Rapid Limestone Calcination using Microwave Assist Technology™

Morgana Fall*

Shawn Allan, Dr. Holly Shulman, Ceralink Inc

Keith Espelien, Mississippi Lime

Ceralink Inc.

Rensselaer Technology Park

Troy, New York

Outline

- Background
- Materials Characterization
- Experimental Results
- Summary

Uses of Cement and Lime

- Cement is used extensively in concrete and mortars for the construction industry

- Lime- main applications:
  - metallurgical (45%)- iron and steel production as a flux to remove impurities
  - construction (25%)- stabilize soils, increase strength aggregate products
  - environmental (20%)- sanitize sludge, control soil pH
  - chemical (10%)- sulfur dioxide capture from flue gas emissions

Background

Problem: Lime & cement plants huge energy consumers

- Typical plants consume 4.5 Mil BTU/ton of material made
- 90% of energy used in calcining →485 Tril BTU/year

Solution: Use Microwave Assist Technology™ (MAT™)

- Reduce energy by 50%*

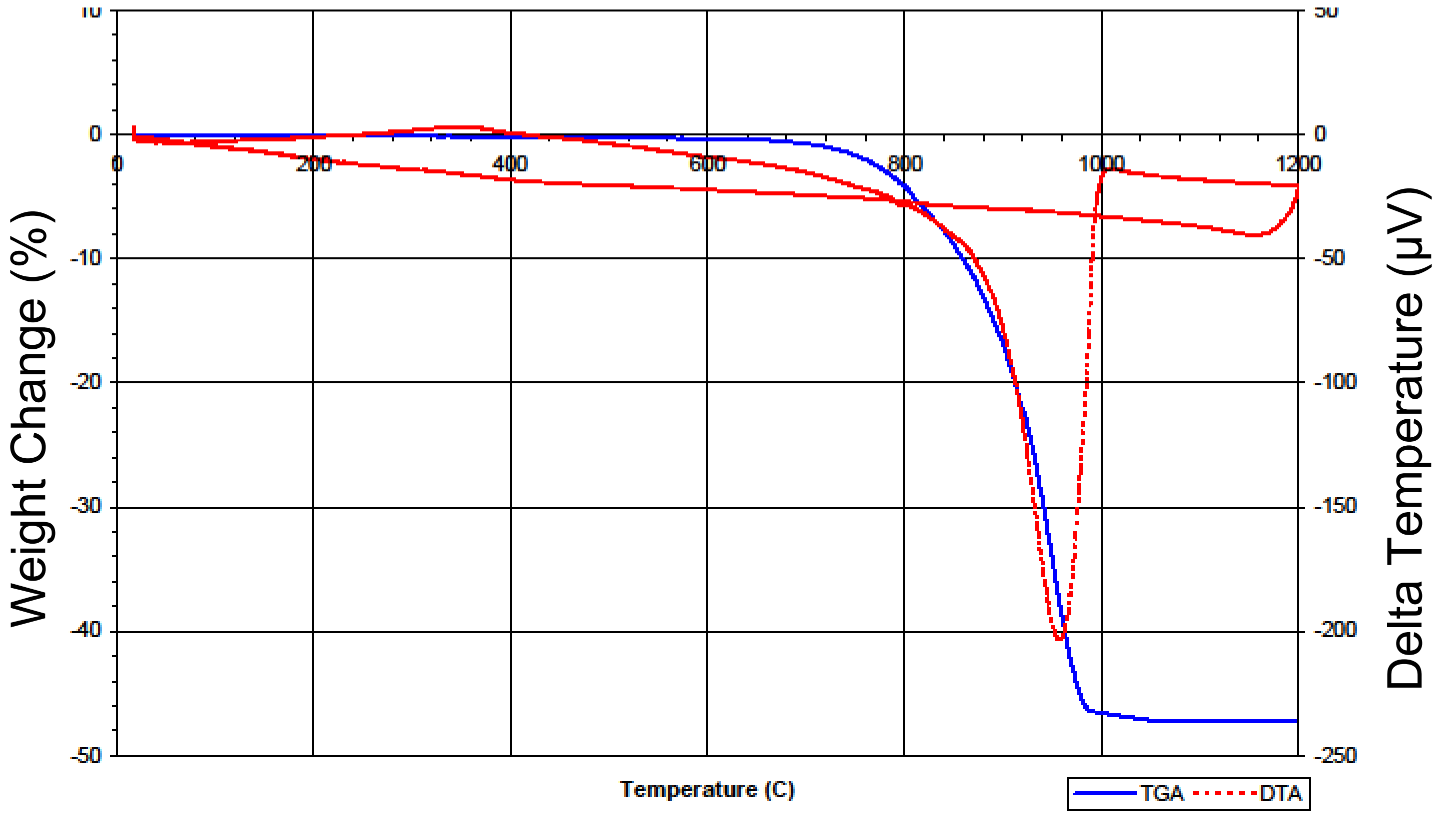
Year	Energy (Tril BTU/yr)	Environmental Benefit CO_2 (Mlb)	Economic Benefit ($/yr)
2020	24.3	896	12.2 Bil

