Solidia Technologies

RUTGERS
School of Engineering

Utilization of CO_2 in High Performance Building and Infrastructure Products

DE-FE0004222

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U.S. Department of Energy
National Energy Technology Laboratory
Carbon Storage R&D Project Review Meeting
Developing the Technologies and Building the
Infrastructure for CO2 Storage
August 21-23, 2012

Presentation Outline

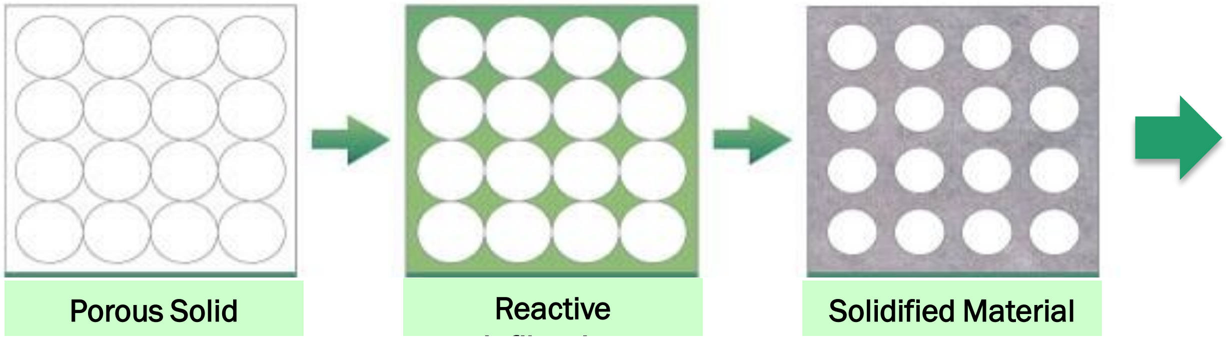
1. Quick Introduction
2. Progress on DE-FE0004222
3. Progress toward commercialization

1. Quick Introduction

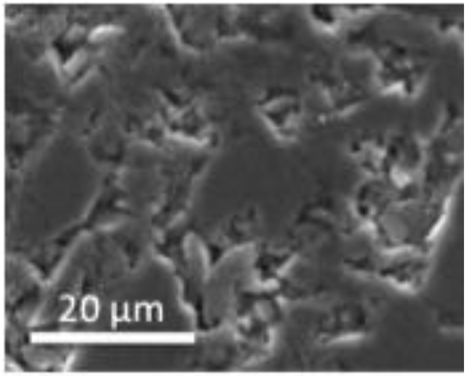
Our Technology

Enables production of versatile building and construction materials

- Porous Solid Matrix
- Fill Pores with Water and CO_2
- Water Dissolves the Calcium from the Matrix and CO_2 from the Pores
- CO_2 and Calcium React to Form Calcium Carbonate
  - Bonds the Matrix Together

