the Energy to Lead

Bench-scale Development of a Transformational Graphene Oxide-based Membrane Process for Post-combustion CO_2 Capture

DOE Contract No. DE-FE0031598

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NATIONAL ENERGY TECHNOLOGY LABORATORY

CO_2 Capture Technology Project Review Meeting

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Project overview

- **Performance period**: June 1, 2018 – Sep. 30, 2021
- **Funding**: $2,914,074 from DOE; $728,738 cost share
- **Objective**: Develop a transformational graphene oxide (GO)-based membrane process (**GO²**) for CO_2 capture with 95% CO_2 purity and a cost of electricity (COE) at least 30% lower than DOE amine reference baseline SC PC plant case
- **Team:**

Member	Roles
gti	• Project management and planning • Quality control • CO_2 capture performance tests
Rensselaer	• GO membrane development and scale-up
The Ohio State University	• Scale-up of flat sheet GO membrane modules • Process design and optimization
Trimeric Corporation	• Technical & economic study

GO membrane technology based on our work published in *Science* and *Nature Communications*

Science AAAS

Ultrathin, Molecular-Sieving Graphene Oxide Membranes for Selective Hydrogen Separation
Hang Li *et al.*
Science **342**, 95 (2013);
DOI: 10.1126/science.1236686

nature COMMUNICATIONS

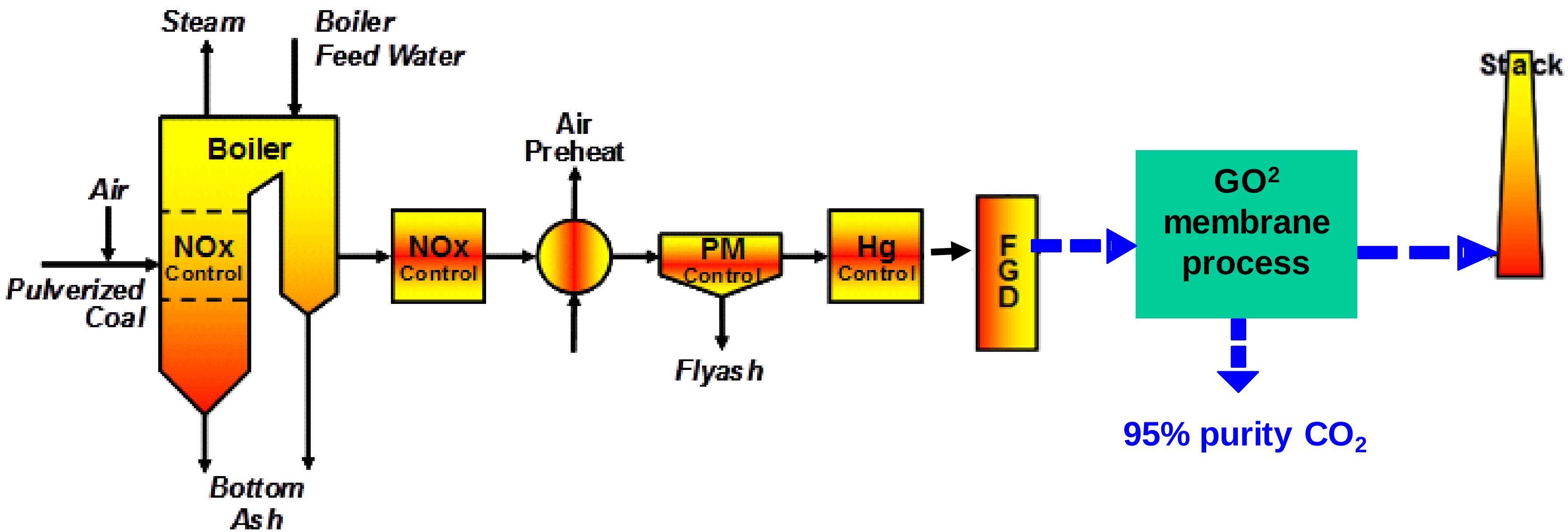
ARTICLE

DOI: 10.1038/s41467-017-02318-1 OPEN

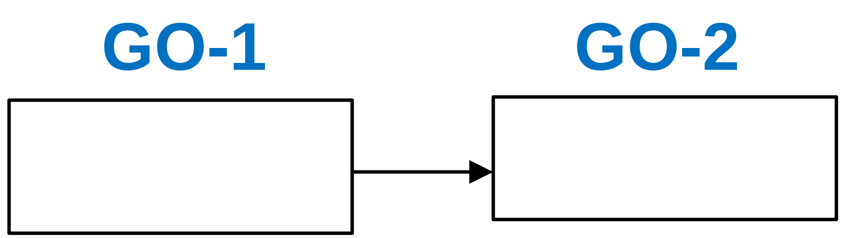
Ultrathin graphene oxide-based hollow fiber membranes with brush-like CO_2-philic agent for highly efficient CO_2 capture