Projected Annual Energy and CO_2 Savings for MAT Implementation year 2020.

Background

- Calcining reaction: $\mathbf{CaCO_3 \rightarrow CaO + CO_2}$
- Strong endothermic reaction (44.3 kcal/mole)
  - Material actively cooling
  - Preventing the diffusion of heat deeper into the unreacted limestone
  - Heat transfer is effectively stopped at the reaction front
- Weight loss 44%, complete reaction
- Dissociation depends:
  - Temperature, time, pressure, particle size

TGA and DTA



43.75% wt loss

Background

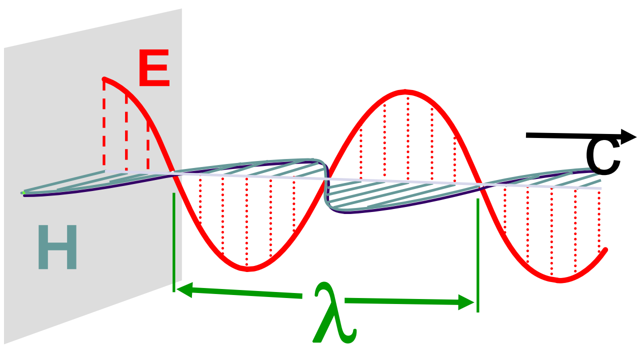
Microwave Heating

Conductivity increasing →

Transparent to microwaves
Very Low
Dielectric loss
Tan D < 0.01

Absorb microwave (heats)
Dielectric loss
Tan D ~ 0.01-20

Reflects microwaves
Electrical conductor



E = electric field H = magnetic field

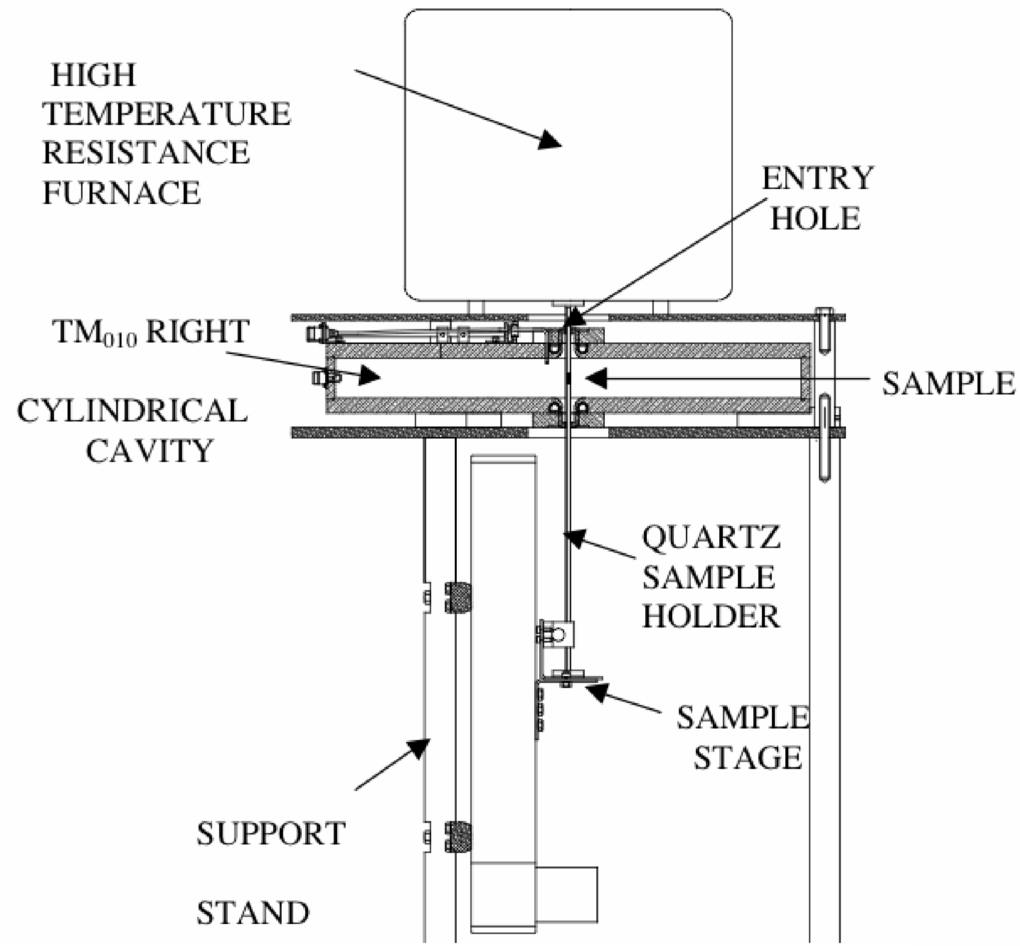
λ = wavelength (12.2 cm for 2450 MHz)