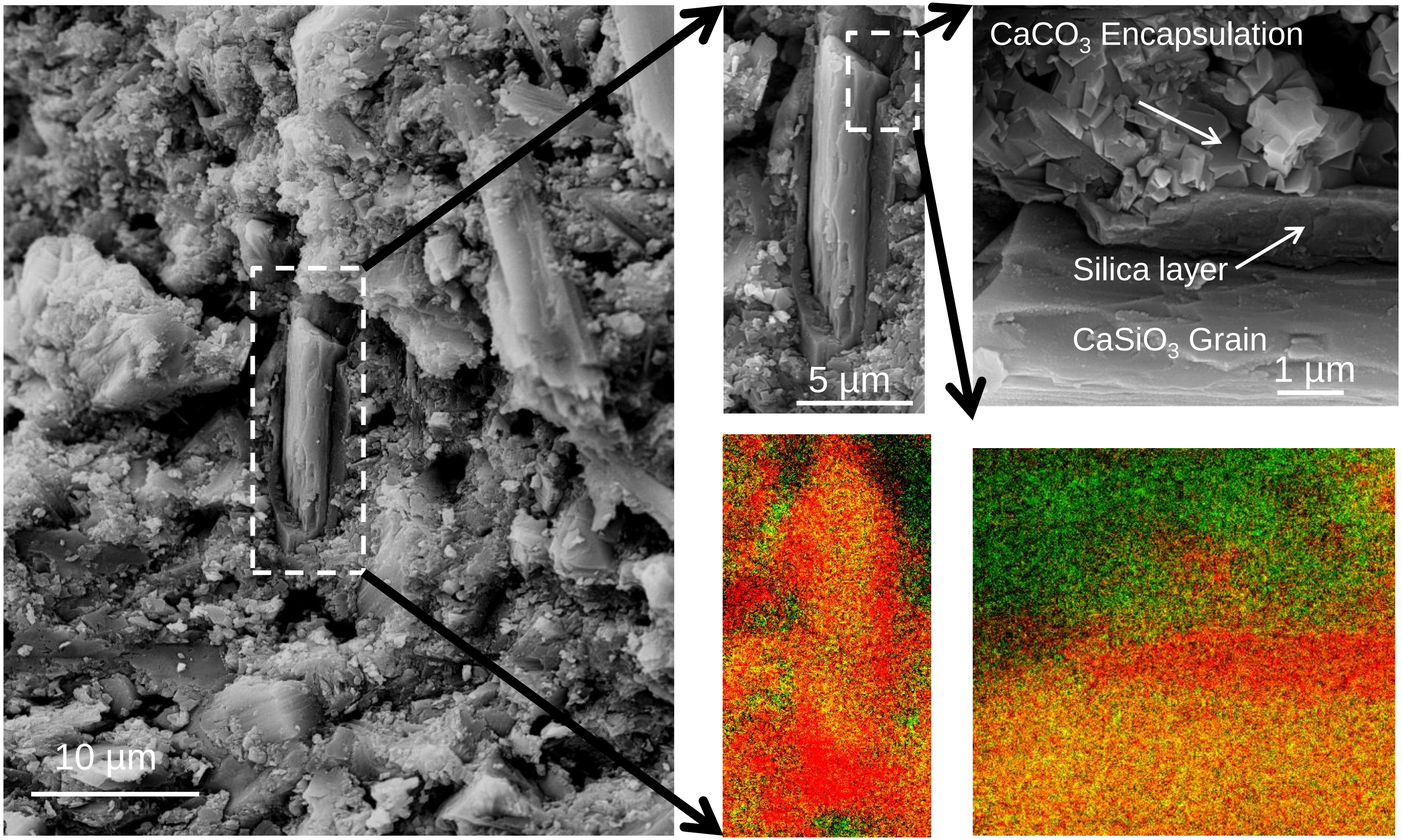


$CaSiO_3$ + CO_2 = SiO_2 + $CaCO_3$



Solidia Concrete™ Typical Microstructure

Novel Microstructure



Fractured Surface of Solidia Cement

Unique grain structure

(Yellow – $CaSiO_3$, red – SiO_2, and green – $CaCO_3$)

Solidia Cement: Technology Overview

	Basic Chemistry	Cured with	End Product
Portland Cement	C3S + C2S (~80% LS)	Water	Portland Cement Concrete
Solidia Cement	CS (~50% LS)	CO_2	Solidia Concrete

Same Raw Materials

Cured with CO_2 & Steam

At Ambient Pressure in <16 hours

Benefit to the Program

Program Goals:

- To develop a cost-effective method of CO_2 Utilization

Project Benefits Statement:

- The research project is working to make commercially viable a process to react CO_2 with a mineral to make a solid matrix capable of meeting specifications of a construction material. The technology, when successfully demonstrated, will provide an opportunity to drastically reduce CO_2 emissions associated with the concrete production life cycle and provide a useful application for CO_2. This technology contributes to the Carbon Storage Program’s effort of developing cost effective methods of CO_2 utilization.

2. Progress on DE-FE0004222

Project Overview:

Goals and Objectives

Key Objectives

- Monitor chemistry and physics of carbonation
- Control natural wollastonite carbonation rate by controlling particle size

Key Deliverables

Design and build instrumentation for monitoring LTS (g-HLPS process)

New milling method to control particle size

Correlate particle size with carbonation rate

Design and build hydrothermal reactor with one or more in situ probes installed (Phase II Option)

Why *In Situ* Measurements?

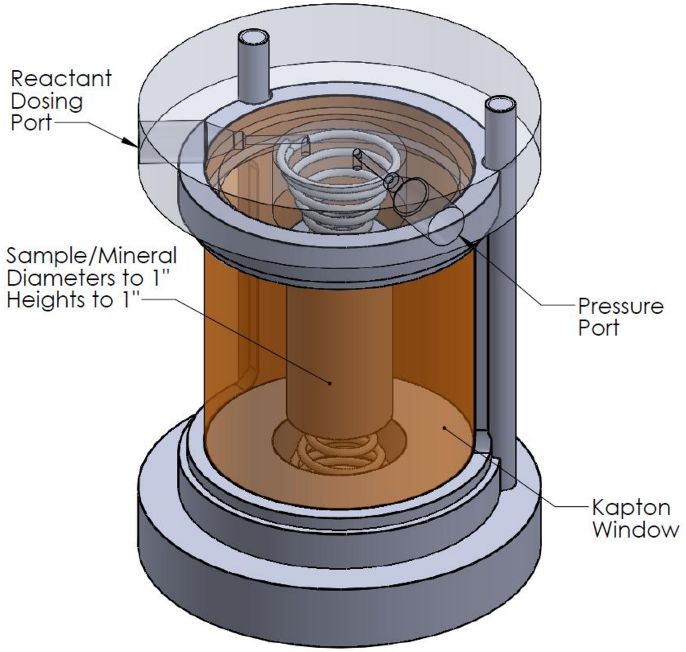
Solidia Cement Science:

- Process control – thermo or kinetics?
- Reaction mechanism – where is the bottleneck?
- Reaction rate – how fast does it go?
- Classify reactivity – which silicate is most reactive?
- Rate scalability – which variables are important?