Fanglei Zhou[1], Huynh Ngoc Tien[2], Weiwei L. Xu[2], Jung-Tsai Chen[2], Qiuli Liu[2], Ethan Hicks[2], Mahdi Fathizadeh[2], Shiguang Li[3] & Miao Yu[1]

GO² process description



GO² process integrates a high-selectivity GO-1 membrane and a high-flux GO-2 membrane for optimal performance



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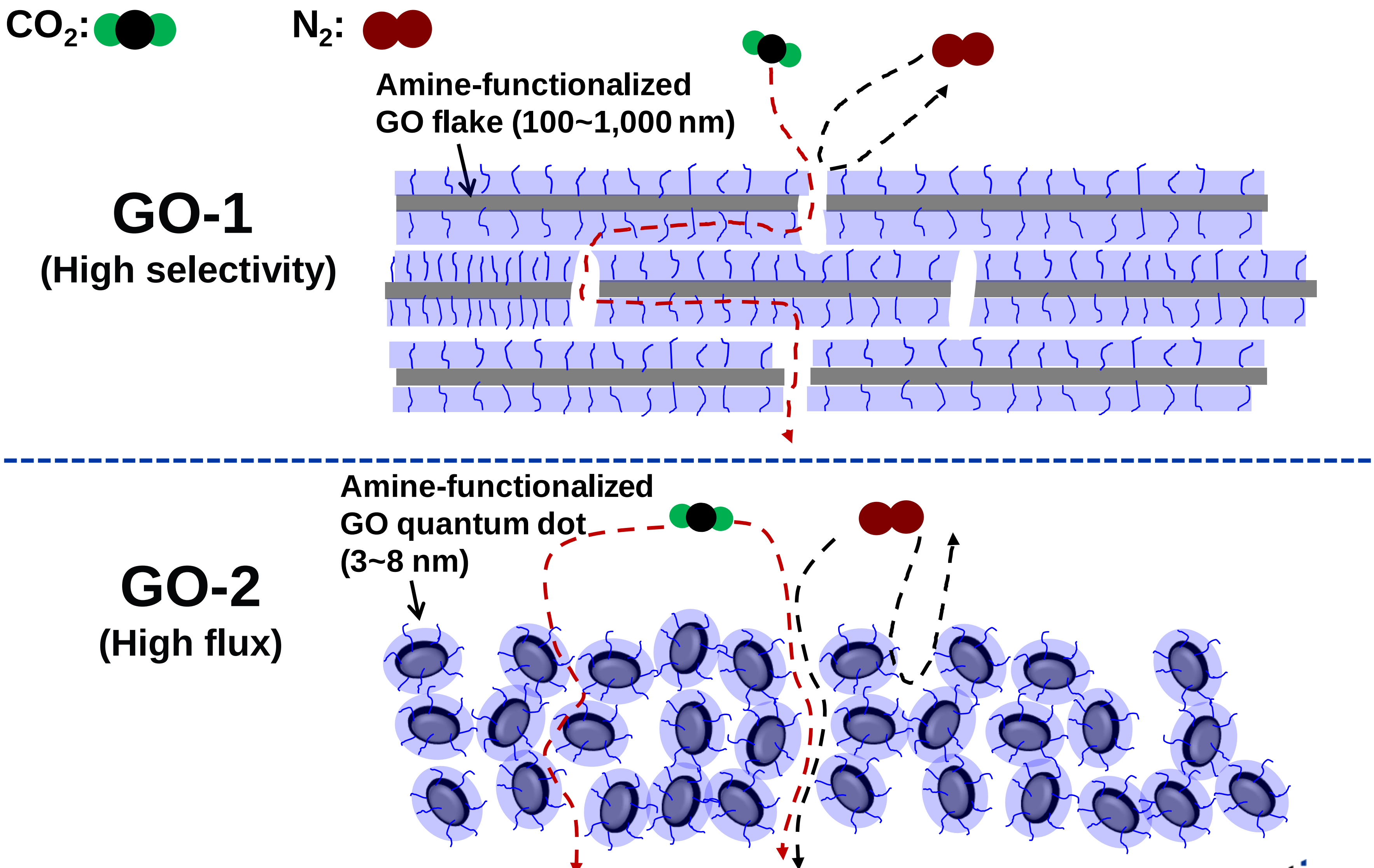
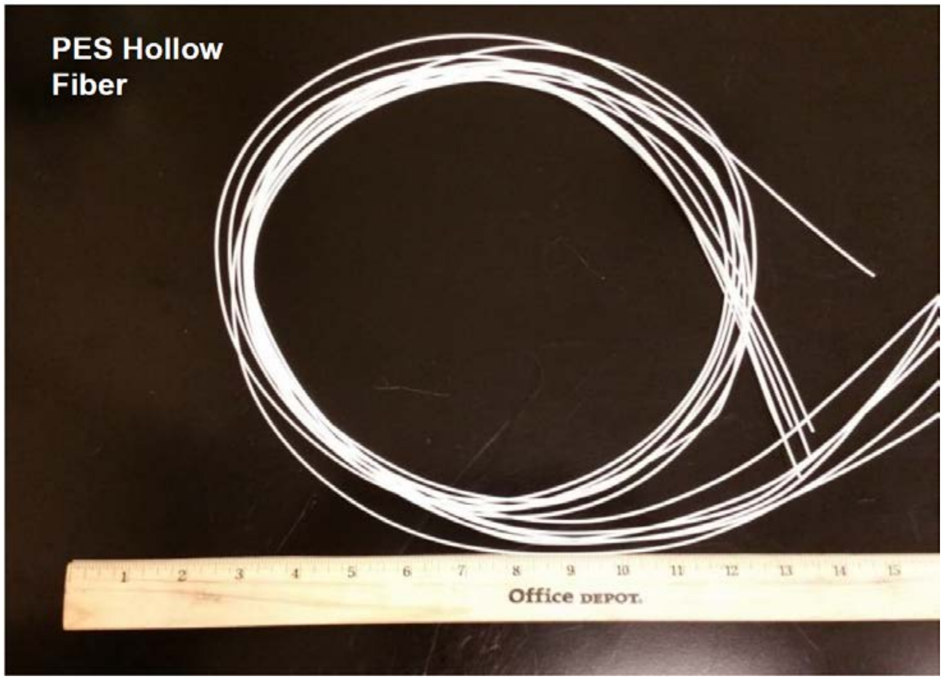
GO-1 and GO-2 membranes developed under laboratory-scale program (DE-FE0026383)

