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Title: Colloid and Interface Science Research at EES

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He, Peng
Tarimala, Sowmitri

Intended for: DOE
Vist by U of A researchers
Groundwater
Remediation
Reading Room
RCRA

Title: Colloid and Interface Science Research at EES

Abstract

This is an overview presentation for visitors for the University of Alberta who are visiting LANL between May 23-24. The purpose of the meeting/visit is to communicate current research interests, capabilities, and skills between these researchers and LANL staff in areas related to colloid and interface science in the context of energy security and environmental applications.

Colloid and Interface Science Research at EES

Experimental Capabilities & Interests

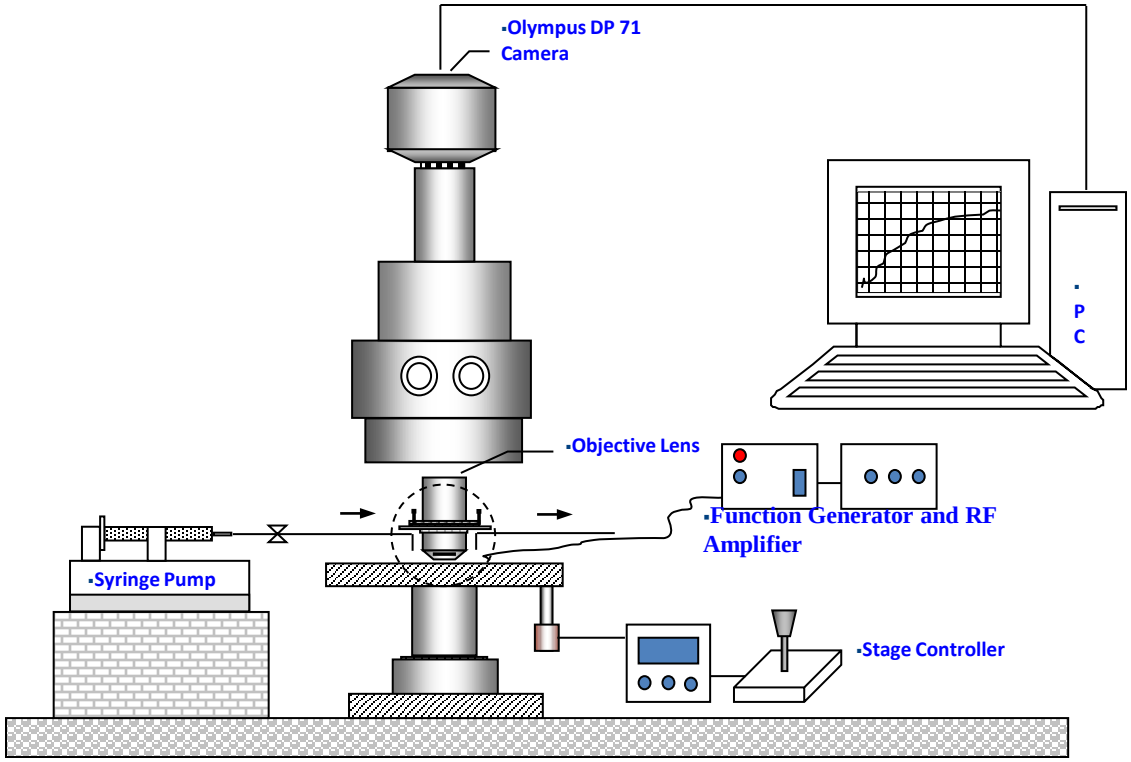
- Quantitative direct colloid visualization (AVMIDAS)
- Microfluidics
- Particle and flow manipulation (Acoustic/Electric)
- Shear thickening/thinning
- Coagulation/flocculation/sedimentation/floatation/ deposition & release kinetics
- Electrokinetic phenomena
- Surface modification (Switchable properties)
- New Colloid counting, sizing, and ζ-potential measuring technologies

Experimental Capabilities (*cont.*)

- Surface energy and contact angle
- Stability and Phase separation
- Dynamic core stimulation
- Field Flow Fractionation
- BET Surface area
- Flow Cytometry
- Dynamic column transport
- Batch and column sorption/desorption

Quantitative Direct Visualization

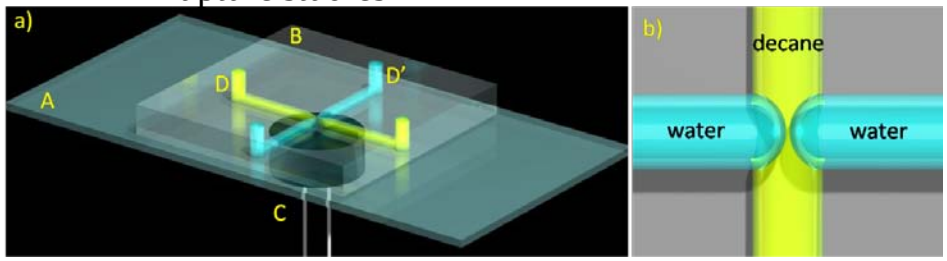
Automated Video Microscopic Imaging and Data Acquisition System (AVMIDAS)

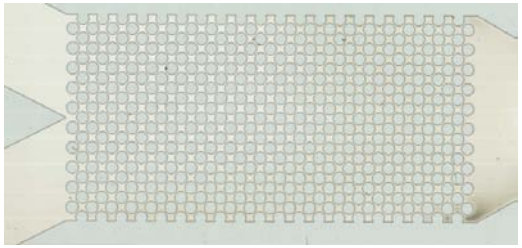


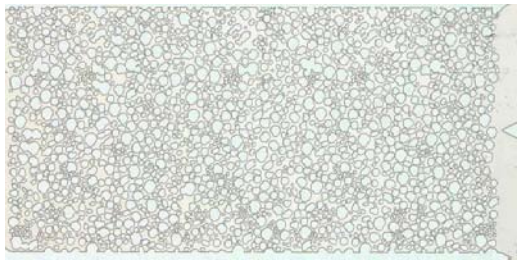
Abdel-Fattah et al., U.S. Patent No. 6,836,559

Microfluidics

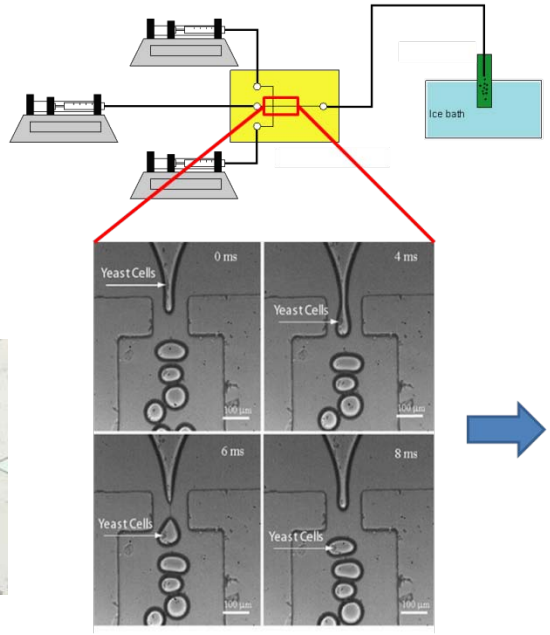
Thin film rupture studies



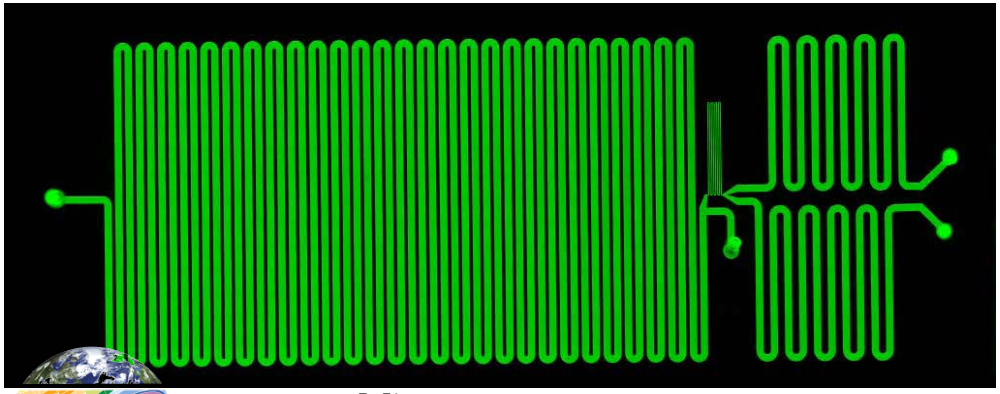




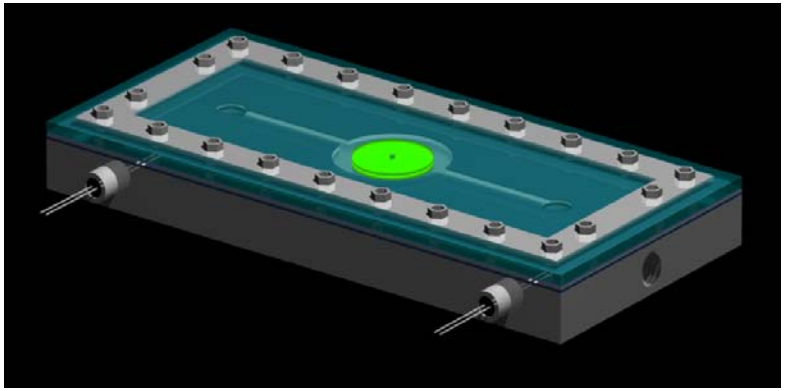
Reactive transport and mixing visualization