Solidia Cement Technology

- Minimum reaction temperature and pressure
- Conditions for process robustness
- Raw material acceptance/rejection
- In plant or on-site process diagnostics and product certification
- Fast solving

Sample Stage, Reactor truly Novel



- Stainless Steel
- Kapton (window)
- Ports for liquid and gas delivery
- Temperatures from 25 to 100 °C
- Pressures up to 30 psig

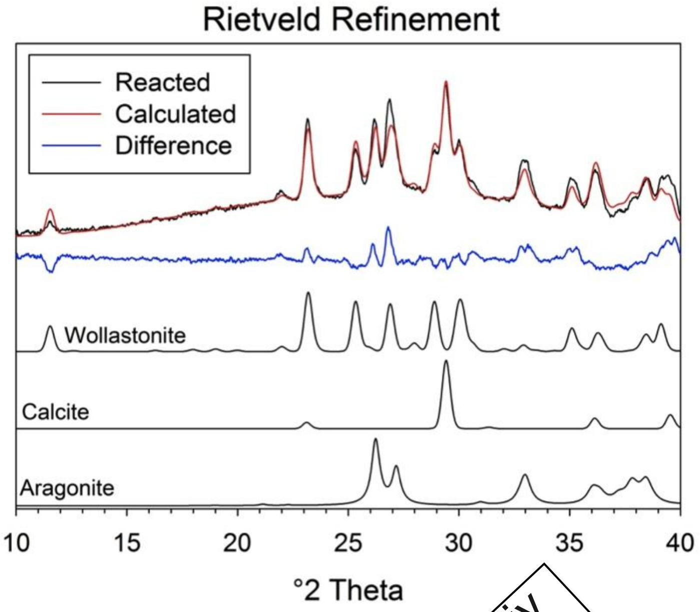
- Motorized travel range of 100 mm in X, Y and Z directions
- Large samples up to 10 kg
- Multiple samples can be run individually or simultaneously

In situ Wollastonite Carbonation

$$\overset{\text{Wollastonite}}{[CaSiO_3]} + CO_2 = \underset{\text{Aragonite}}{\overset{\text{Calcite}}{[CaCO_3]}} + \overset{\text{Amorph.}}{[SiO_2]}$$

- Short Duration Experiments
  - 16 h, 90°C
  - H_2O refluxing on sample
  - Static CO_2 set at 20 psi