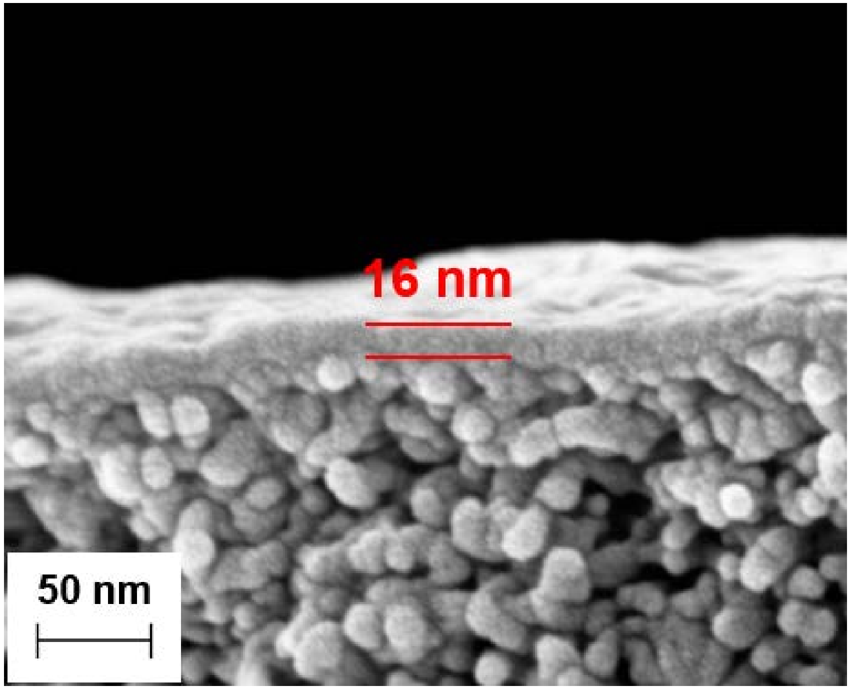


Procedure developed for coating GO membranes on hollow fibers under lab-scale program (DE-FE0026383)