c = speed of light (300,000 km/s)

	Tan Delta 20 C 2.45 GH	Penetration Depth (m)
Alumina	0.0010	12.8
Zirconia	0.015	1.0
Silicon Carbide	0.08-1.05	0.004-0.047
Aluminum	-	0.000001

Dielectric Property Testing

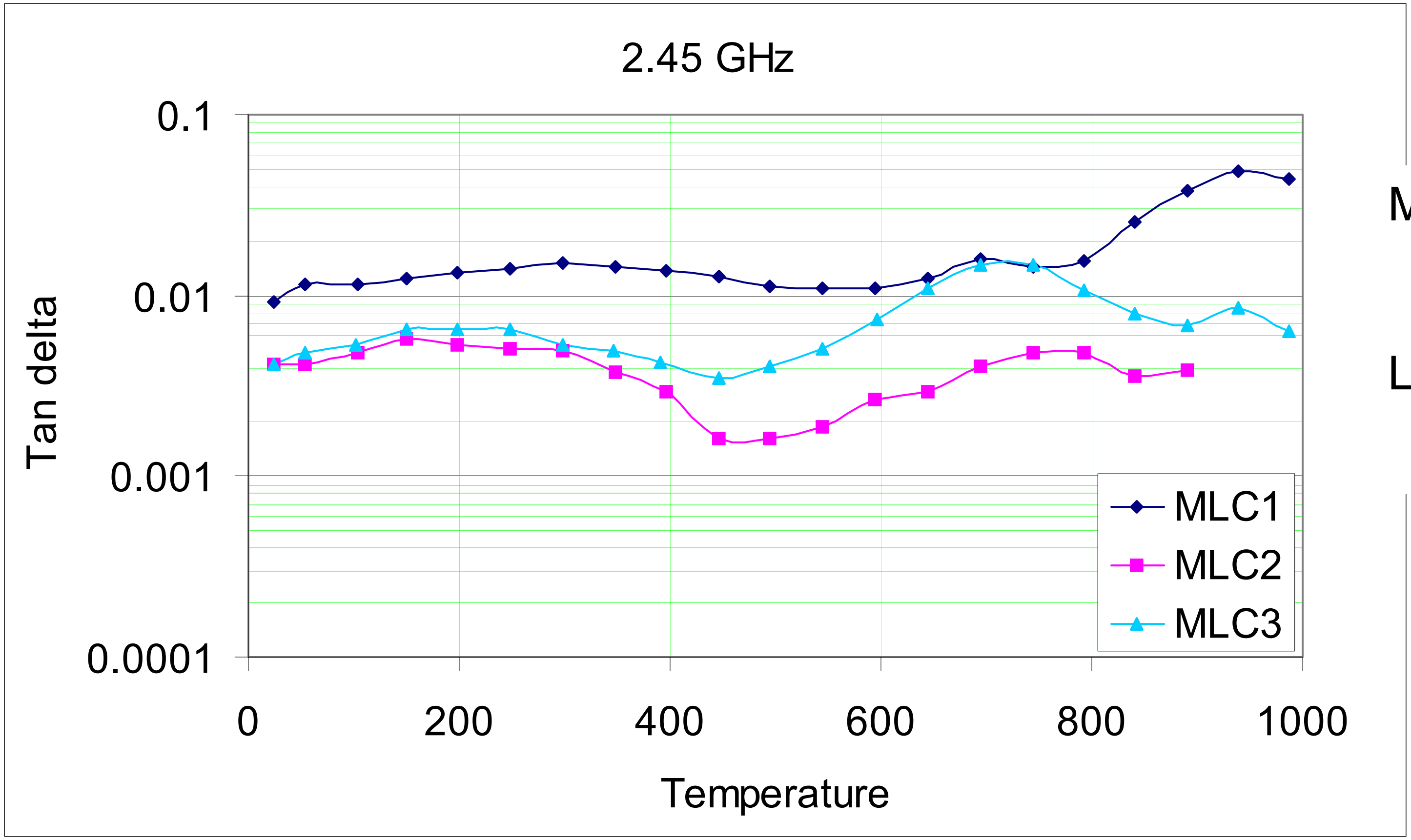
Cavity perturbation method



- Measures ε' and ε”
- Frequencies: 400 MHz - 3000 MHz
- Temperatures: 25°C to 1450°C