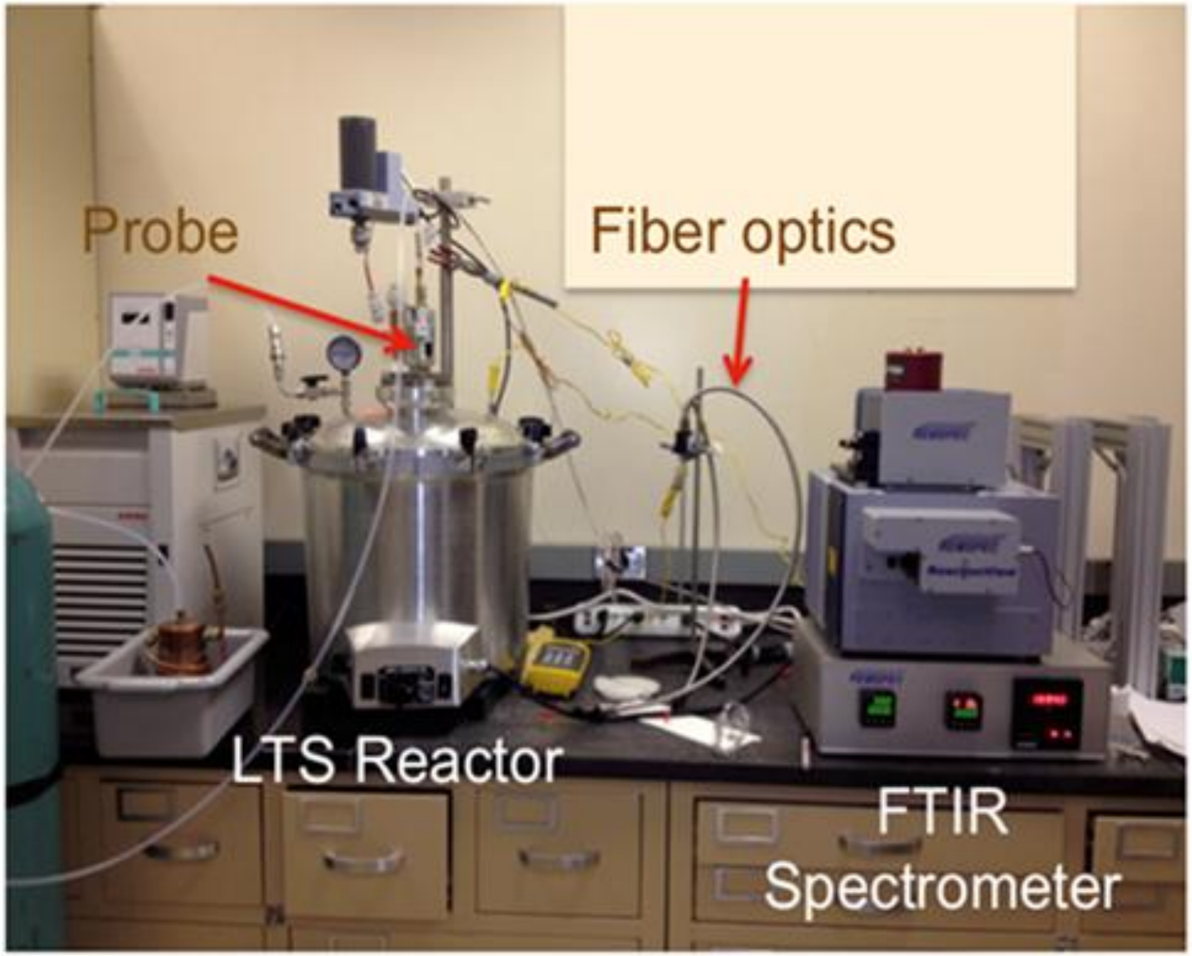
in situ XRD

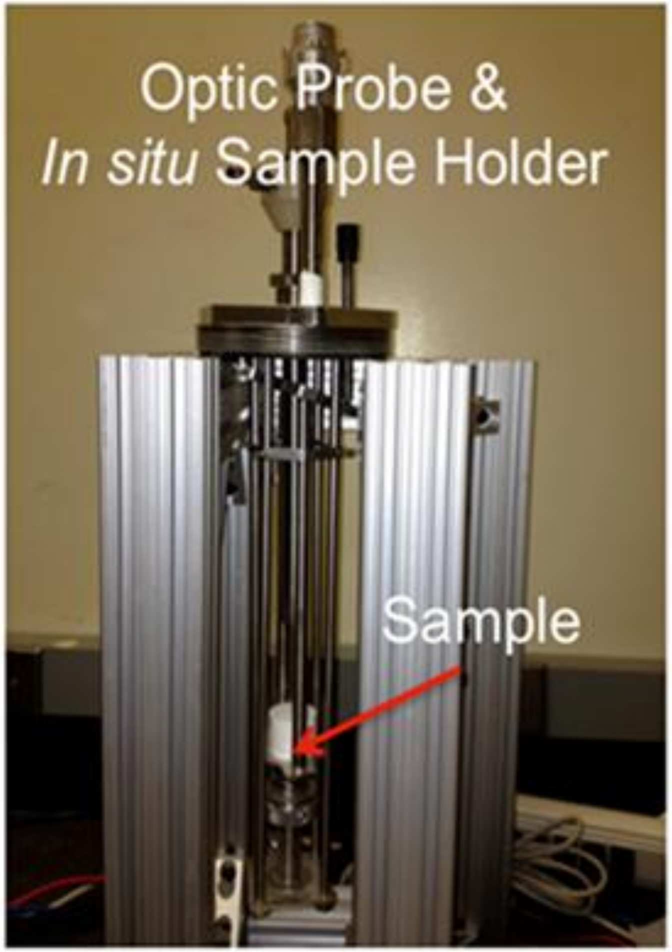

Rietveld Refinement

Quantitative

Sample	Rietveld Refinement					TGA-MS Carbonate
	Wollastonite	Calcite	Aragonite	Amorphous SiO_2	Total Carbonate	
EXP 4	18%	33%	14%	35%	47%	45%
EXP 5	23%	13%	30%	34%	43%	40%
EXP 7	27%	9%	30%	34%	39%	38%
EXP 13	17%	3%	45%	36%	48%	49%