Encapsulation

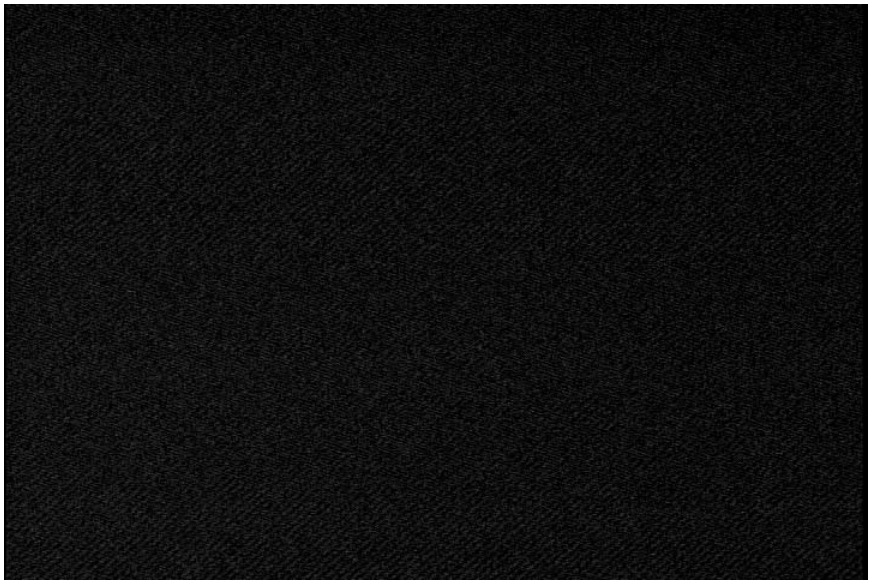


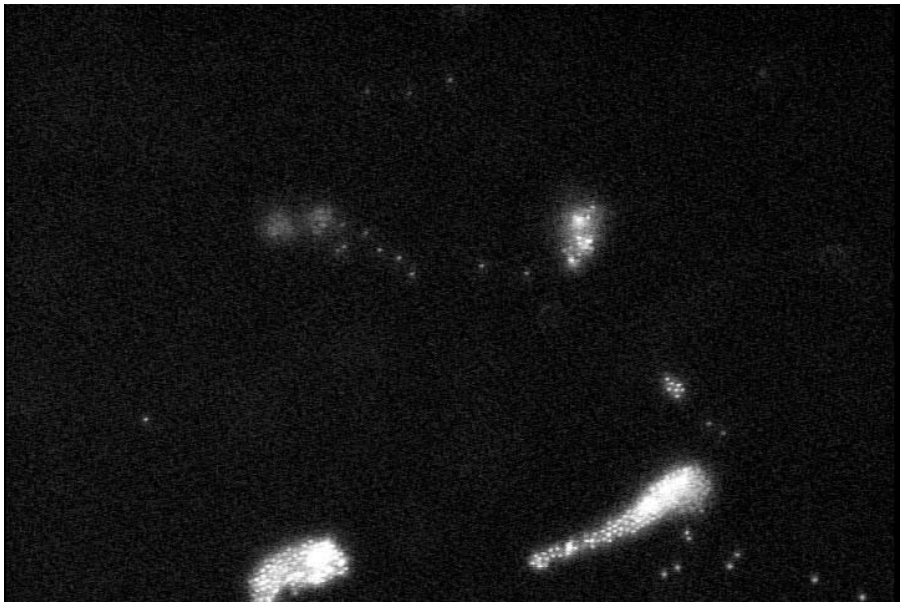
Microreactor



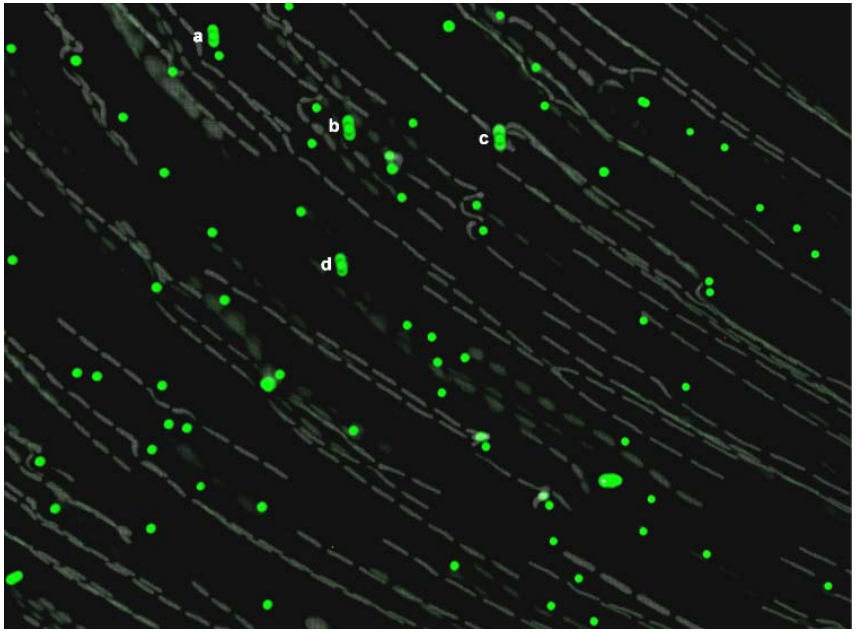
Controlled pressure and temperature

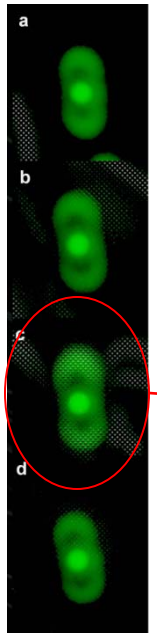
Particle Manipulation



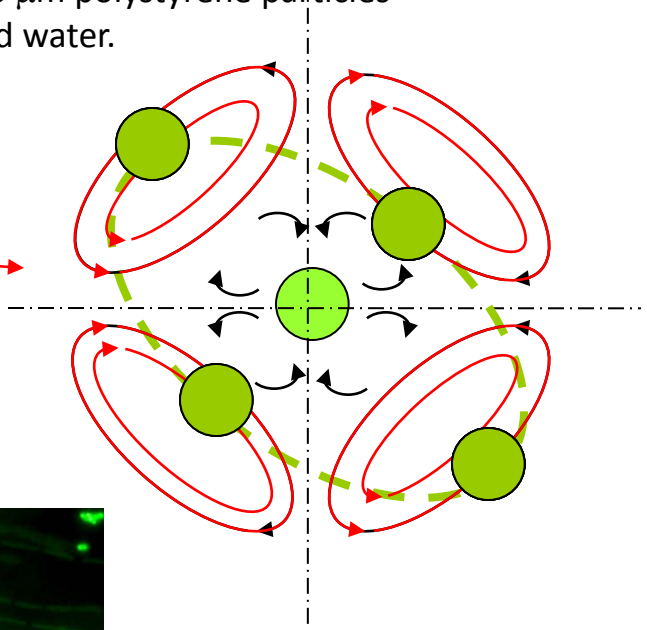


Particle Manipulation

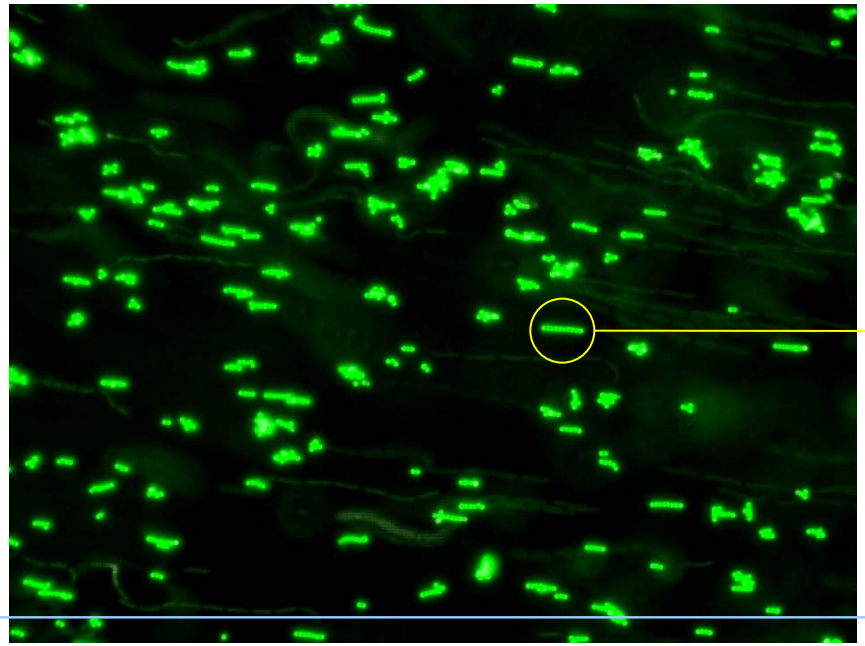


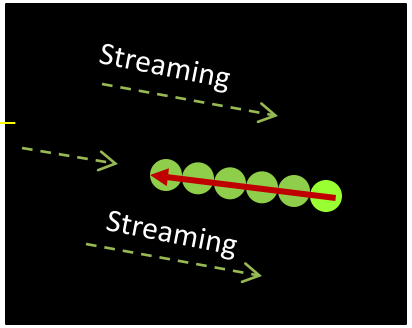


Acoustic waves induce bulk streaming and boundary-layer orbiting (> 3000 rpm) of 2.26 μm polystyrene particles in de-ionized water.



Acoustic waves induce bulk streaming and chain-like surface clustering of 2.26 μm polystyrene particles in 0.1*M* NaCl electrolyte.