- Specified rate and temp range
- Selected cover gas atmosphere
  - vacuum to 6 atm absolute

Dielectric Properties

3 Grades of Limestone

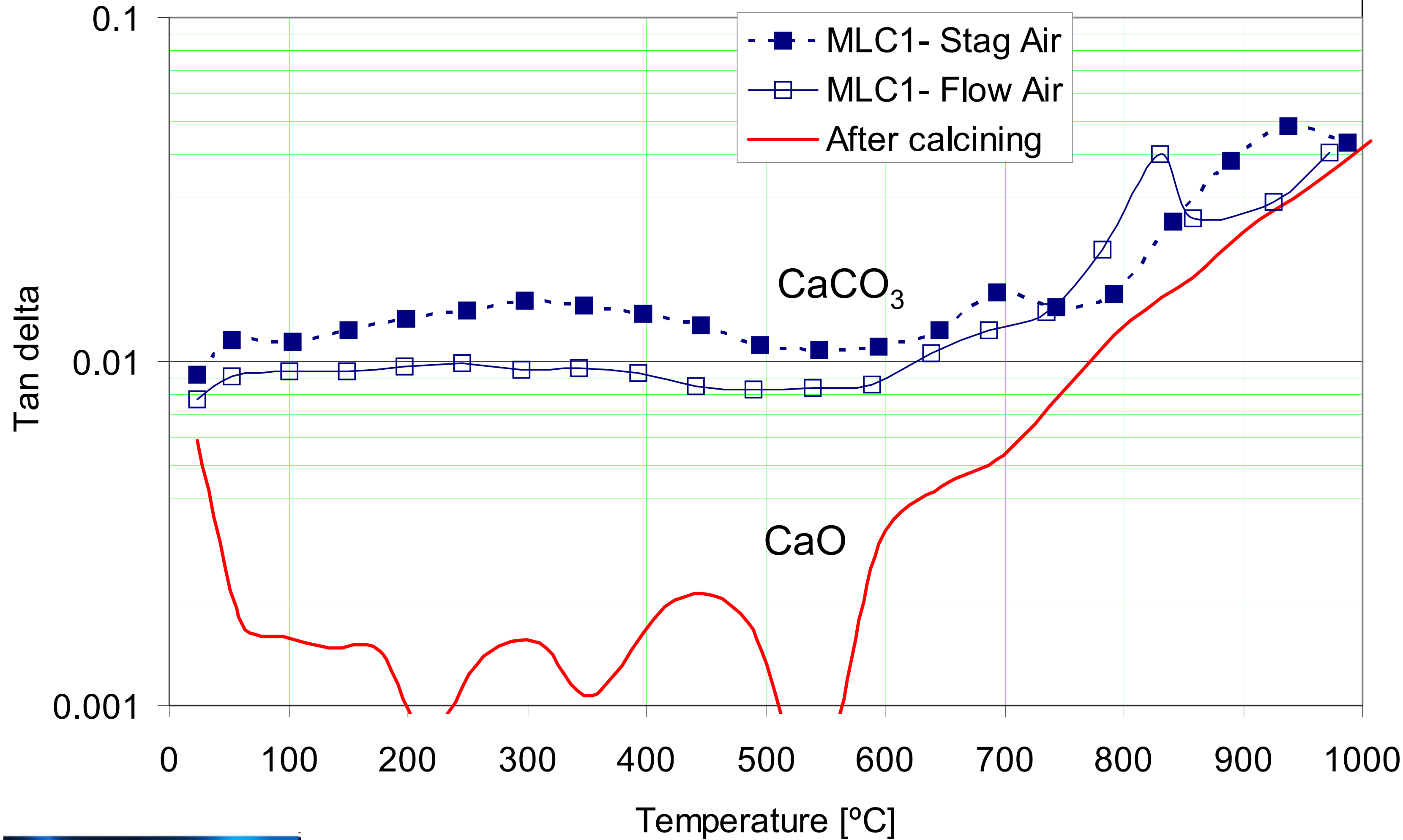


More impurities

Less impurities

Different grades of limestone at 2.45 GHz

Dielectric Properties



Flow rate effect on dielectrics

Microwave Assist Technology™ (MAT)