In situ ATR-FTIR





In Situ ATR-FTIR Results for Wollastonite

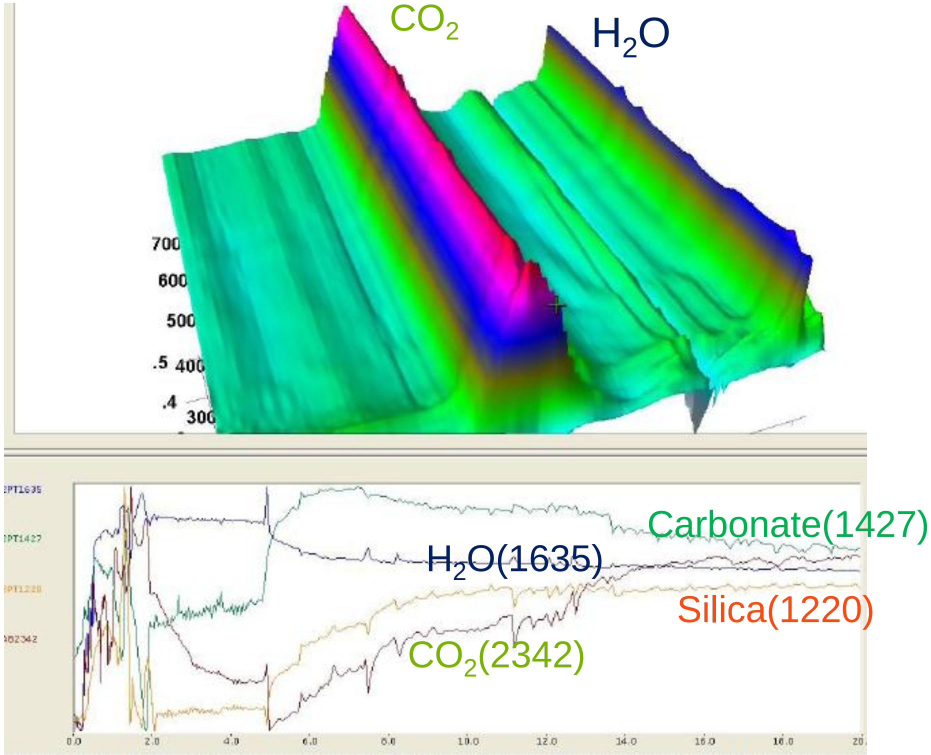
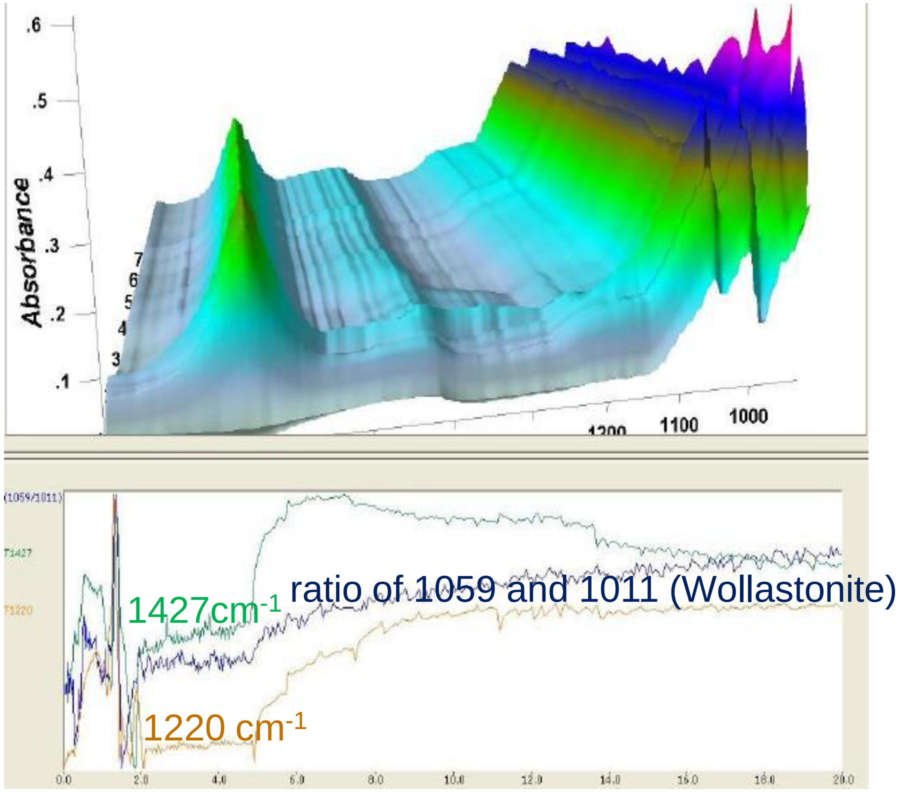


Figure 4: VizIR screen showing trendlines for CO_2 (2342), water (1635), carboante (1427), and silica (1220 cm^{-1})



Monitor Solution and Solid Species

Monitor All Solid Species