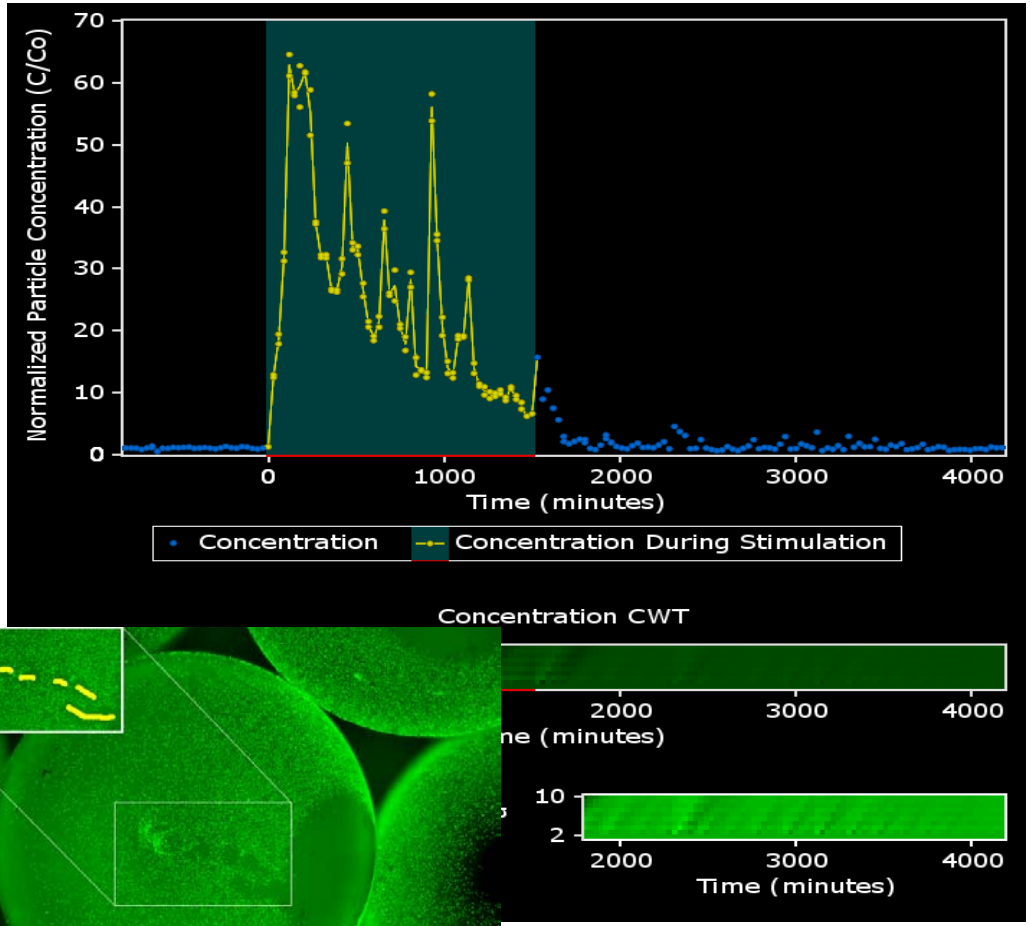




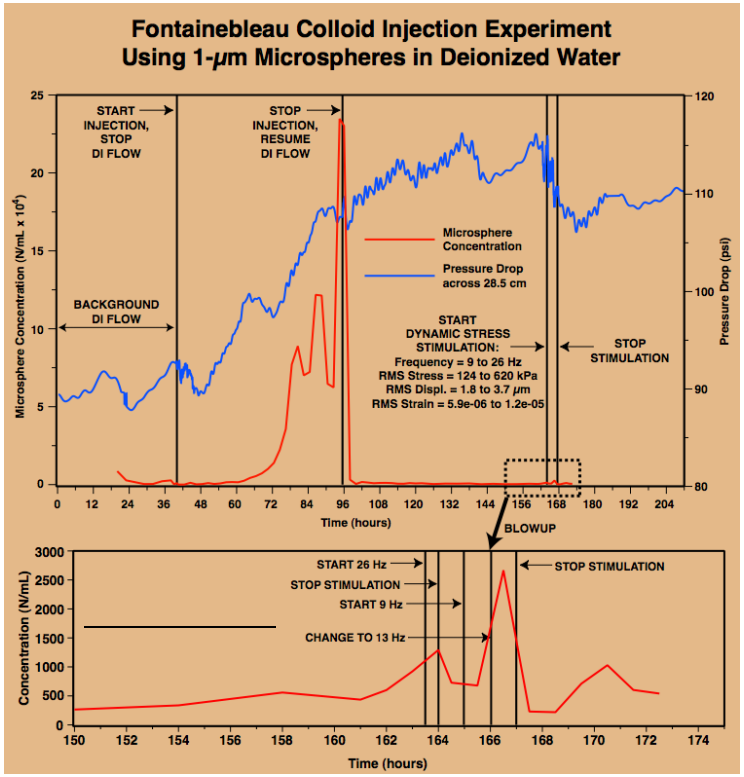
Earth & Environmental Sciences

Los Alamos

Particle mobilization by low-frequency dynamic stress affects oil/gas recovery

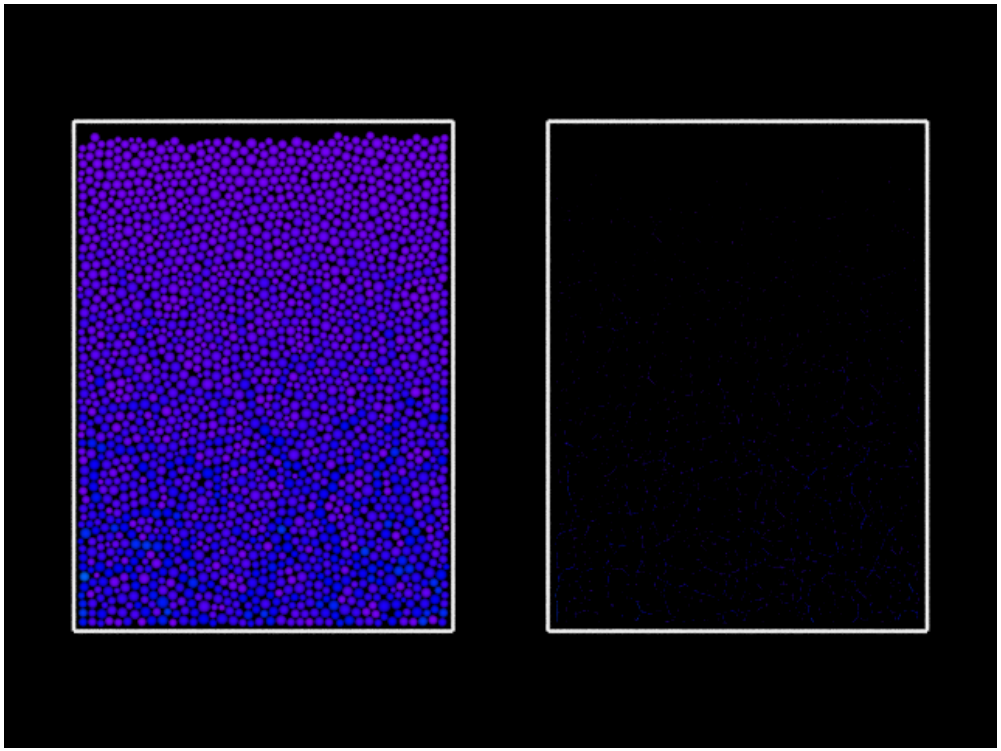


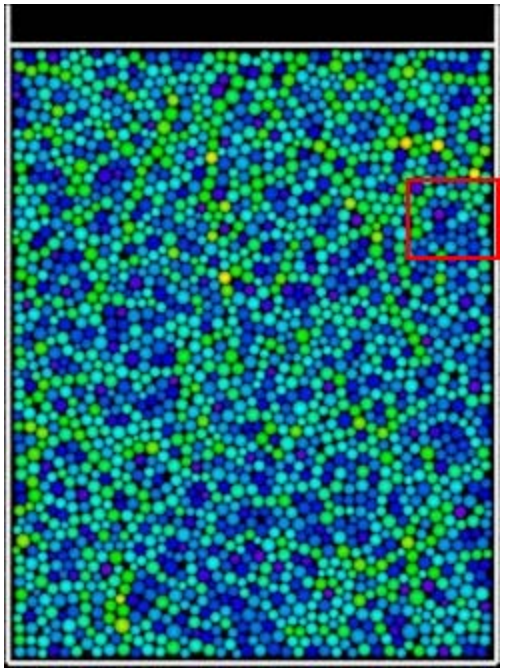
Synthetic core
stimulation at 26 Hz



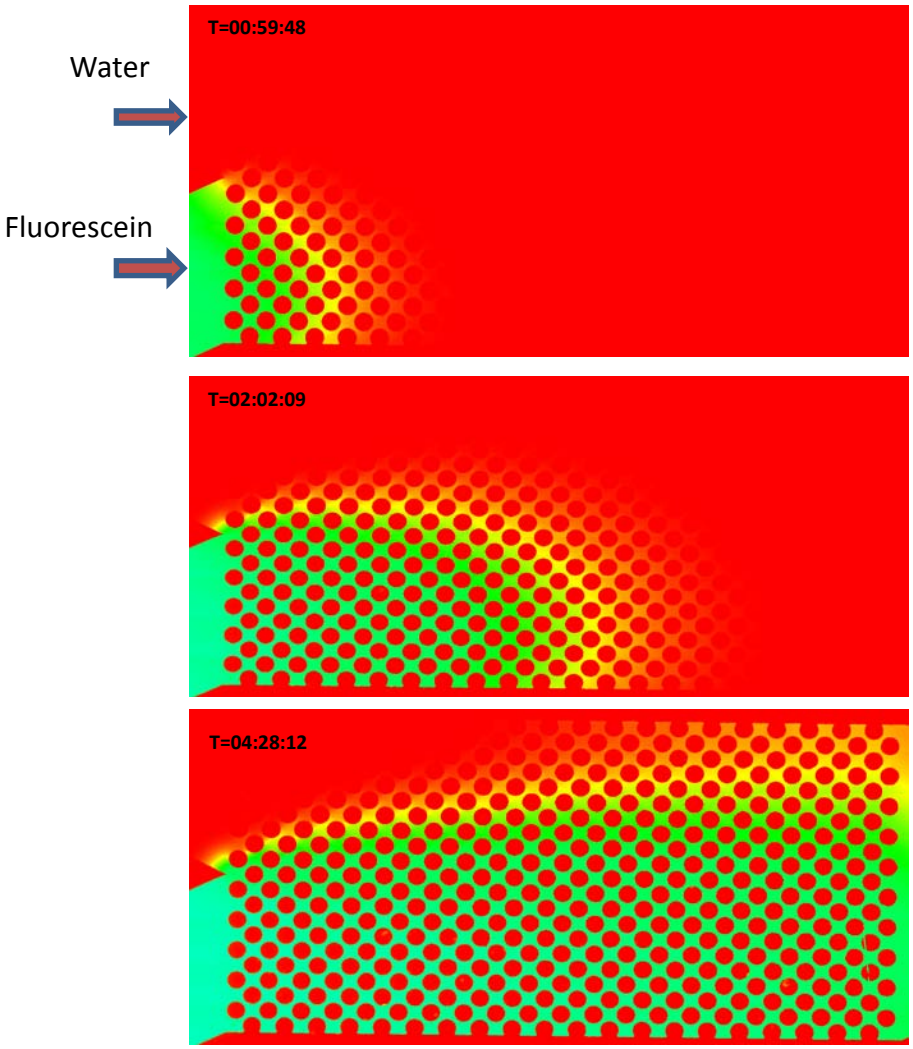
Natural core
stimulation at 26 Hz

DEM Simulations

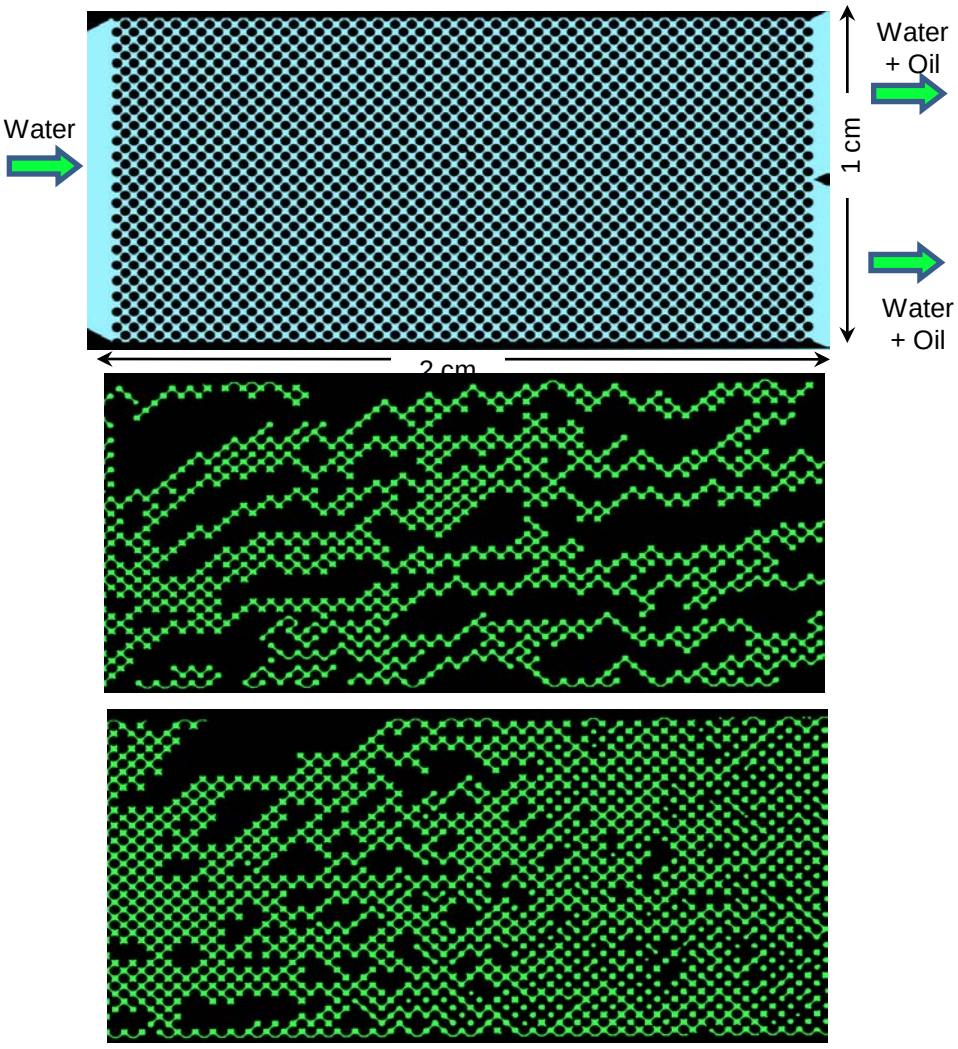




Mixromixing and displacement Experiments

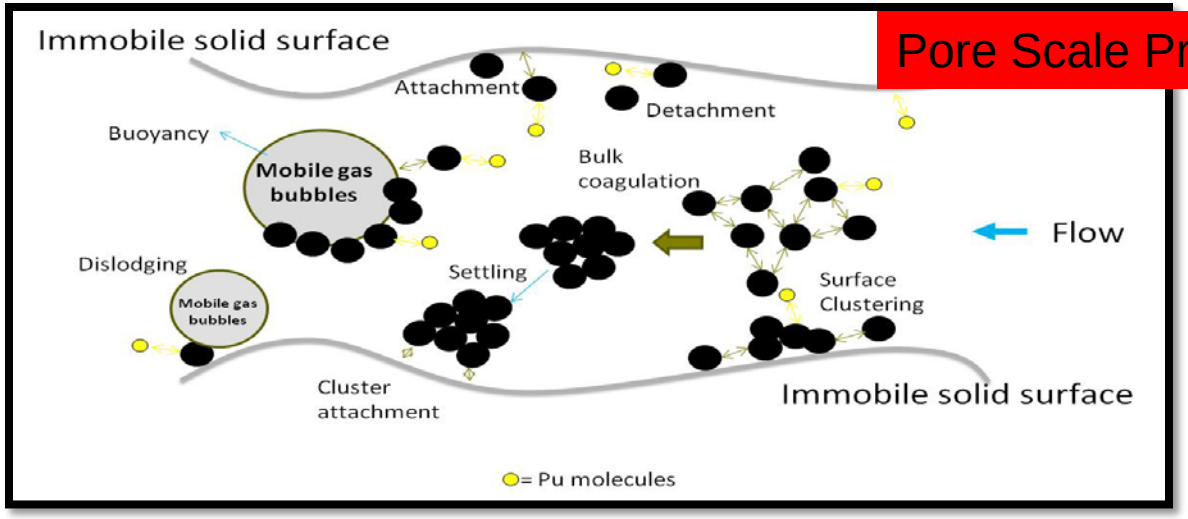


Nonreactive mixing of fluorescein in water



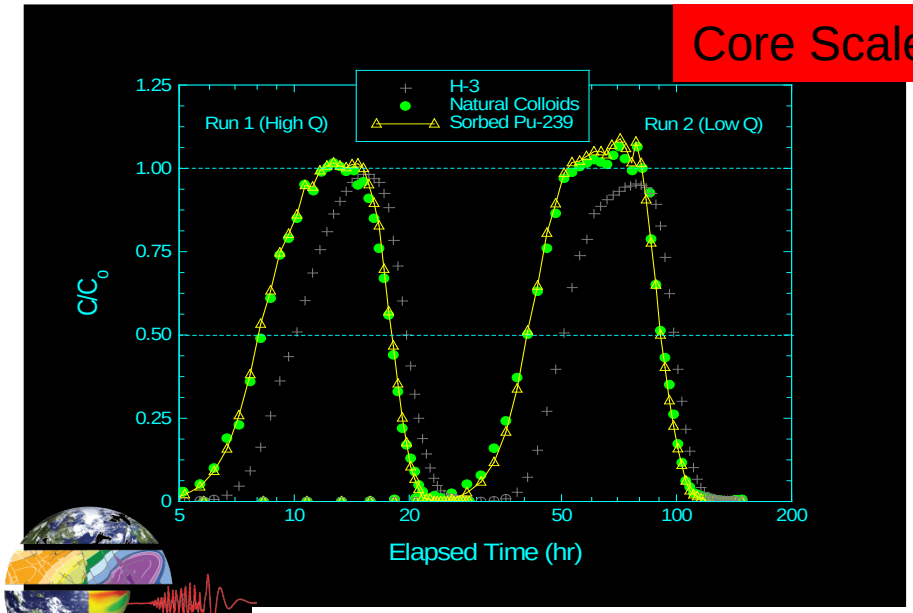
Oil displaced with water at different flow rates

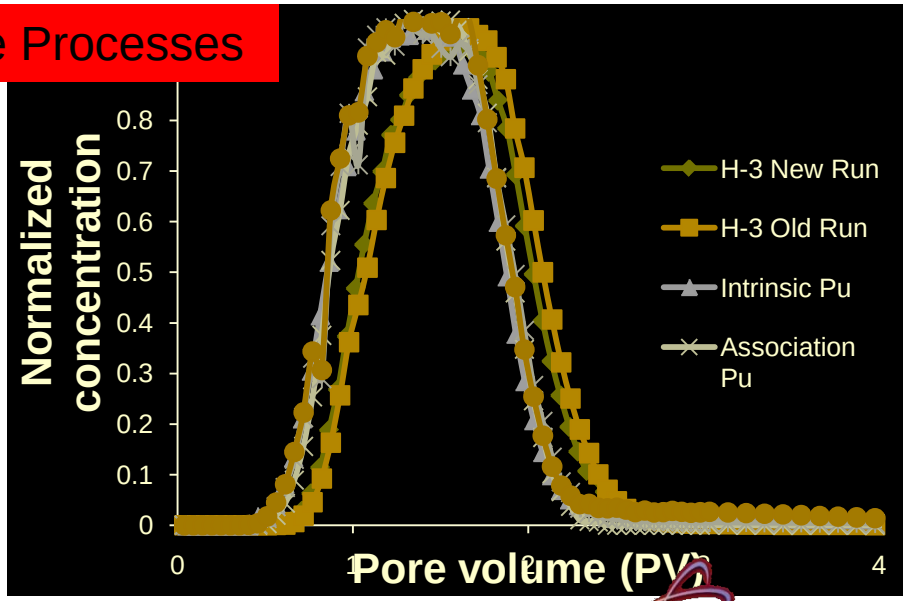
Colloidal Pu Transport



Pore Scale Processes

Core Scale Processes





What we want to do……

- Particle deposition and removal at interfaces
- Interface modifications for controlled switching properties of surfaces
  - Controlled flow in engineered systems (pipes, microfluidics)
  - Separation and filtration processes
- Subsurface flow manipulation for enhanced oil and geothermal recovery, remediation, and leach mining
  - Colloids with “triggered” functionality
  - Biofilms and natural precipitates

Immiscible Fluid Displacement Experiments – Overview and Recent Results

Sowmitri Tarimala[1], Amr I. Abdel-Fattah[1], Scott Backhaus[2] & James W. Carey[1]

[1]Earth System Observations (EES-14), LANL
[2]Condensed Matter & Magnet Science (MPA-CMMS), LANL

Scientific Challenge – Flow Patterns & Dissolution of CO_2 into Brine

Numerical models and experiments on immiscible displacements in porous media

R. Lenormand, E. Touboul and C. Zarcone

J. Fluid Mech. (1988), *vol.* 189, *pp.* 165–187

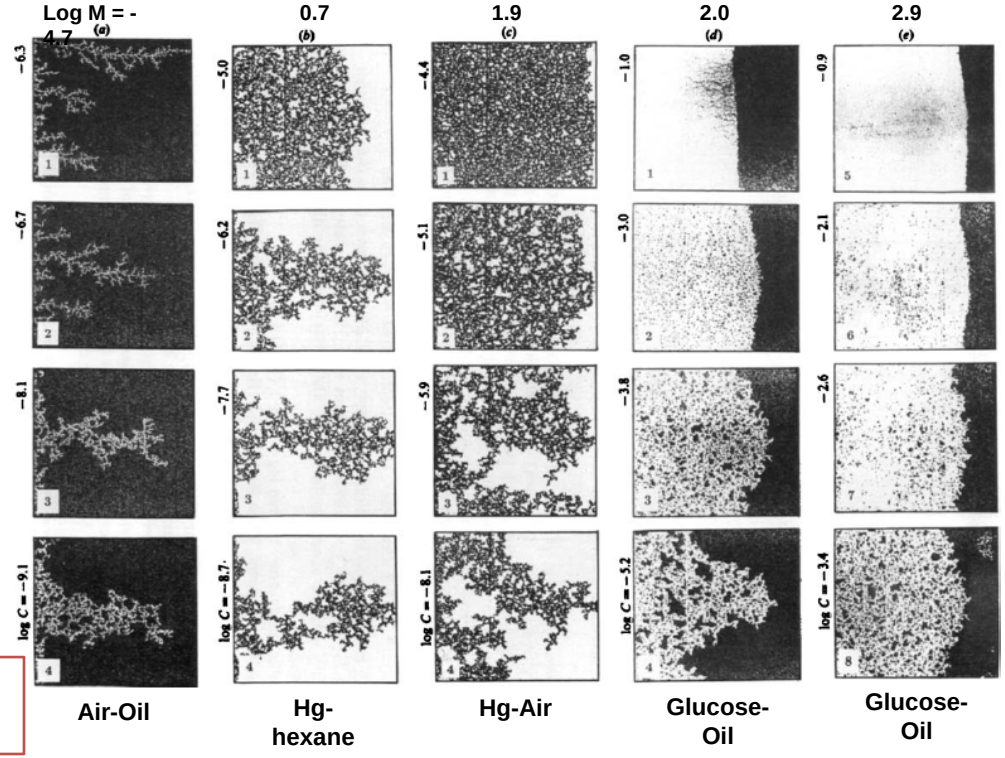
M = viscosity ratio (Invading/Defending fluid)

