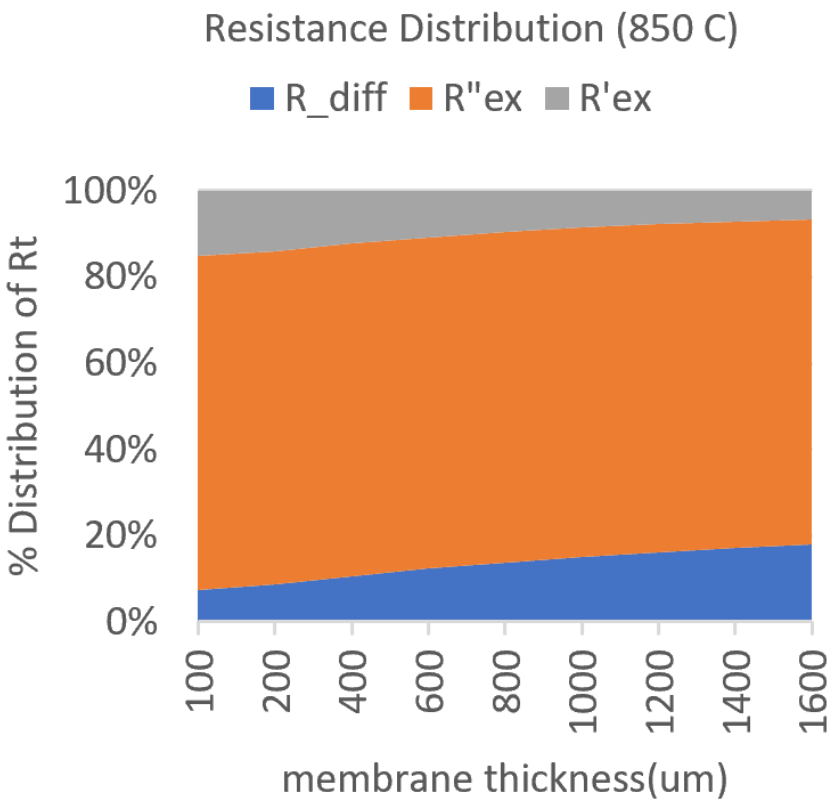
Multiphysics Modeling of Membrane



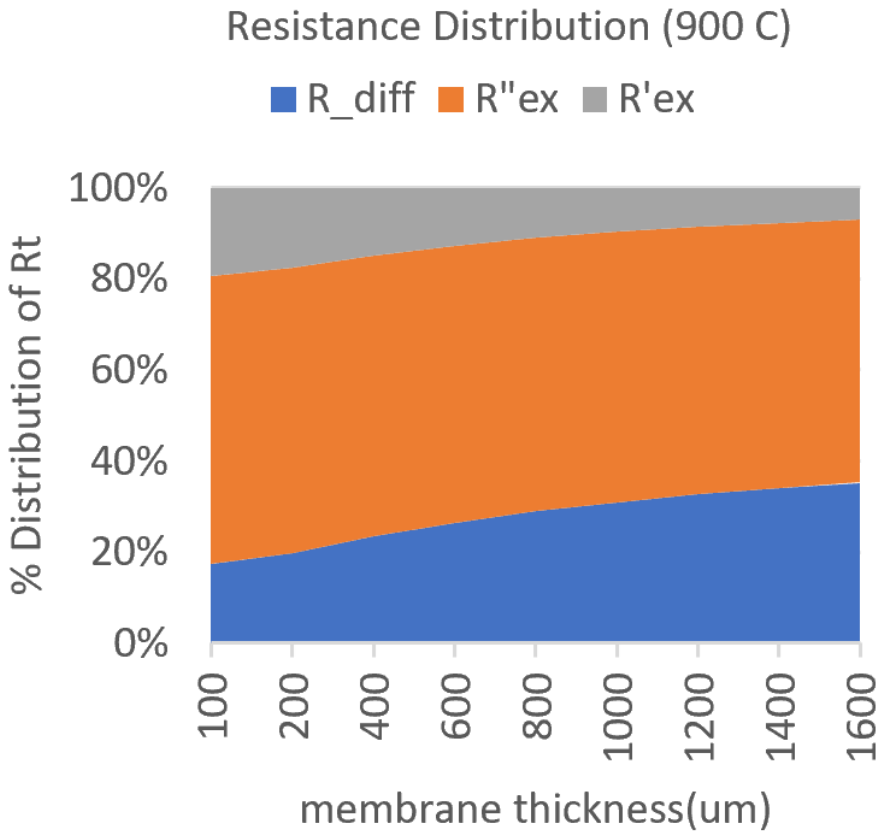


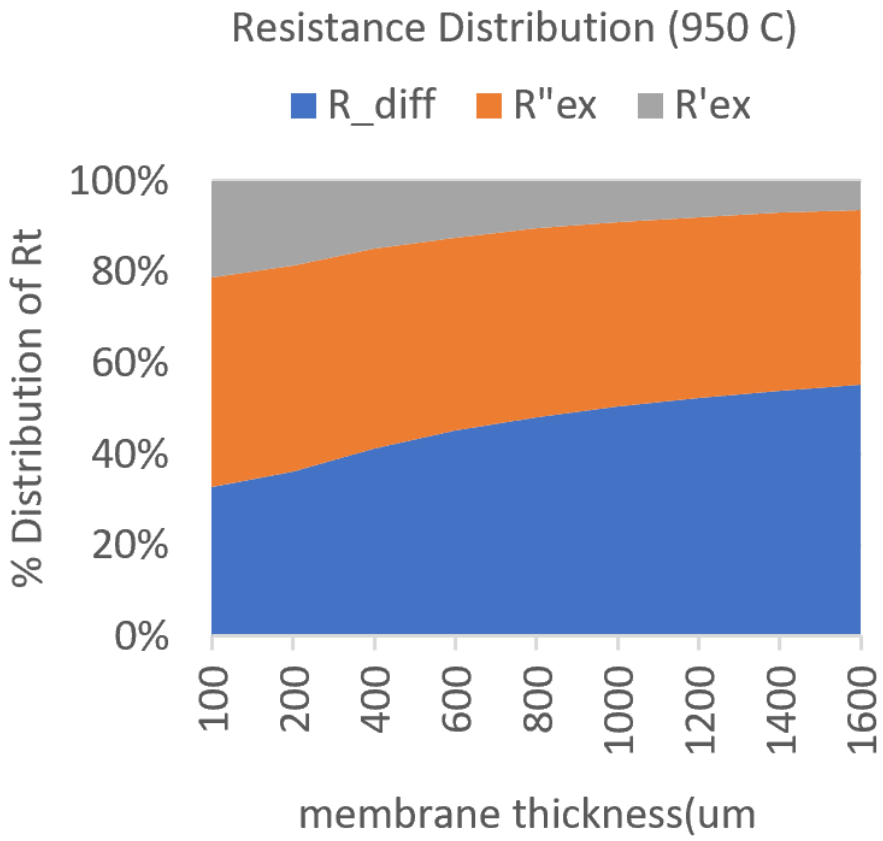
Multiphysics Modeling of Membrane





Multiphysics Modeling of Membrane





Summary

- Successfully fabricated hollow fiber-supported thin film oxygen separation membrane
- Hollow fiber substrate was embedded with radially aligned microchannels.
- Oxygen permeation performance was systematically measured and analyzed.
- Accelerated long-term stability was tested and the membrane demonstrated excellent stability and robustness.
- Single membrane was upscaled to a membrane stack with three hollow fiber membranes
- Oxygen permeation performance of the stack was systematically measured and compared with single membrane.
- Accelerated long-term stability was tested and the membrane stack demonstrated excellent stability and robustness.
- The microstructures of membranes demonstrated excellent stability and robustness.
- CFD-based Multiphysics model of single hollow fiber membrane was developed and comprehensive analysis is on-going.

Acknowledgments

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