Accomplishments to Date

- Designed and built instrumentation for monitoring LTS (g-HLPS process)

- Scoped and Commissioned mill to control particle size and enable experiments to correlate carbonation rate with particle size

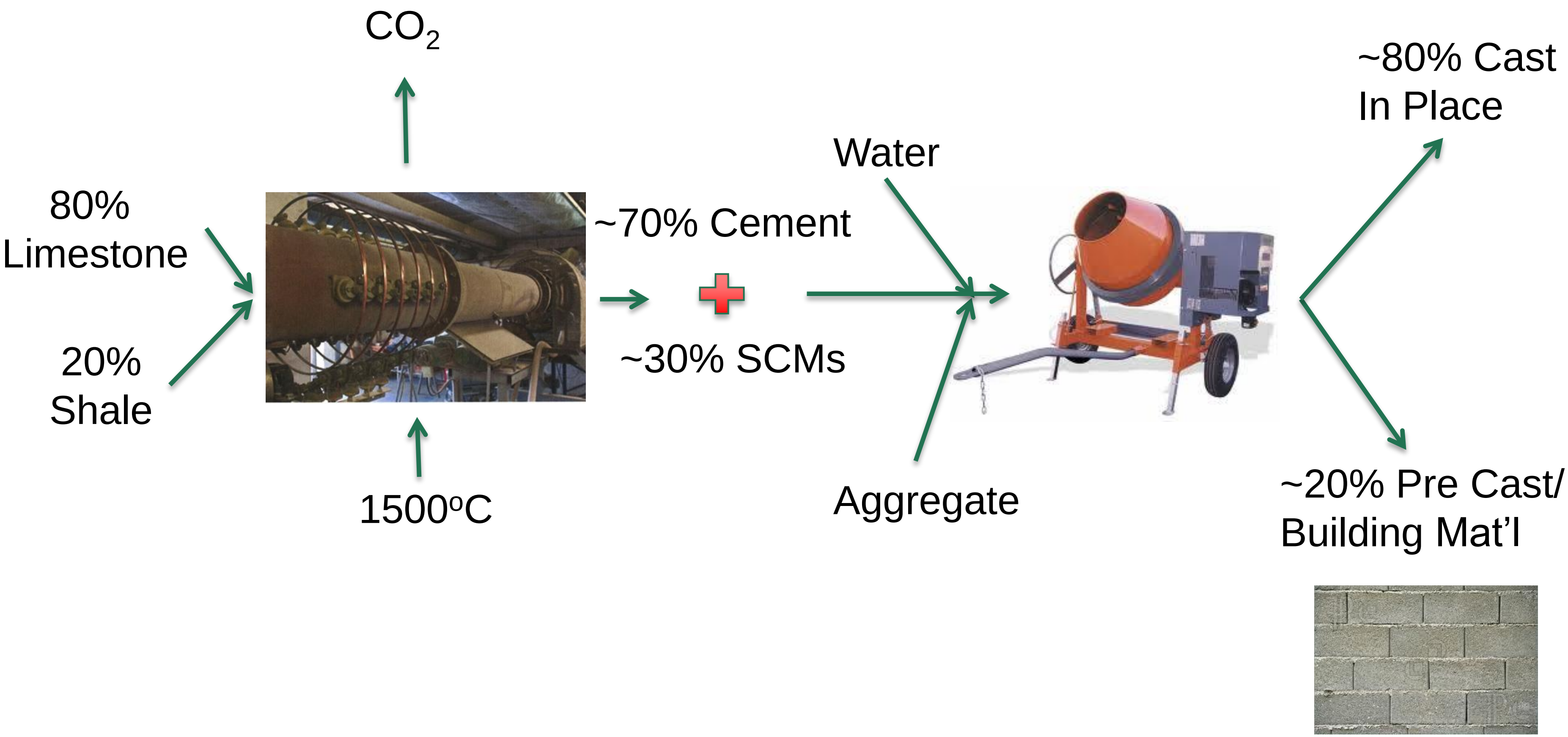
- Showed ability to react mineral at atmospheric pressure and at 60°C