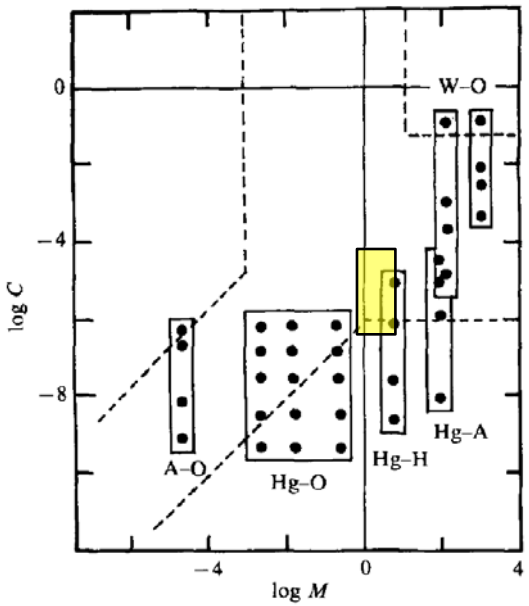
Capillary Number = Viscous forces/Capillary forces

Viscous Fingering

Stable Displacement

Capillary Fingering

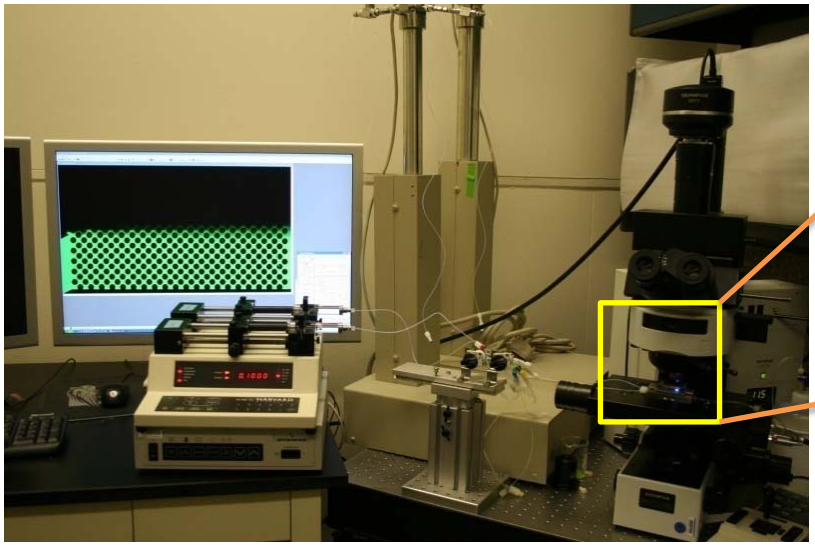


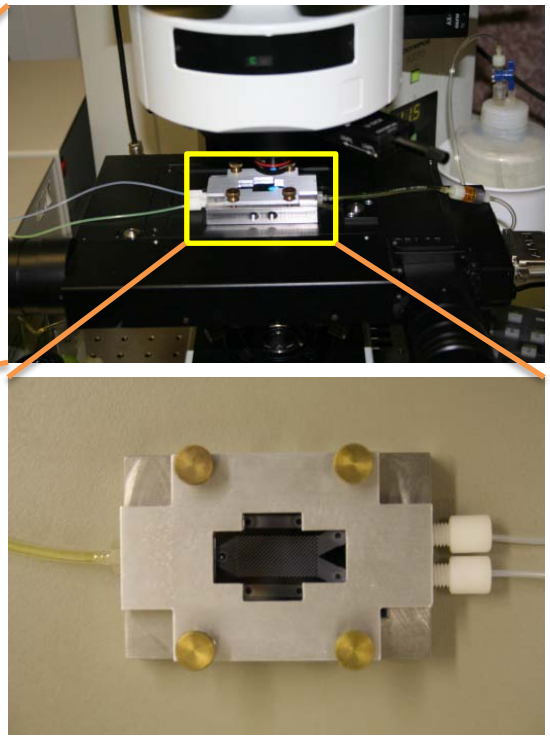


Parameters relevant to sc CO2-Brine system

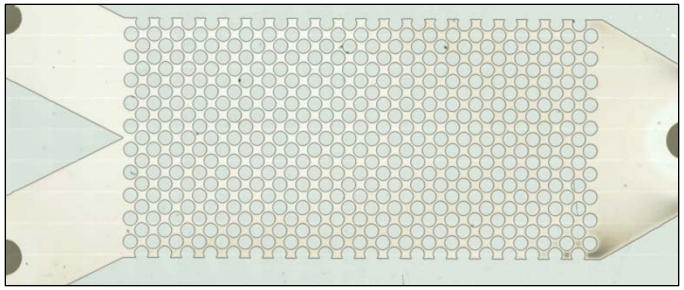
- **M=0.22-1.1 (log M= -0.66 to 0.05)**
- **C = $1E^{-6}$ - $1E^{-4}$ (log C = -5.91 to -3.91)**

Experimental Setup

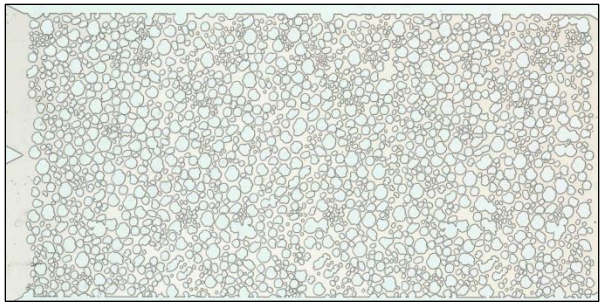




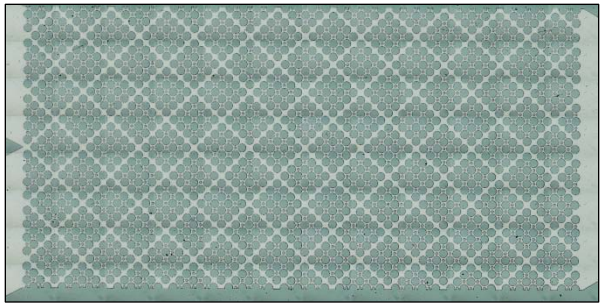
- Automated Video Microscopic Imaging and Data Acquisition System (**AVMIDAS**) (U.S. Patent No. 6,836,559)- an advanced quantitative imaging and visualization tool
- Engineered manifold to house micromodel



Staggered array of Circular grains



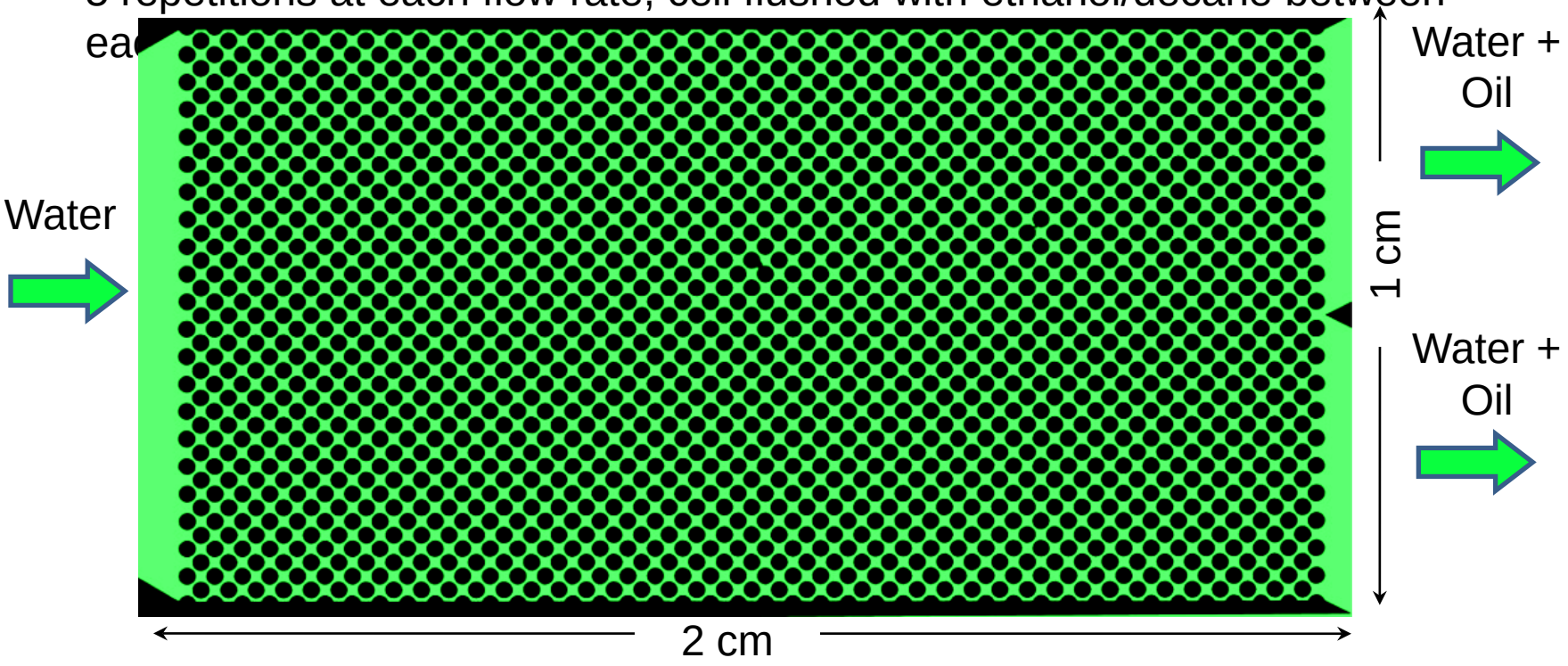
Random Heterogeneous array



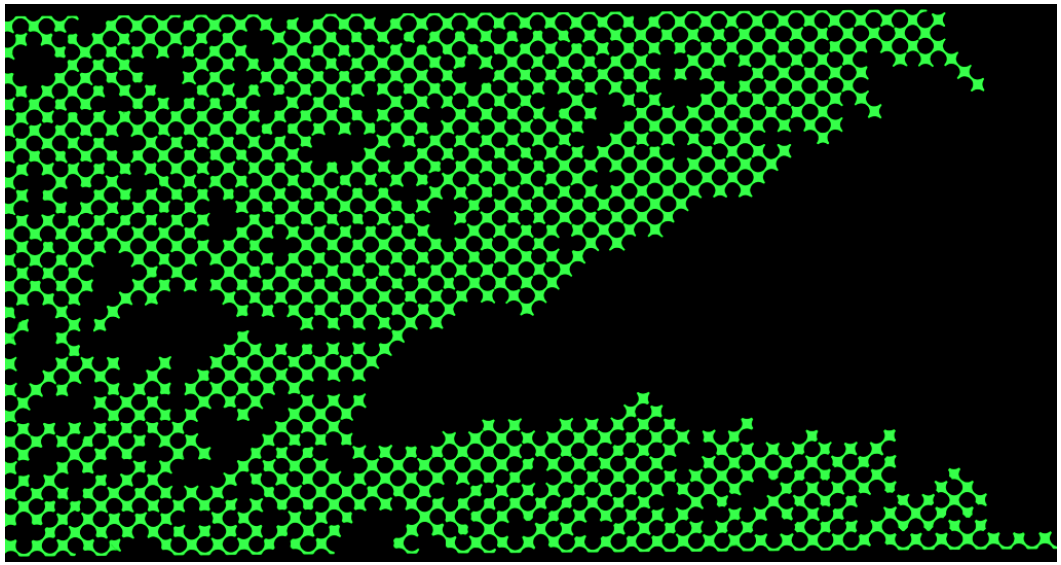
Diamond Aggregate array

Experimental Methodology

- Silicon Micromodel with etched circular grain network (300 μm dia; 140 μm deep)
- Cell is filled with Silicone oil (5cSt, 20cSt) which is displaced with water with dissolved dye
- Water flow rate varied from 0.1-5 ml/hr (C = $1.2E^{-6}$-$6.1E^{-5}$)
- 5 repetitions at each flow rate, cell flushed with ethanol/decane between ea



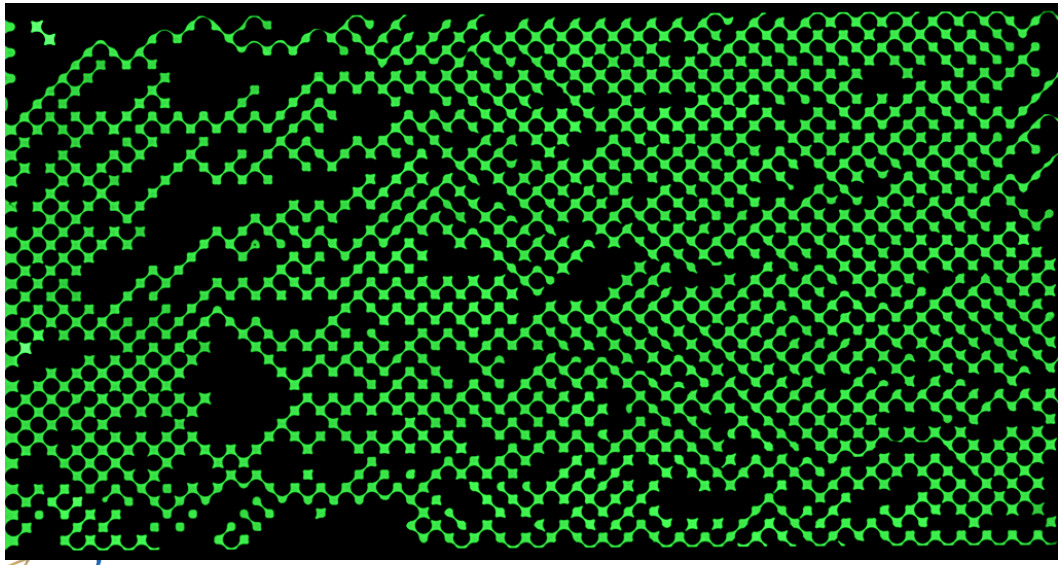
Results – Representative Residual Saturation Patterns



Water + Dye (Invading Fluid)