Polyethersulfone fiber



Coated fiber (GO-PZ) cross section



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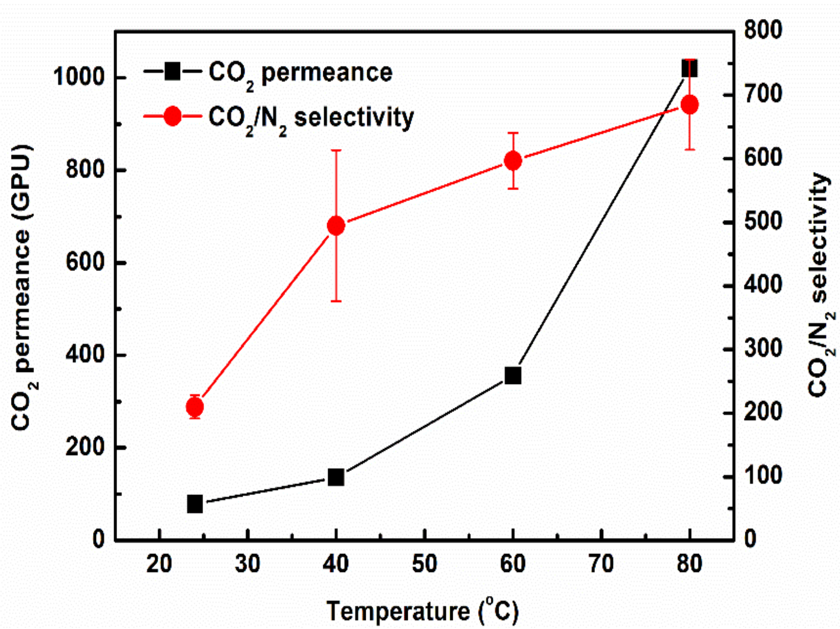
1,000 GPU CO_2 permeance achieved in both sweep gas and vacuum permeation modes with selectivity >200

Sweep gas mode

- GO-PZ membrane
- Feed gas:15% CO_2/85%N_2 with saturated water vapor



Vacuum mode

Membrane	Improved GO-PZ membrane
Temperature	75°C
Humidity	85%
Feed gas	15% CO_2/85% N_2
CO_2 permeance, GPU	**1080 ± 55**
CO_2/N_2 selectivity	**650 ± 31**