3. Progress on Commercialization

Current Portland Cement and Concrete Value Chain

Portland Cement

Concrete



CO_2

80% Limestone

20% Shale

1500ºC

~70% Cement

~30% SCMs

Water

Aggregate

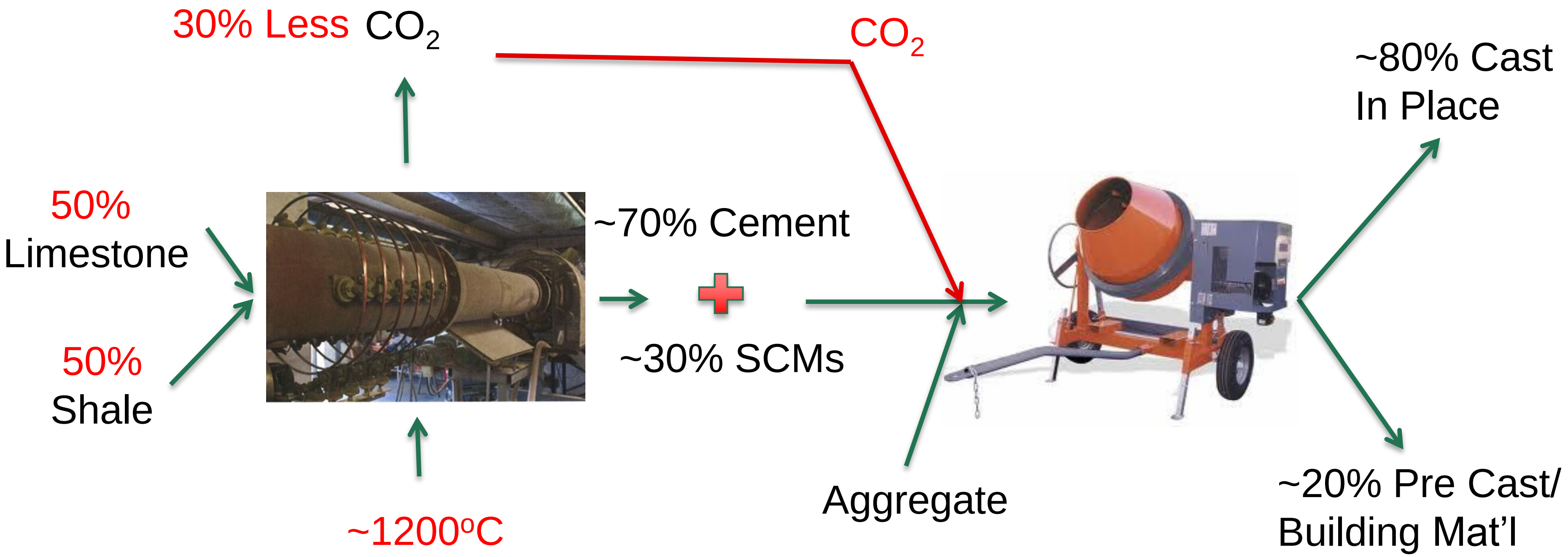
~80% Cast In Place

~20% Pre Cast/ Building Mat'l

Solidia Cement and Concrete Value Chain

Natural Wollastonite
or
Solidia Cement™

Solidia Concrete™



30% Less CO_2

CO_2

~80% Cast In Place

50% Limestone

50% Shale

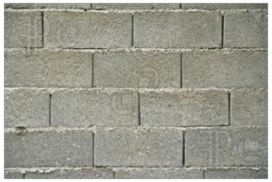
~70% Cement

~30% SCMs

~1200°C

Aggregate

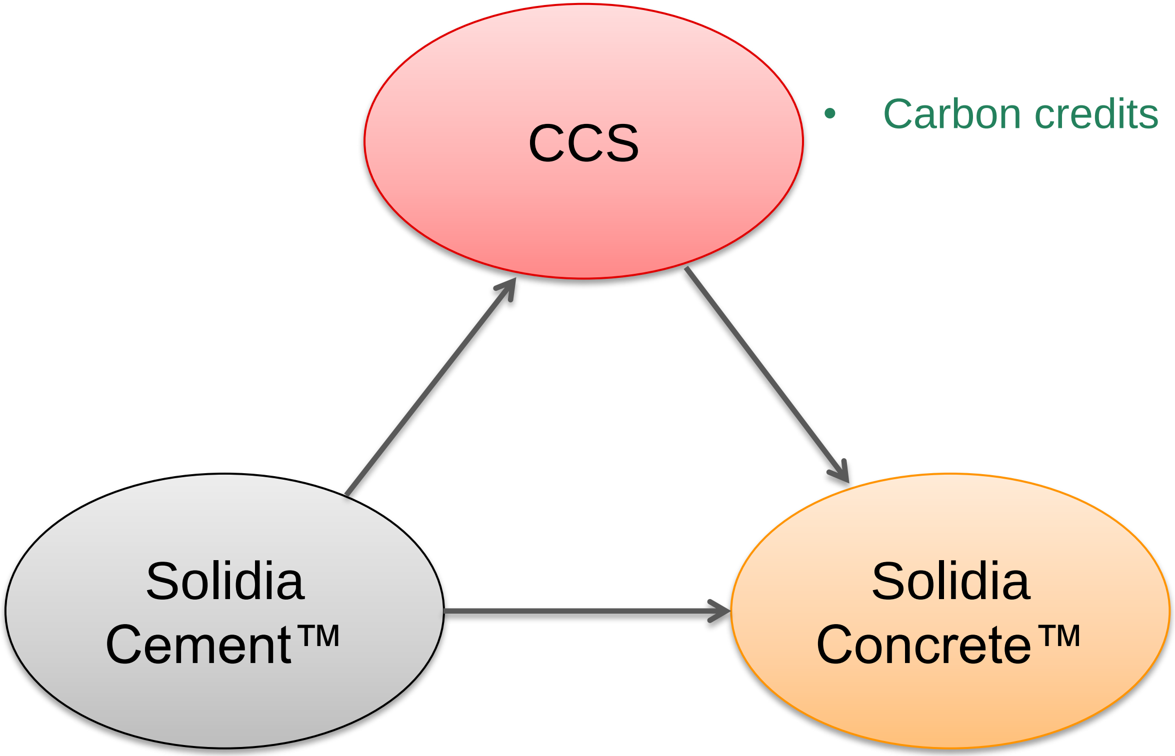
~20% Pre Cast/ Building Mat'l



Higher Durability → Better Concrete.

Property	ASTM Test	Solidia Concrete
Compressive Strength	C39	10,000 psi
Chloride Permeability	C1202	~ 200 C
Freeze Thaw Durability (dynamic modulus of elasticity, %)	C666	No Damage
Coefficient of Thermal Expansion	CRD C-39	6.8 to 7.6 x 10^{-6} (cm/cm/^{0}C)
Scaling	C672	No scaling at 50 cycles
Shrinkage	C157	90 μstrain
Creep	C512	8 μstrain/MPa