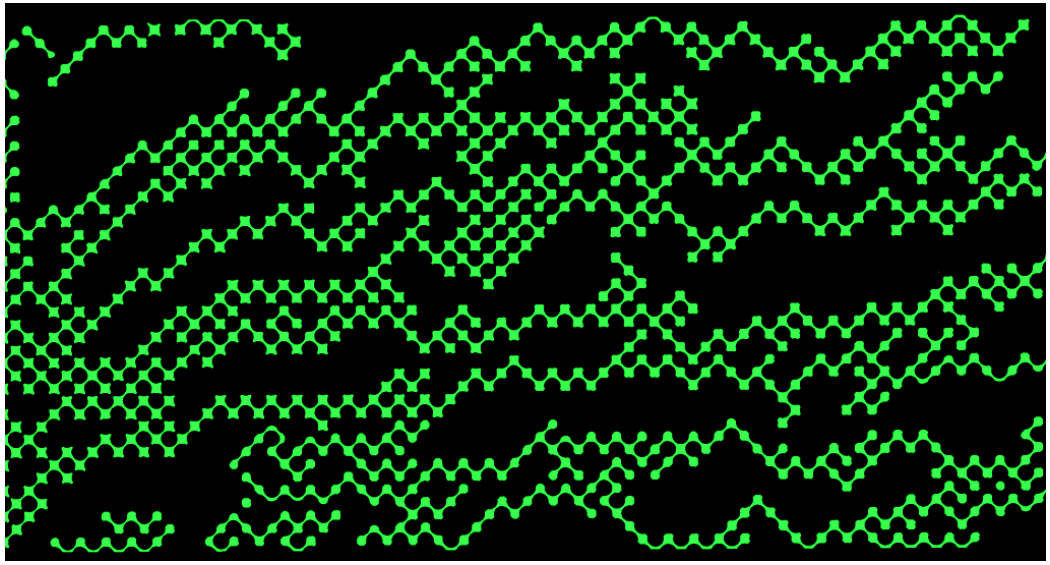
Oil + Posts (Defending Fluid)

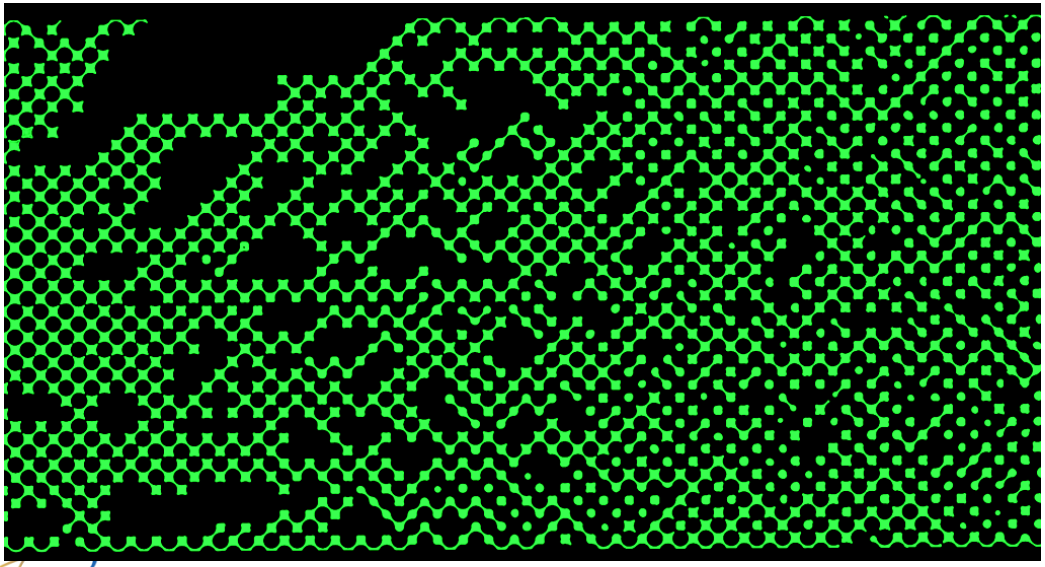
5cSt System (M = 0.22)
Water – 0.3 ml/hr, (C = $4E^{-6}$)
Avg % Oil Displaced – 55.9%
Avg. Fractal Dimension – 1.65



5cSt System (M = 0.22)
Water – 5.0 ml/hr, (C = $6E^{-5}$)
Avg % Oil Displaced – 68.9%
Avg. Fractal Dimension – 1.69

Results – Representative Residual Saturation Patterns





Water + Dye (Invading Fluid)

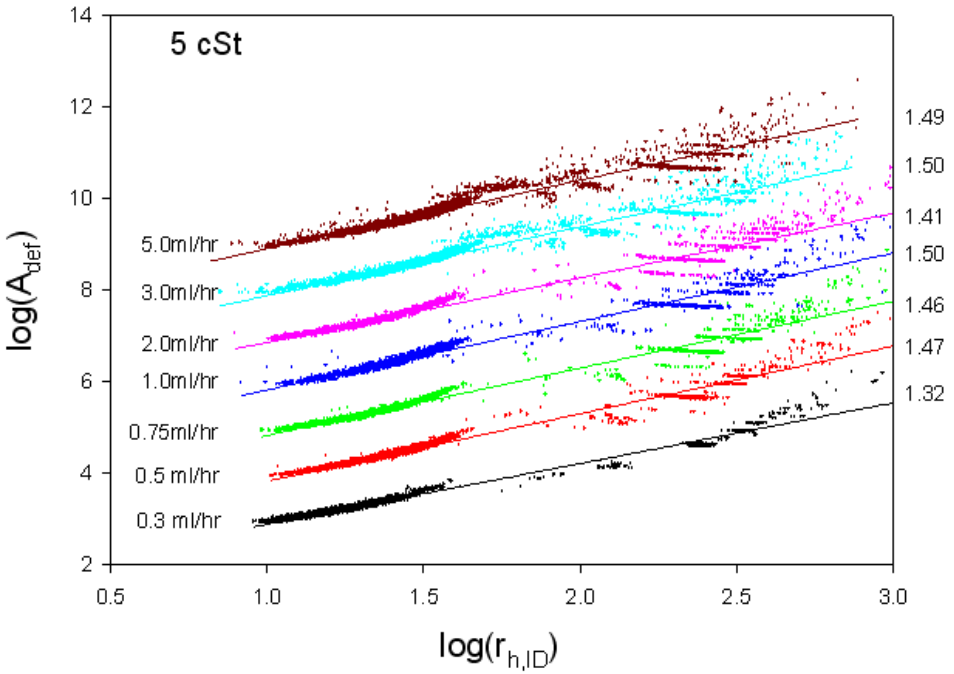
Oil + Posts (Defending Fluid)

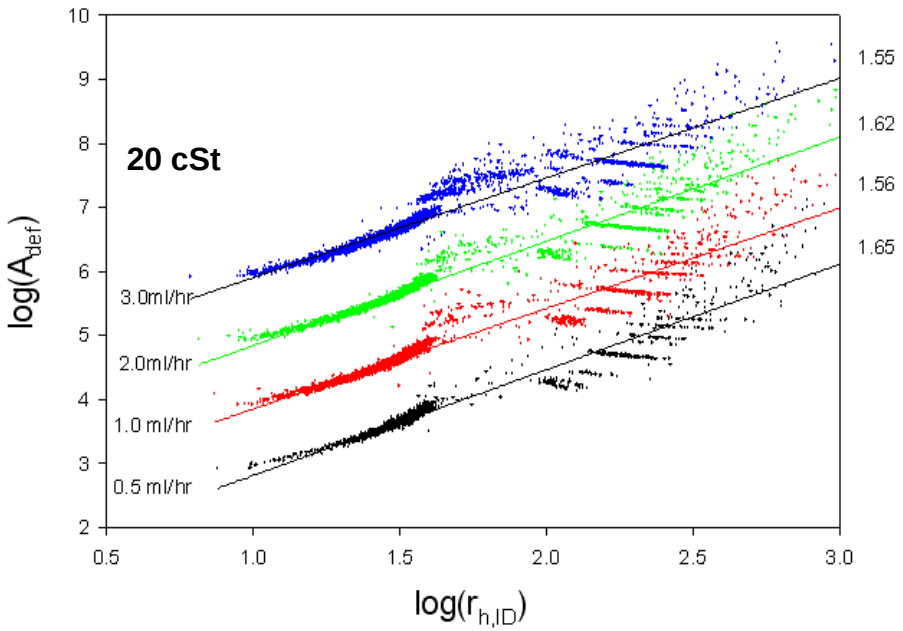
20cSt System (M = 0.05)
Water – 0.5 ml/hr, (C = $6E^{-6}$)
Avg % Oil Displaced – 28.1%
Avg. Fractal Dimension – 1.55

20cSt System (M = 0.05)
Water – 3.0 ml/hr, (C = $4E^{-5}$)
Avg % Oil Displaced – 60.1%
Avg. Fractal Dimension – 1.68

Saturation, Hydraulic radii, area of blobs, pair correlation

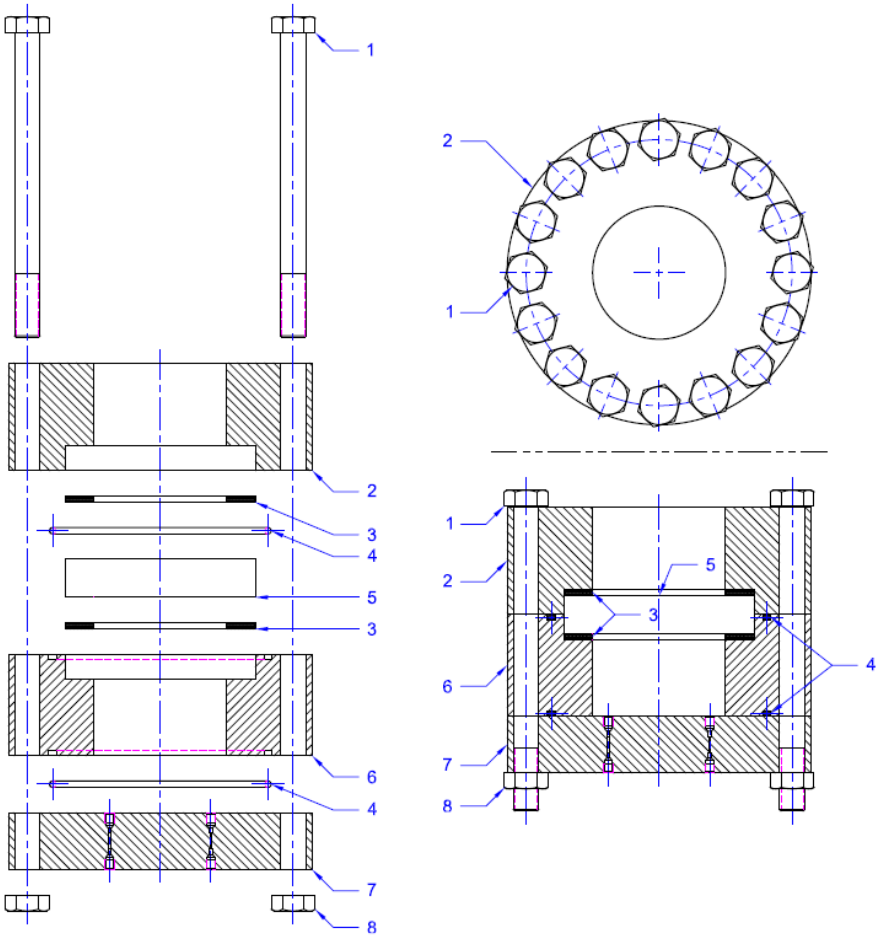
Results – Area Distribution of Defending blobs





Dissolution kinetics of trapped blobs in scCO2-Brine system?