Addition of microwaves to traditional kilns

Limitations of Traditional Heating

Heat transfer by conduction → gradients → slow process → energy intensive

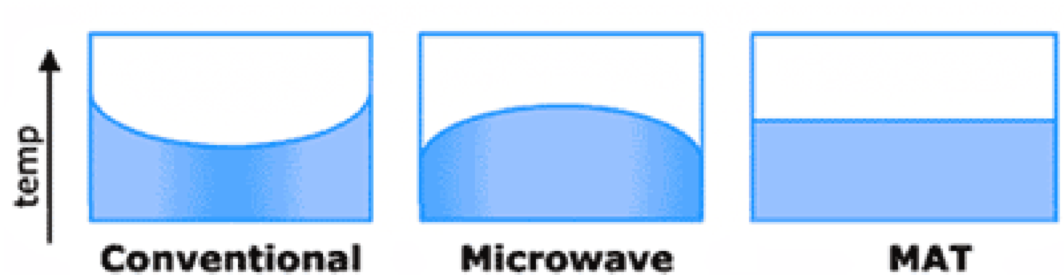
↳ grain growth

MAT Solution to Heating

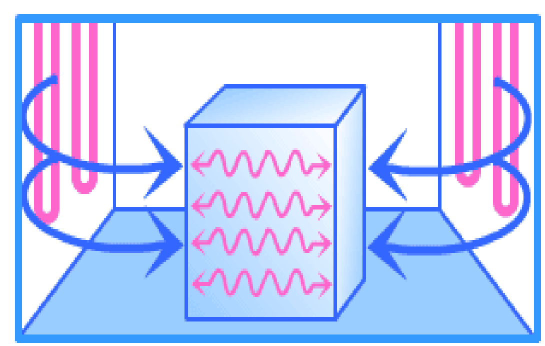
Apply microwaves and radiant heat → uniformity → fast process → lower energy cost