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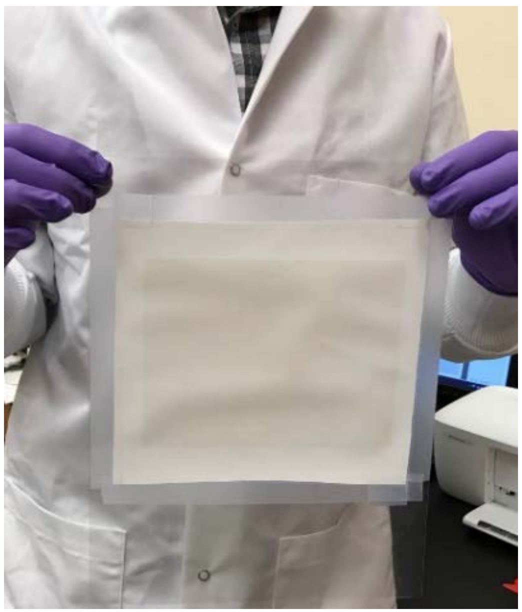
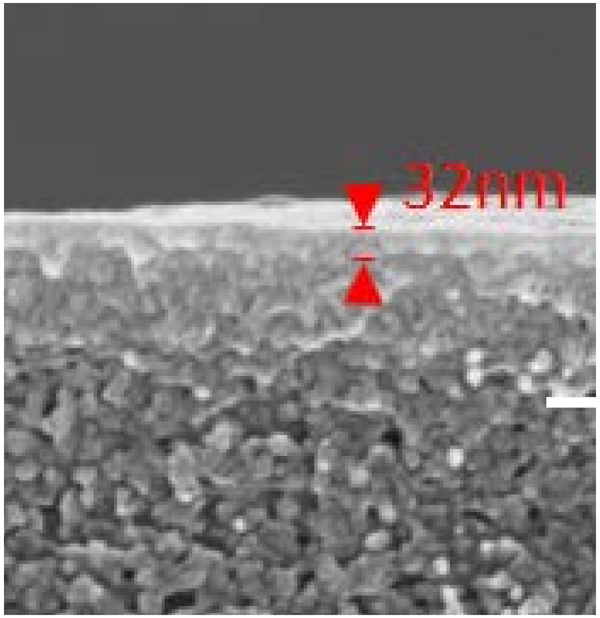
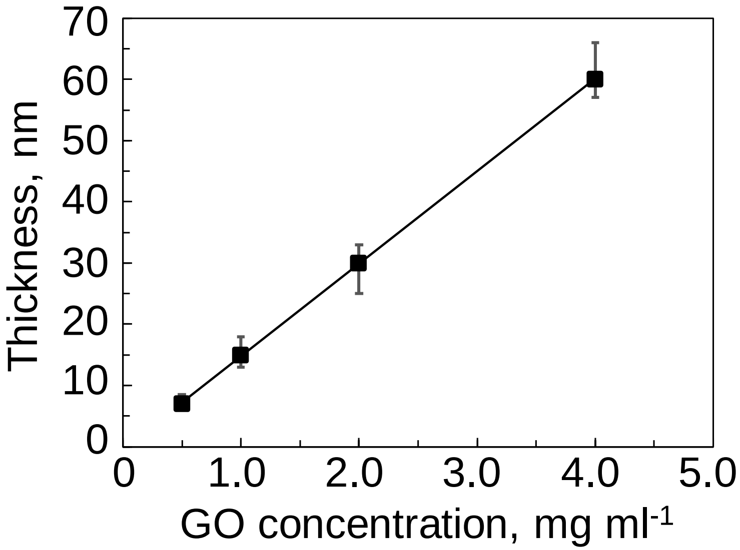
In addition to hollow fiber membranes, flat sheet membranes were successfully prepared by printing







Overview/roadmap

Task 1 Project management and planning (*throughout the project*) ← **We are here**

Membrane Development

Process Development

BP1

- **Task 2 – Development of GO membrane with area of 50-100 cm^2**
- **Task 3 – Improvement of 50-100 cm^2 membranes towards higher selectivities**
- **Task 4 – Stability testing of membranes at near realistic flue gas conditions**

BP2

- **Task 5 – Scale-up of GO membrane modules to effective areas of 1000 cm^2**
- **Task 6 – 100-h stability tests for GO membranes developed under Task 5**
- **Task 7 – Design and construction of a GO^2 system**
- **Task 8 – Testing of the GO^2 system using NG flue gas**
- **Task 9 – Testing of the GO^2 system using coal flue gas**
- **Task 10 – TEA**

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Success criteria and key milestones

- Success criteria:

Decision Point	Date	Success Criteria
Go/no-go decision points	3/31/20	1) Production of 50-100 cm^2 area membranes with CO_2/N_2 selectivity ≥200 and CO_2 permeance ≥1,000 GPU for the GO-1, and with CO_2/N_2 selectivity ≥20 and CO_2 permeance ≥2,500 GPU for the GO-2 2) Stability testing shows the CO_2 permeances and CO_2/N_2 selectivities decreased by less than 10% in the presence of flue gas contaminants
Completion of the project	9/30/21	1) Production of 1,000 cm^2 area membranes with CO_2/N_2 selectivity ≥200 and CO_2 permeance ≥1,000 GPU for the GO-1, and with CO_2/N_2 selectivity ≥20 and CO_2 permeance ≥2,500 GPU for the GO-2 2) Testing with flue gas complete, 95% CO_2 purity validated 3) Final TEA report issued; final report submitted

- Key milestones set to effectively measure progress
  - Each task has at least one milestone

Preliminary risk assessment: technical challenges and mitigation strategies

Challenges/Risks

1) Scaled membrane CO_2/N_2 separation performance not sufficiently high

Mitigation:

- 1a: Improve PES substrate quality
- 1b: Identify new approaches to improve separation performance

2) 95% CO_2 purity not achieved

Mitigation:

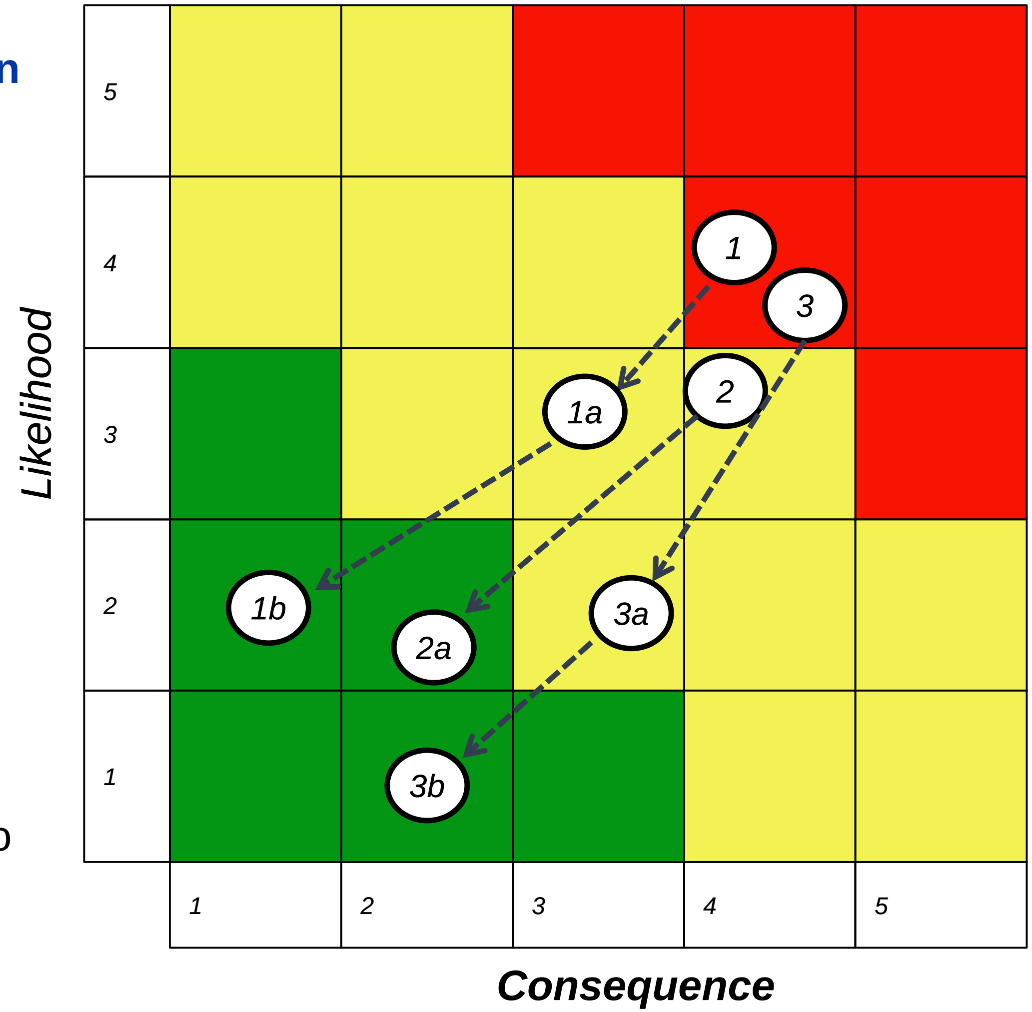
- 2a: Improve process design

3) Cost of the process not in line with expected outcome

Mitigation:

- 3a: Increase CO_2 permeance for the membranes
- 3b: Improve manufacturing process to lower membrane costs

Risk summary



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Summary

- In a laboratory-scale program (DE-FE0026383), we have developed high-selectivity (GO-1) and high-flux (GO-2) graphene oxide-based membranes
- In the current program, we will scale up the membranes for bench-scale development
- The GO^2 process integrates the GO-1 and GO-2 membranes offering a new opportunity to explore further reductions in the cost of CO_2 capture
- The GO^2 process will be tested at the NCCC with actual flue gas for CO_2 capture with 95% CO_2 purity

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U.S. DEPARTMENT OF ENERGY

NATIONAL ENERGY TECHNOLOGY LABORATORY

DE-FE0031598

CO_2 Capture Project - Phase 4

CCP

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- Andrew Sexton, Trimeric Corporation (Trimeric)

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