High-Pressure Microfluidic Experiments

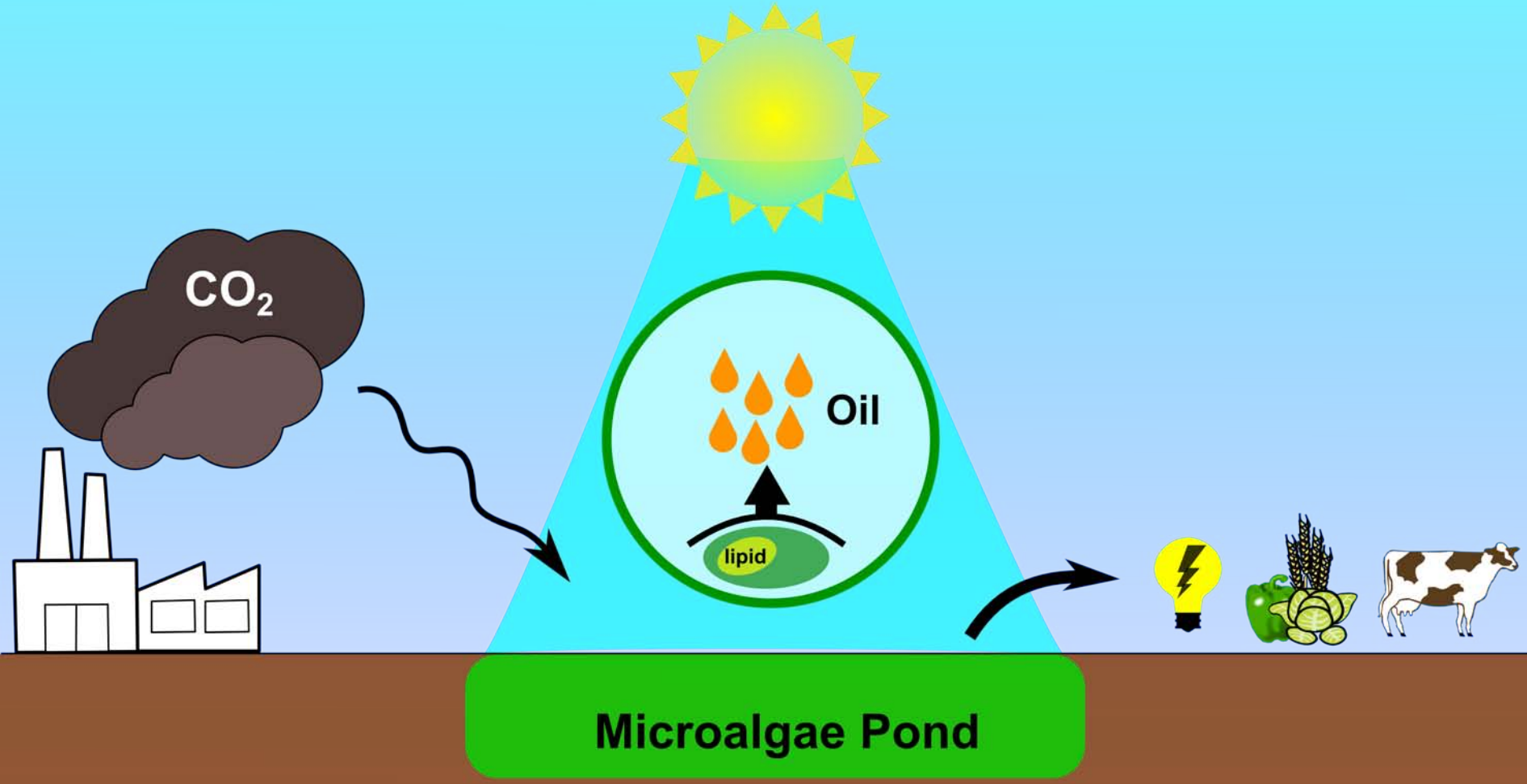


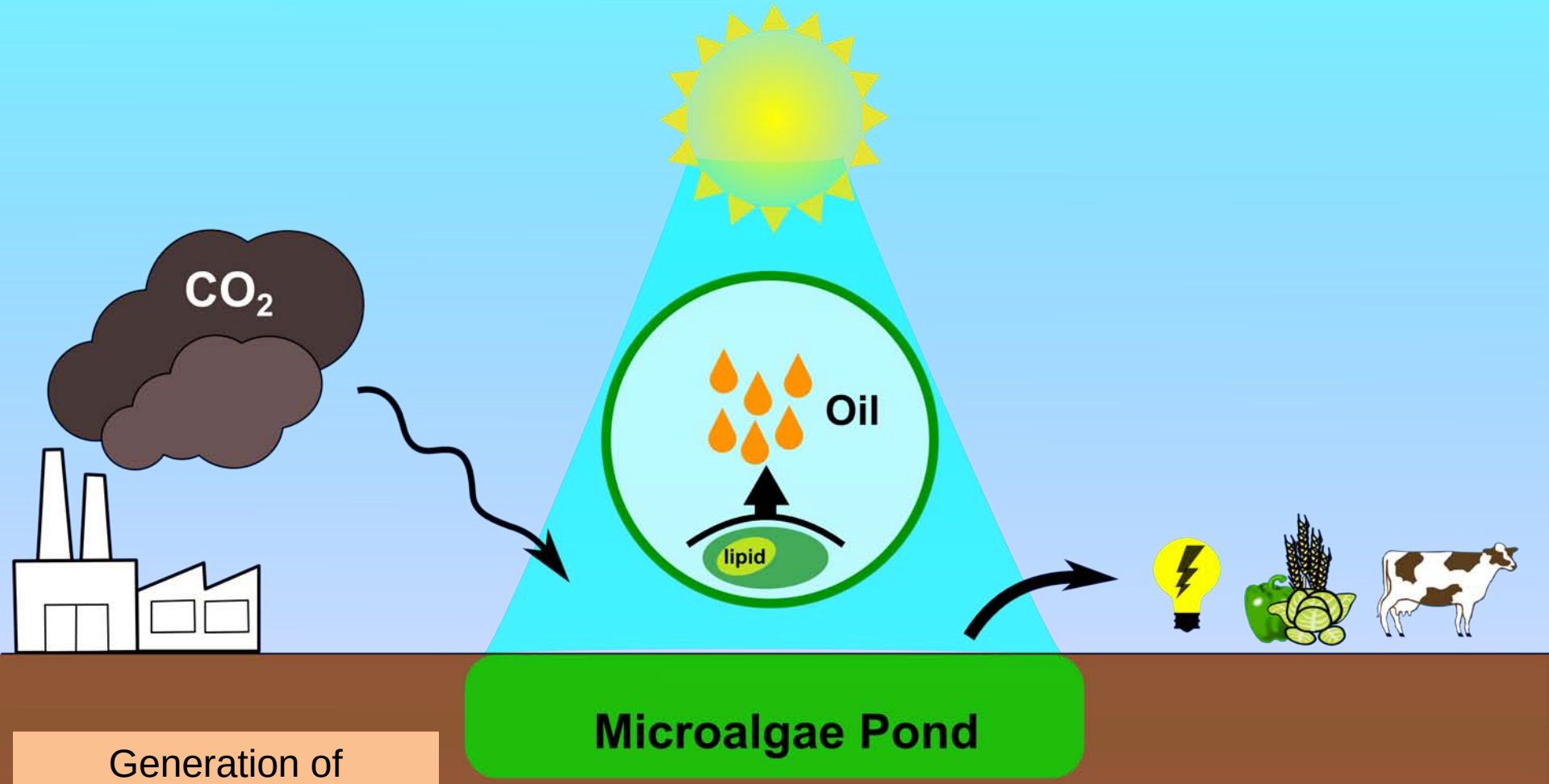
NO.	PART NAME	MATERIAL
1	6" HEX HEAD BOLT 1/2"-20 THREAD	GRADE 8 STEEL
2	LARGE OPENING FLAT HEAD	INCONEL 600
3	LAGRE WINDOW GASKET	EXPANDED TEFLON
4	O-RING	NEOPRENE
5	LARGE WINDOW	SAPPHIRE
6	BODY	INCONEL 600
7	BASE	INCONEL 600
8	HEX NUT 1/2"-20 THREAD	GRADE 8 STEEL

- High-Pressure cell to house micromodel for supercritical CO_2–Brine displacement experiments
- Max operating temp – 100^{O}C
- Max operating pressure – 1500 psig
- Visualization of displacement patterns under different conditions

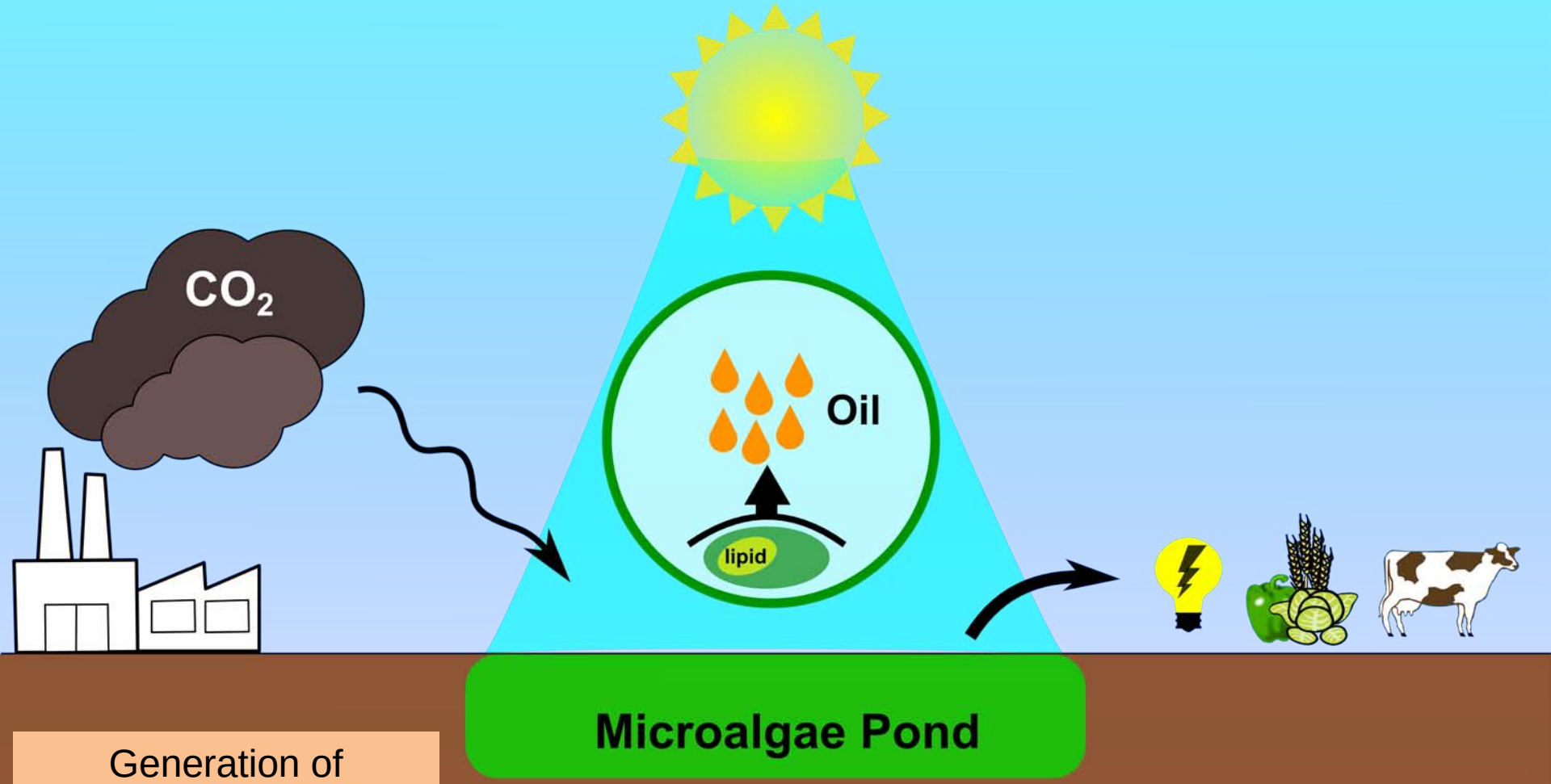
Hydrogel: *Integrated Environments for Microalgae Cultivation*

Peng He and Amr Abdel-Fattah


CO_2
Oil
lipid
Microalgae Pond

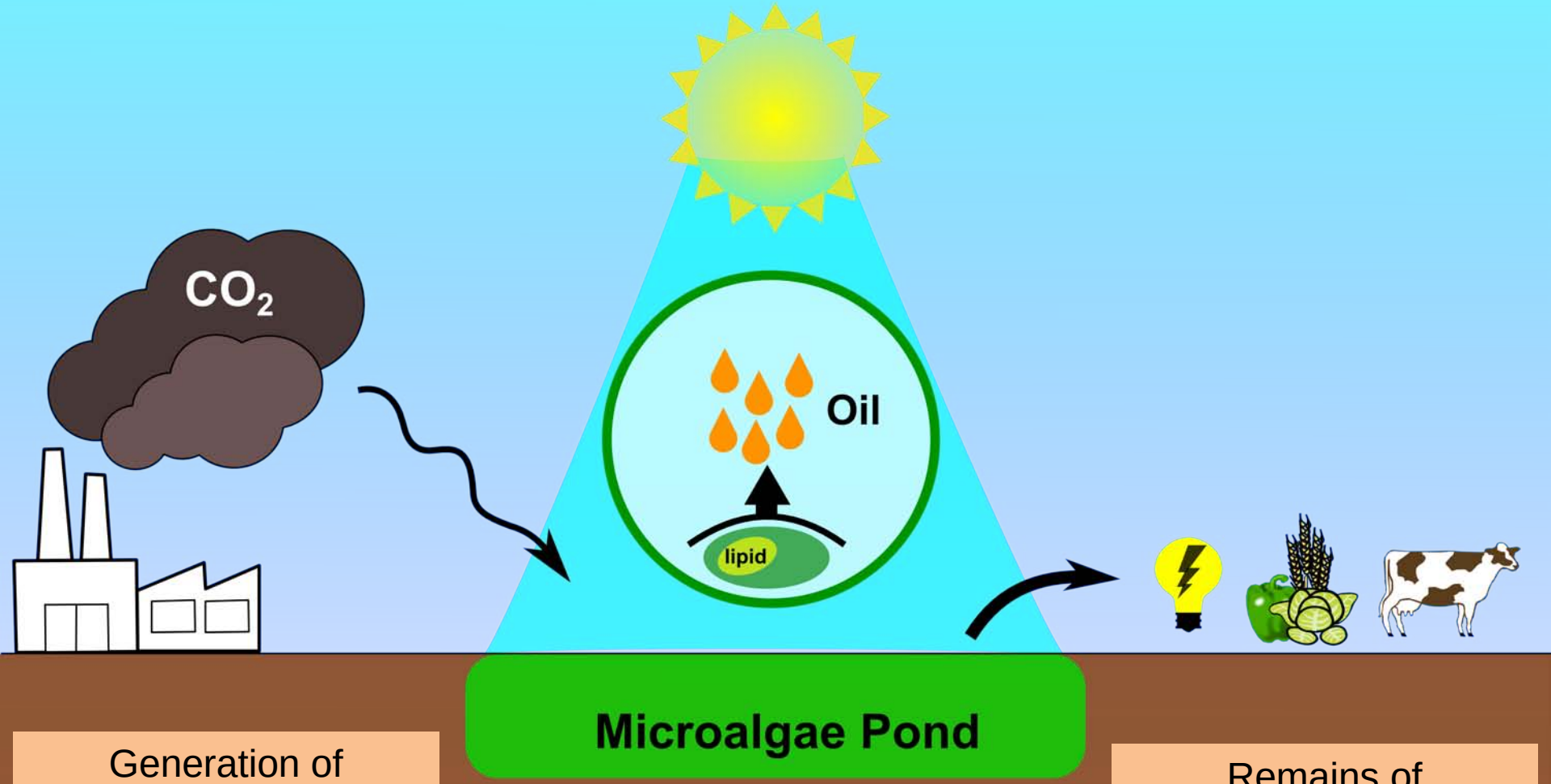


Generation of microalgae oil by photo-synthesis will help clean green-house gas (GHG) emission from power plants and other sources



Generation of microalgae oil by photo-synthesis will help clean green-house gas (GHG) emission from power plants and other sources

Oil is extracted from lipid in microalgae cells to produce fuels with high energy density (bio-diesels). Microalgae could be harvested year-round. Arid land and wastewater could be used.