Green Cement, Carbon Credits and Strong Concrete


CCS

Solidia Cement™

Solidia Concrete™

- Carbon credits

- Green Cement
- Same Raw Materials

- Higher value (More Durable)
- Lower Environmental Impact

Summary

- In-situ probes provide valuable insight into reaction progress at every stage

- Reaction parameters can be brought down to potentially be commercially viable

Thank you

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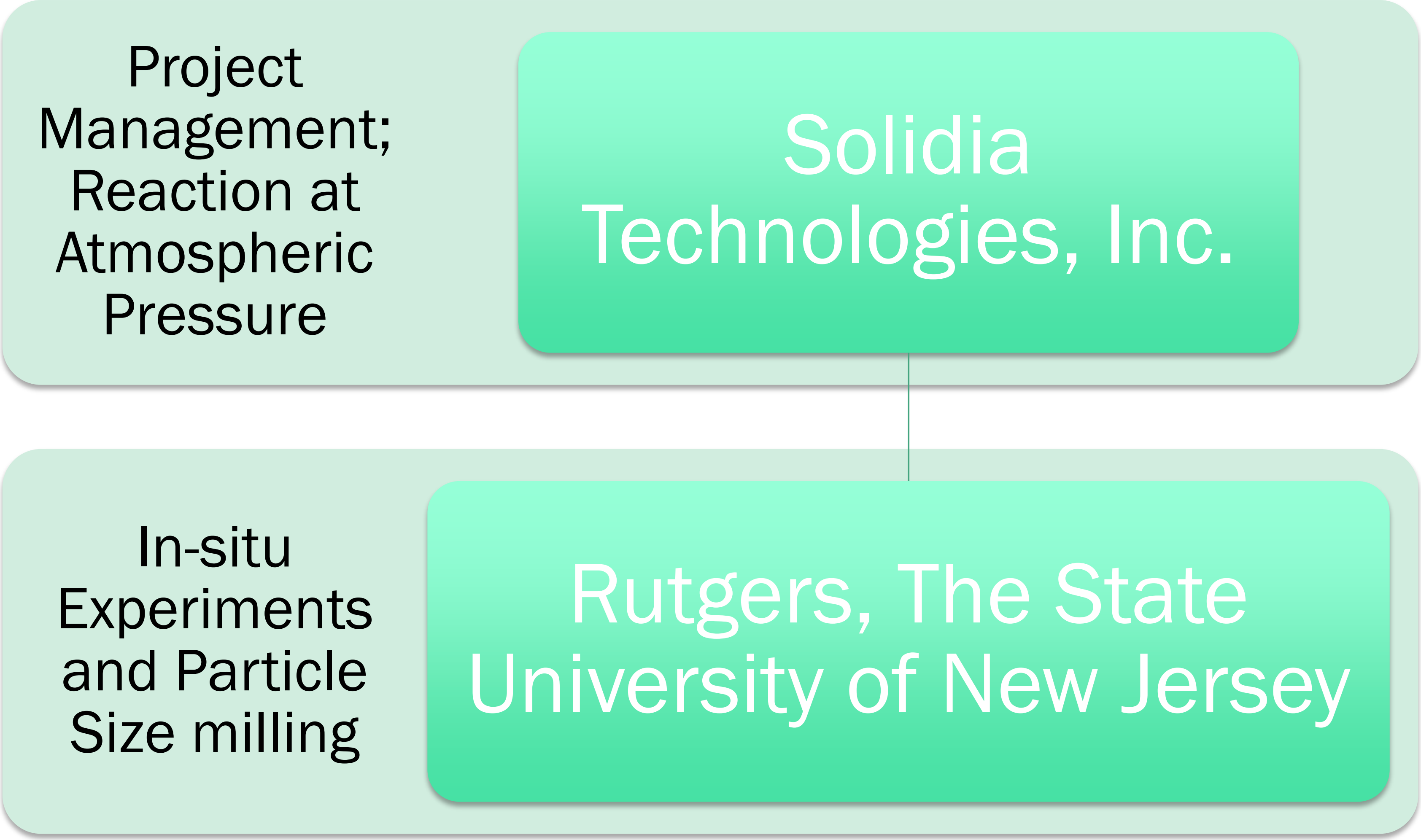
Appendix

Organization Chart



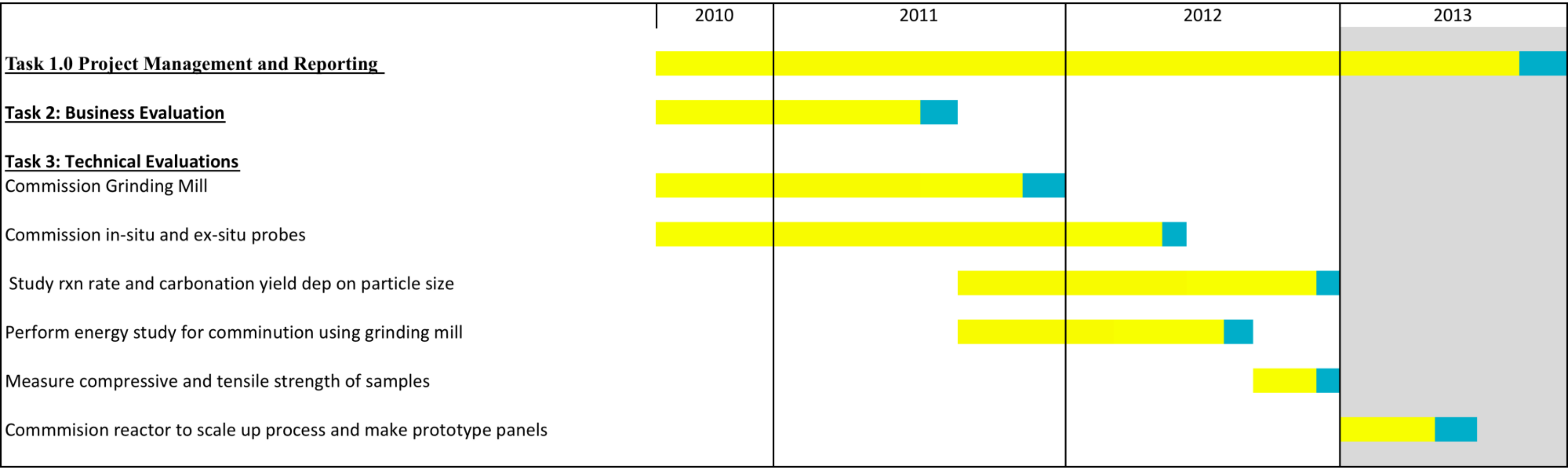
Project Management; Reaction at Atmospheric Pressure

Solidia Technologies, Inc.

In-situ Experiments and Particle Size milling

Rutgers, The State University of New Jersey

Gantt Chart


2010
2011
2012
2013
Task 1.0 Project Management and Reporting
Task 2: Business Evaluation
Task 3: Technical Evaluations
Commission Grinding Mill
Commission in-situ and ex-situ probes
Study rxn rate and carbonation yield dep on particle size
Perform energy study for comminution using grinding mill
Measure compressive and tensile strength of samples
Commmision reactor to scale up process and make prototype panels

Bibliography

No publications have resulted from the work completed under this grant