↳ control grain growth

Lower temperature process → lower energy cost

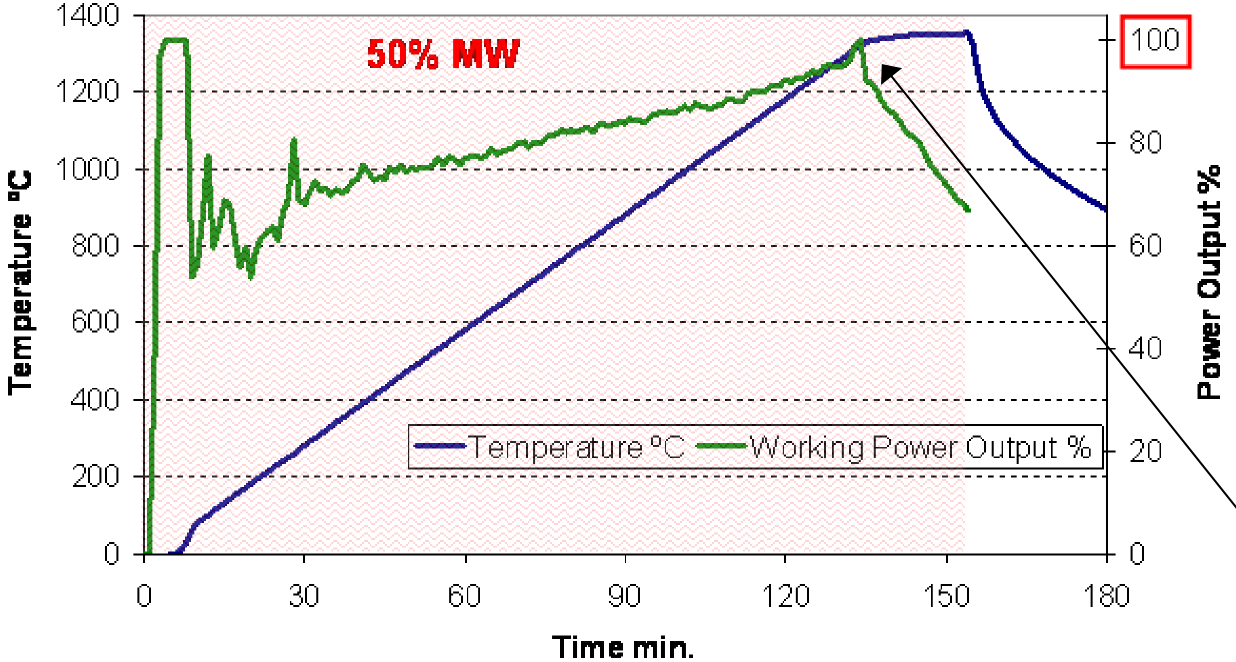


Temperature profile across part thickness



MAT electric kiln

MAT™ Calcining Studies

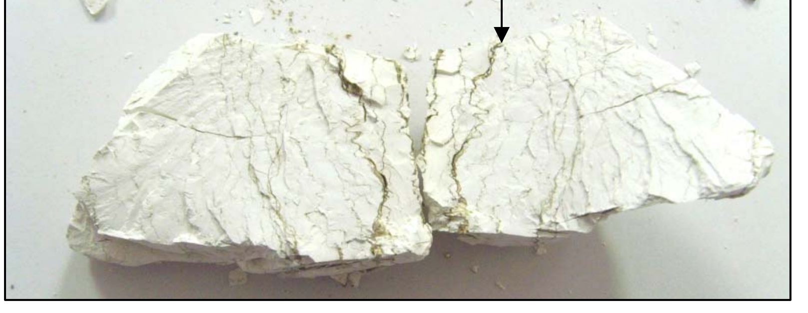


Power drop shows microwave heating

MAT™ Calcining Studies

Before

After

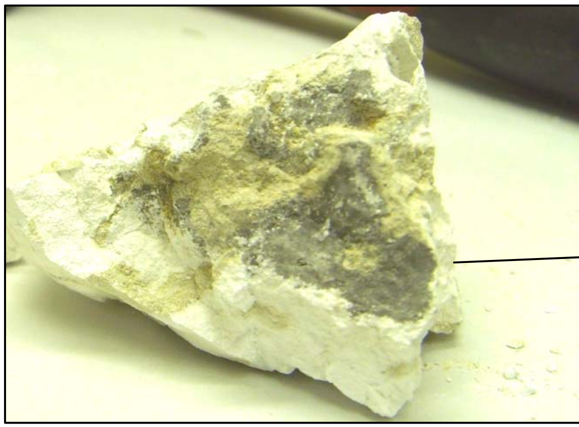


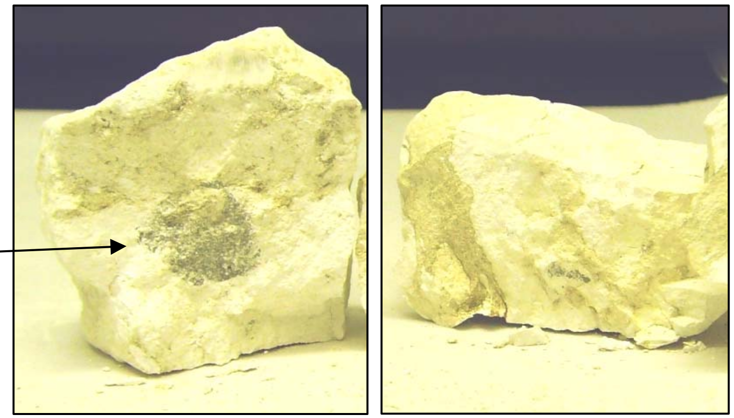
- 1 Kg batch
- 1400 °C
- 10 min dwell

44% wt loss

MAT™ vs. Conventional

1 Kg at 1200 °C, 10 min dwell





Conventional – 38% wt loss

MAT ™ 43-44% wt loss

MAT™ showed enhanced dissociation

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Summary / Future Work

- Microwave energy couples directly with limestone
- Dielectrics correspond to disassociation reaction
- Partial pressure affects dissociation, which affects Tan δ
- Conventional comparison confirmed enhanced disassociation
- Should enhance energy efficiency!

- Develop design for large scale MAT Calciner
- Work with industrial partner to implement

Questions?

Acknowledgements:

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Mississippi Lime

Microwave Properties North

MPN