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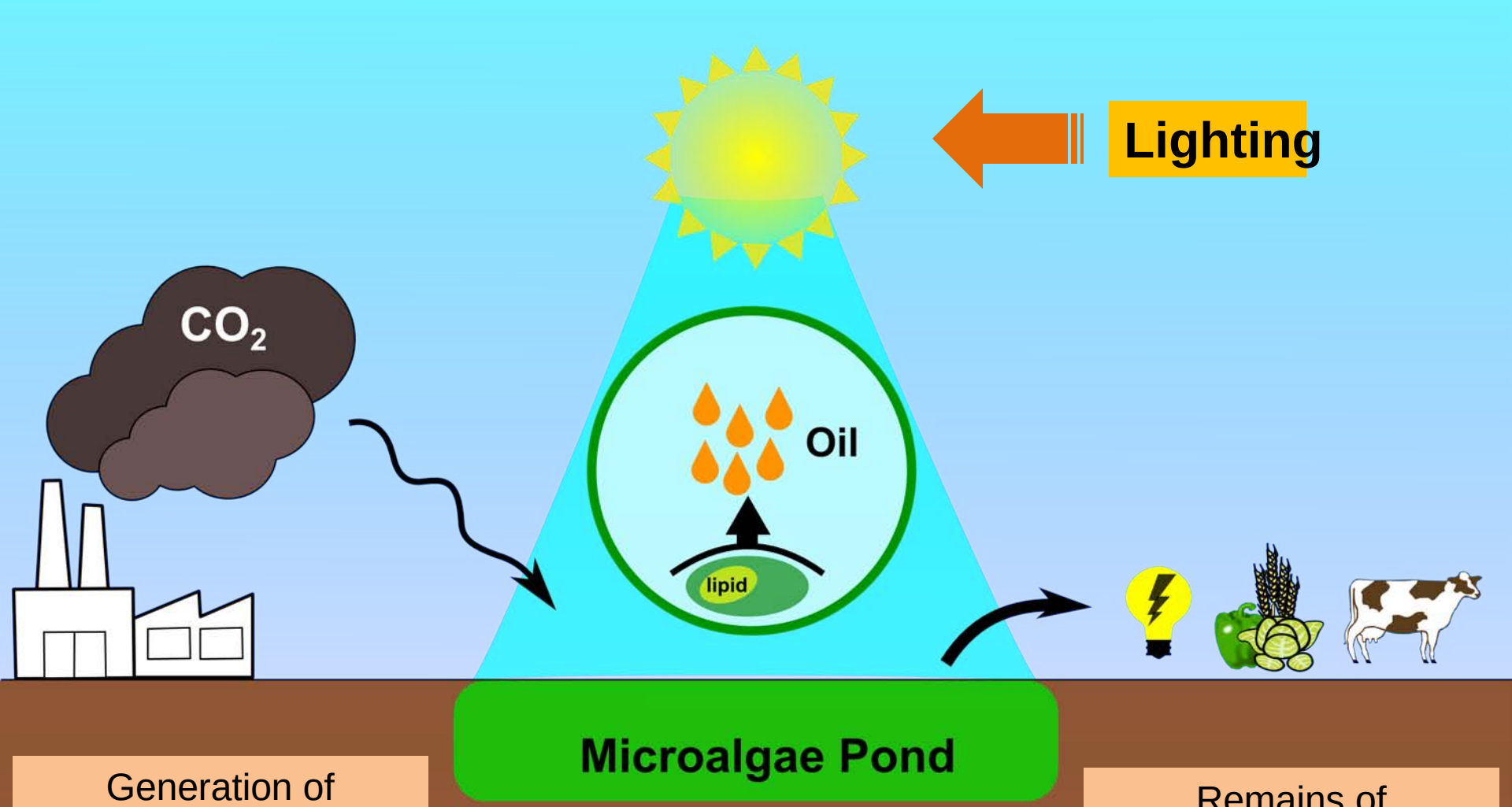
Remains of microalgae after oil extraction can be utilized to produce bio-electricity by fermentation, as soil fertilizer and animal feed



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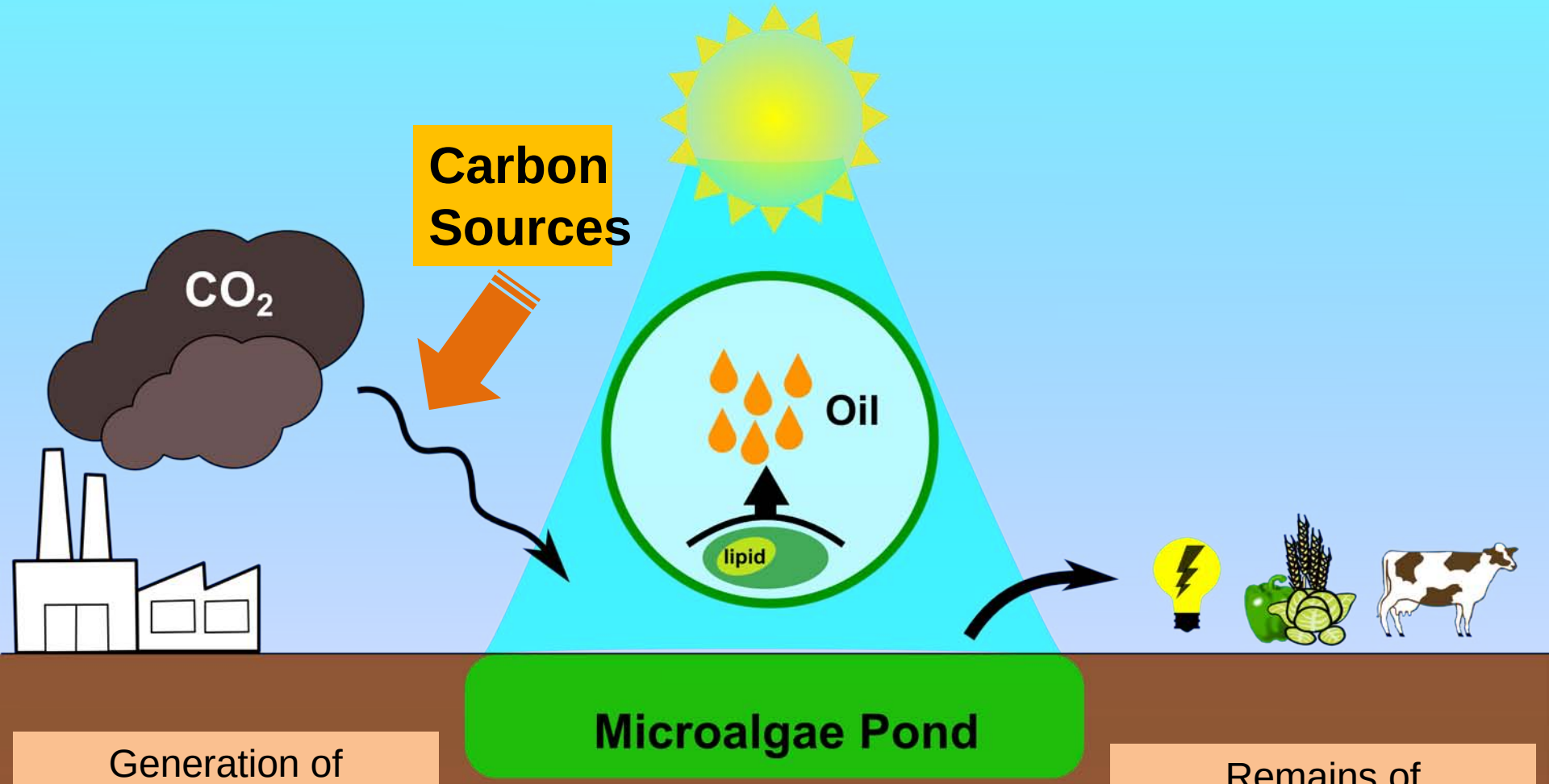

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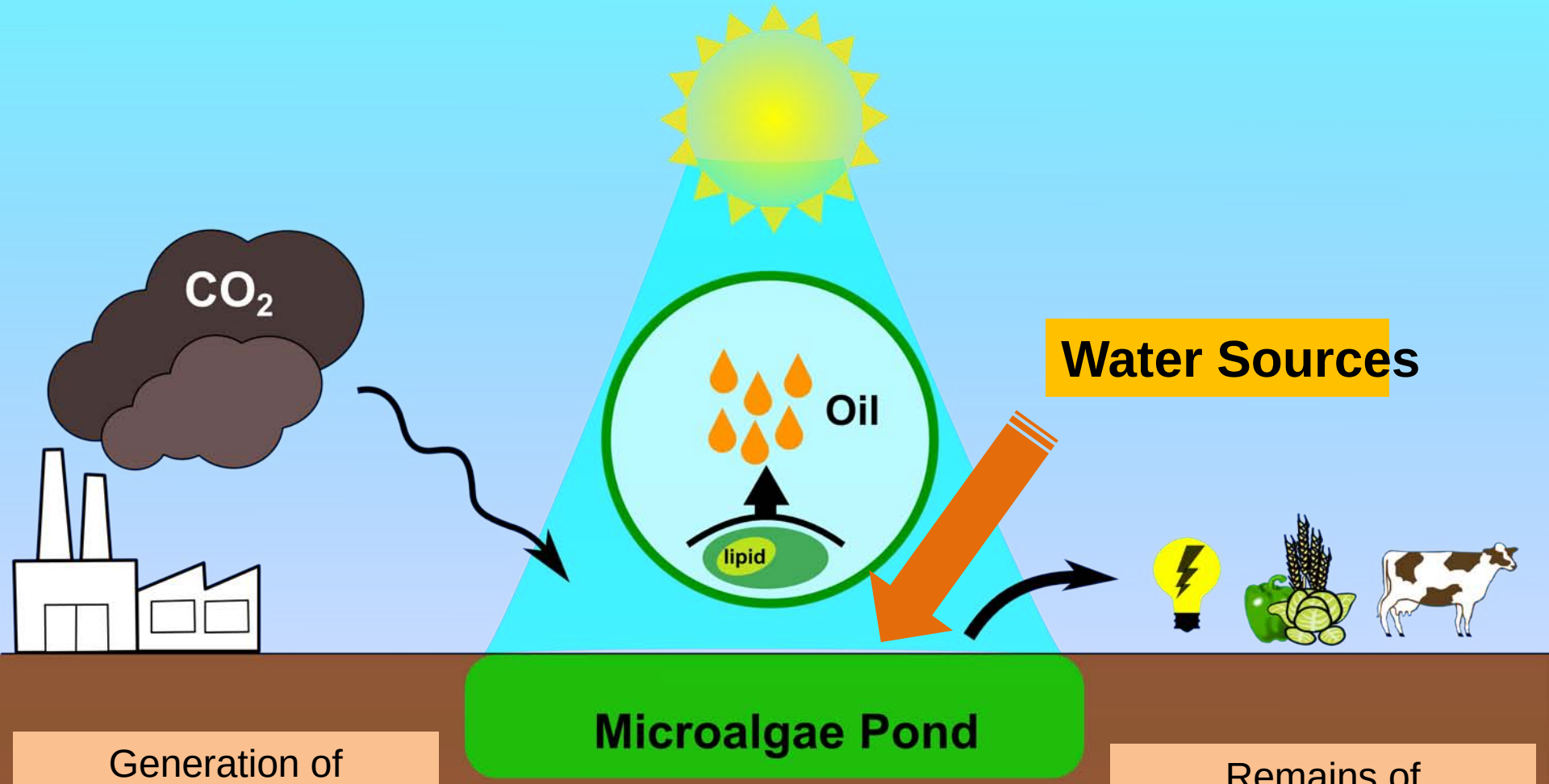

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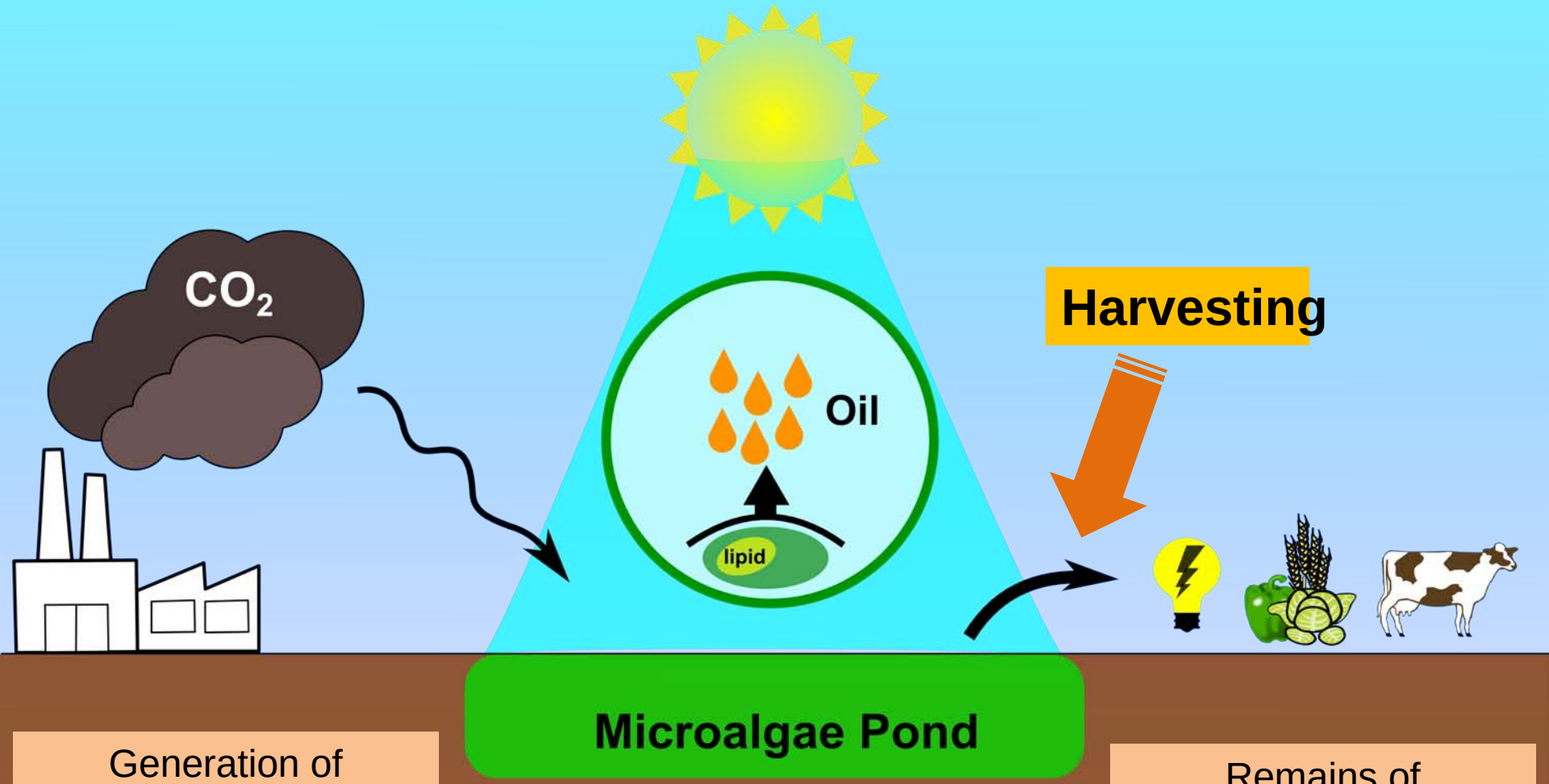

Generation of microalgae oil by photo-synthesis will help clean green-house gas (GHG) emission from power plants and other sources

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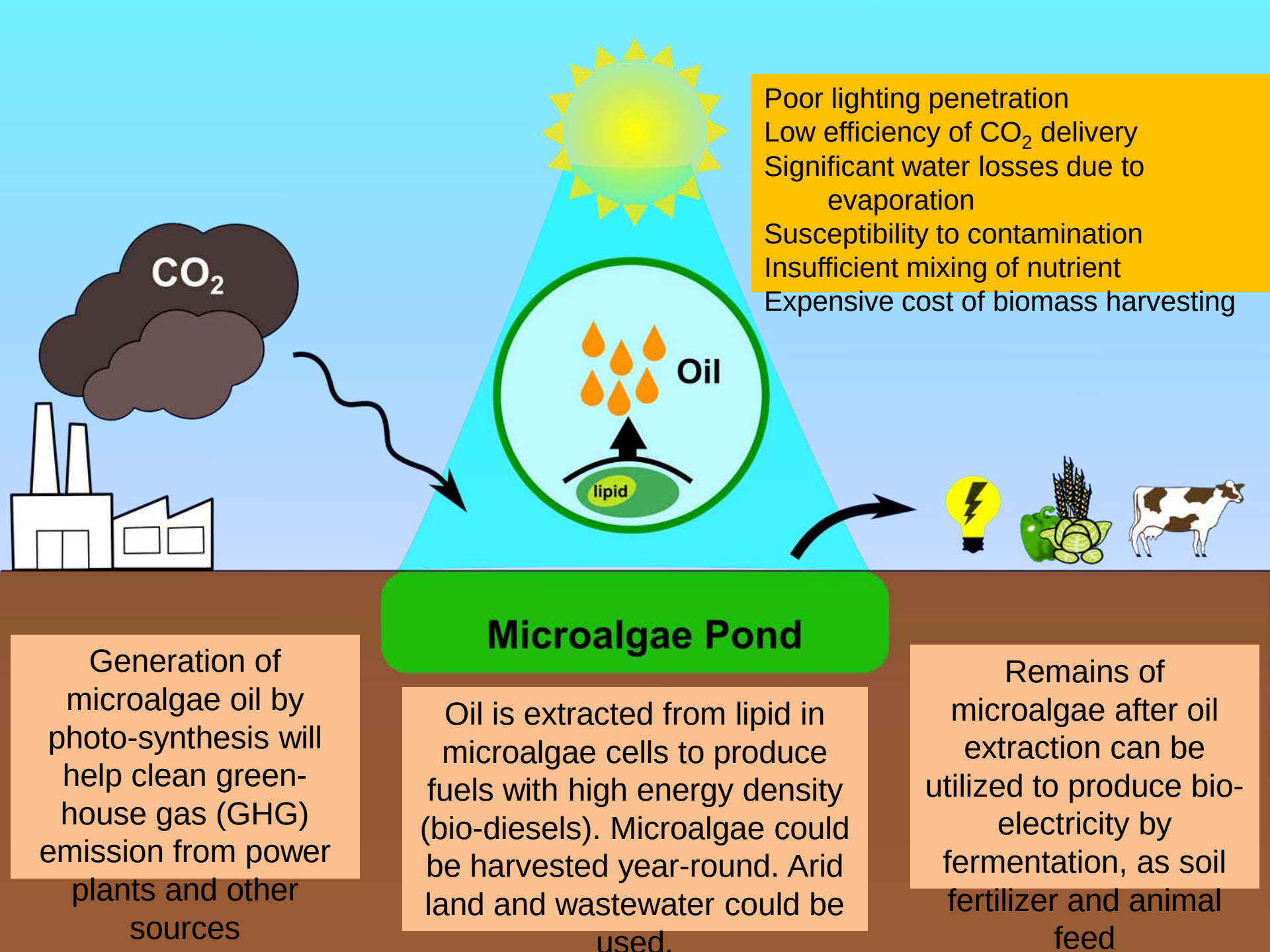
Poor lighting penetration
Low efficiency of CO_2 delivery
Significant water losses due to evaporation
Susceptibility to contamination
Insufficient mixing of nutrient
Expensive cost of biomass harvesting
CO_2
Oil
lipid
Microalgae Pond
Generation of microalgae oil by photo-synthesis will help clean green-house gas (GHG) emission from power plants and other sources
Oil is extracted from lipid in microalgae cells to produce fuels with high energy density (bio-diesels). Microalgae could be harvested year-round. Arid land and wastewater could be used.
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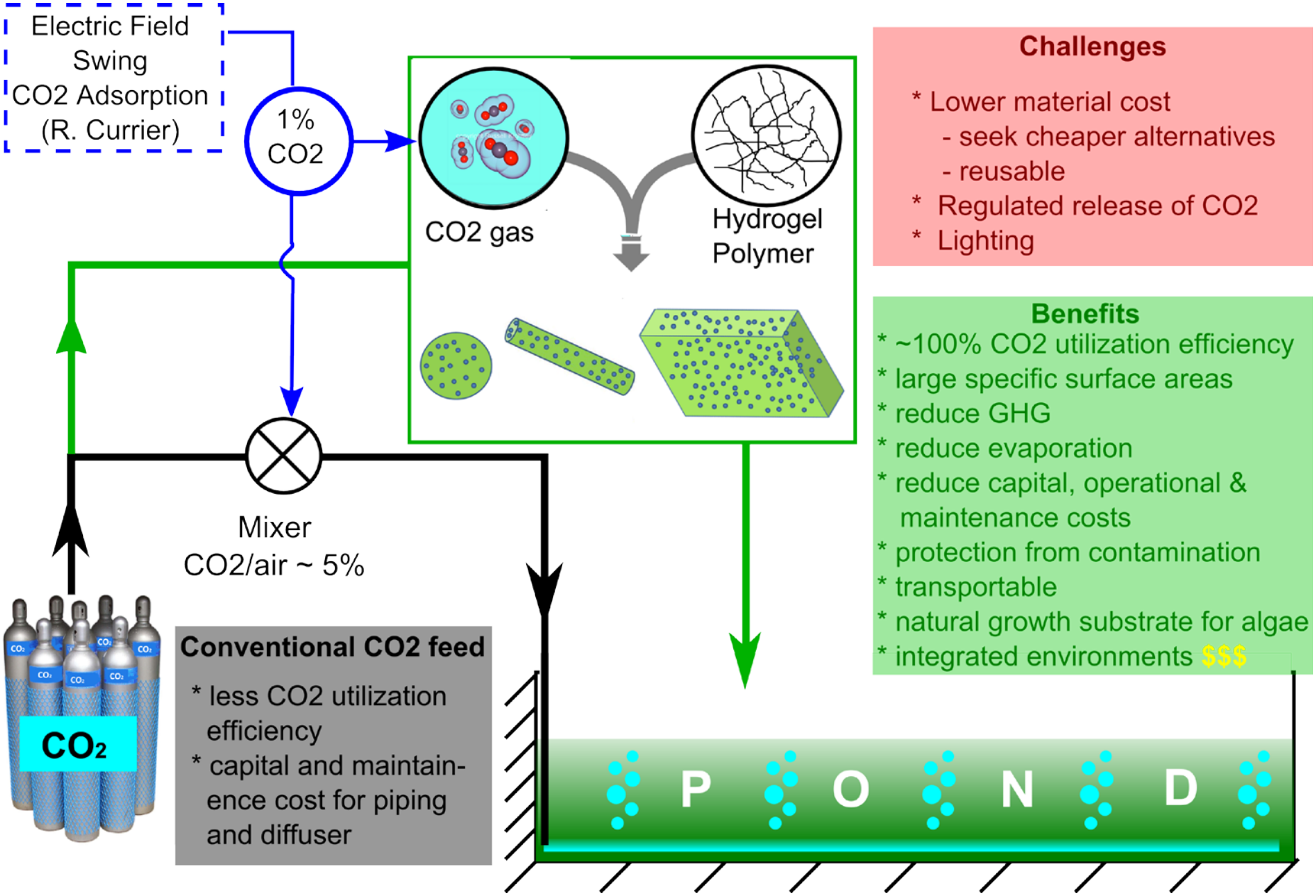
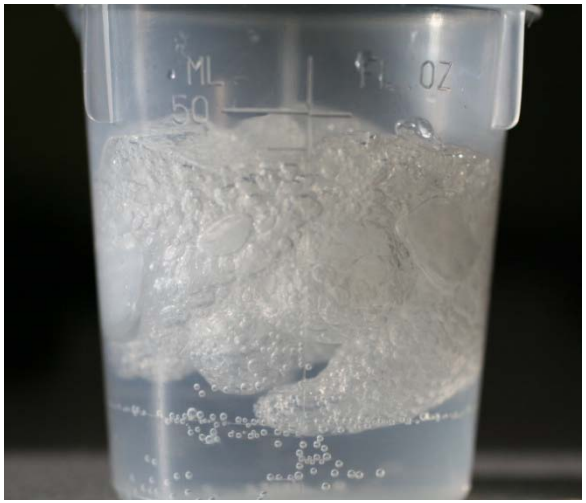
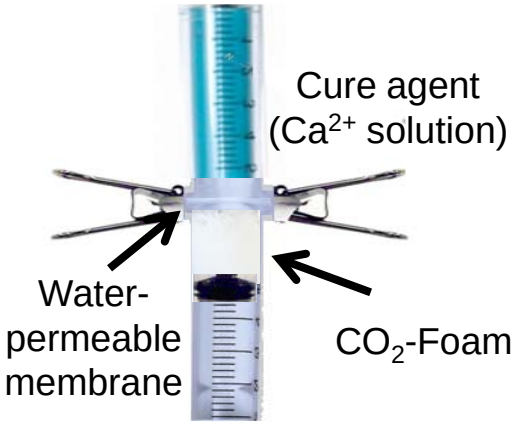
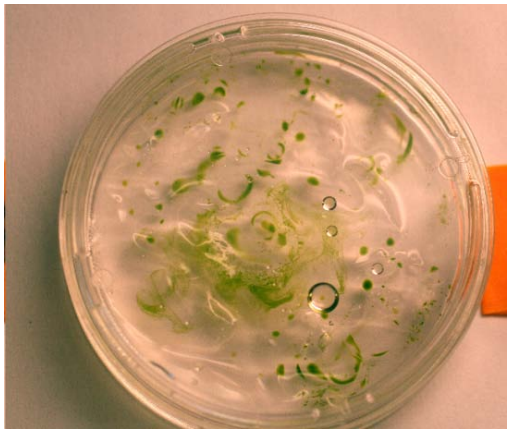

Electric Field Swing CO2 Adsorption (R. Currier)
1% CO2
CO2 gas
Hydrogel Polymer
Mixer
CO2/air ~ 5%
CO2
Conventional CO2 feed
* less CO2 utilization efficiency
* capital and maintain-ence cost for piping and diffuser
P O N D
Challenges
* Lower material cost
- seek cheaper alternatives
- reusable
* Regulated release of CO2
* Lighting
Benefits
* ~100% CO2 utilization efficiency
* large specific surface areas
* reduce GHG
* reduce evaporation
* reduce capital, operational & maintenance costs
* protection from contamination
* transportable
* natural growth substrate for algae
* integrated environments $$$

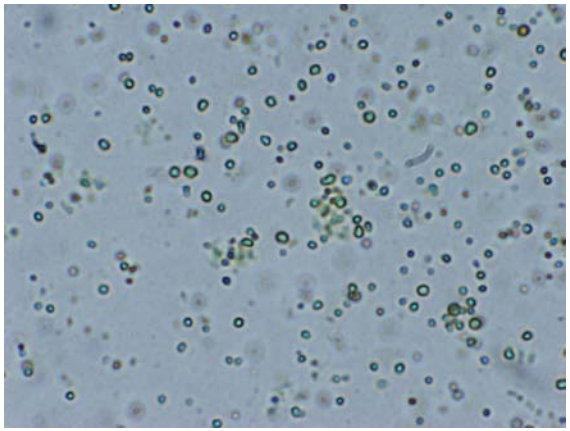




High contents of CO_2 gas (~40-50% by volume) can be stored in the hydrogel foam. The size of individual CO_2 pockets inside the hydrogel foam can be easily tuned in the range of 0.5 - 5 mm by adjusting flow-rates. Slow release of trapped CO_2 while in contact with culture medium.

Hydrogel Microalgae Culture Test





Microalgae (Nanochloropsis Salina 1776) can be cultivated inside nutrient-rich hydrogels or on their surfaces. Steady growth was observed in both cases, and more colonies were observed with hydrogel foam than in the free-swimming conditions. `

What we want to do……

- Smart materials (particles) for EOR and CO2 capture, storage, and release; sealing and monitoring CO2 geologic reservoirs
- Smart actives delivery
- Contaminant interaction and transport
- Surface cleaning, modification, and protection
- Sustainable microalgae growth, harvesting, and processing
- Oil sands with reduced environmental footprint
- Electrokinetic batteries

Current/Potential customers: Industry (Oil, Cosmetics, Surface cleaning, Coating), Office of Science, DHS, DTRA, LDRD, TT, ??

Current/Potential collaborators: MIT, UCSB, UIUC, U of A, ODU, KAUST, TUM, Nancy University, ??

Center for Colloid and Interface Science

CCIS Research Focus Areas	Cosmetics Pharma	Oil Ind.	DOE	DOD
Surface modification and characterization	✓	✓		✓
Process characterization (transport deposition, adhesion, removal)	✓		✓	✓
Miniaturized environments & Microfluidics	✓		✓	✓
Predictive modeling and simulation (transport deposition, adhesion, removal)	✓	✓	✓	✓
Flow Manipulation using SRMs	✓	✓		
Nanostructured surfaces	✓		✓	✓
Biofuel-producing microalgae cultivation, harvesting, and processing		✓		✓
CO2 sequestration/utilization		✓	✓	